Mid Project Report
Volume II

Appendix A
Project Technical Reports

Prepared under support of
United States Agency for International Development
Contract AID/NE-C-1351
All reported opinions, conclusions or
recommendations are those of the writers
and not those of the funding
agency of the United States Government

By

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September 1980

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Project Technical Reports

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PROBLEM IDENTIFICATION REPORT

FOR MANSOURIA STUDY AREA

October 1977 to October 1978

EWUP Technical Report No. 1

Prepared under support of
United States Agency for International Development
Contract AID/NE-C-1351

By

Egyptian and American Field Team

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March 1979

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Preface

This report was prepared by the staff of the Egyptian Water Use and Management Project. The project is funded by the U. S. Agency for International Development, under a grant agreement between the United States of America and the Arab Republic of Egypt. Dr. D. S. Brown is the Mission Director USAID and Mr. Niel Dimick is Project Manager USAID.

The project is in the Water Management and Irrigation Technologies Research Institute, Dr. M. Abu-Zeid, Director, Ministry of Irrigation but the Ministry of Agriculture has a collaborative role with the Soil and Water Research Institute, Dr. A. Serry, Director and the Agricultural Economics Institute, Dr. G. Hindy, Undersecretary, providing personnel and services.

The Consortium for International Development with executive offices in Logan, Utah is the contractor with Colorado State University as the lead university for the project. American personnel on the project are from Colorado State University, Oregon State University and Montana State University.

The study period of this report was from January 1978 to October 1978 and the study was conducted by the following people:

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<u>Consortium for International Development</u>

Colorado State University
New Mexico State University
Oregon State University
Texas Tech University
University of California
University of Arizona
University of Idaho
Utah State University
Washington State University

<u>Arab Republic Of Egypt</u>

Ministry of Irrigation
Ministry of Agriculture

<u>United States Of America</u>

Agency for International Development

CONVERSION FACTORS[1/]

Area		Sq. meter		Acre		Feddan		Hectare
1 feddan (fed)	=	4,200.8335	=	1.03805	=	1	=	0.42008
1 acre	=	4,046,856	=	1	=	0.96335	=	0.40469
1 hectare (ha)	=	10,000	=	2.47105	=	2.38048	=	1
1 sq kilometer	=	100×10^4	=	247.105	=	238.048	=	100
1 sq mile	=	259×10^6	=	640	=	616.4	=	259

Water Use:

1 billion m^3 = 810,710 acre-feet
1,000 m^3 = 0.81071 acre-foot = 9.72852 acre-inch
1,000 m^3/feddan = 0.781 acre-foot/acre = 9.372 acre-inch/acre
= 238 mm of rainfall

Commodity Measurements

	Egyptian Unit	Weight in kg	Weight in lbs
Cotton (unginned)	Metric kantar	157.5	346.92
Cotton (lint or ginned)	Metric kantar	50.0	110.13
Sugar, onion, flax straw	Kantar	45.0	99.12
Rice (rough or unmilled)	Dariba	945.0	2081.50
Lentils	Ardeb	160.0	352.42
Clover	Ardeb	157.0	345.81
Broadbeans, fenugreek	Ardeb	155.0	341.41
Wheat, chickpeas, lupine	Ardeb	150.0	330.40
Maize, Sorghum	Ardeb	140.0	308.37
Linseed	Ardeb	122.0	268.72
Barley, cottonseed, sesame	Ardeb	120.0	264.32
Groundnuts (in shells)	Ardeb	75.0	165.20

Other

1 ardeb = 198 liters = 5.62 bushels (U.S.)
1 ardeb/feddan = 5.41 bushels/acre
1 kg/feddan = 2.12 lb/acre

[1/] From Contemporary Egyptian Agriculture, by H. A. Tobgy.

PROBLEM IDENTIFICATION REPORT

FOR THE MANSOURIA STUDY AREA

OF THE EGYPT WATER USE AND MANAGEMENT PROJECT

ABSTRACT

The Egypt Water Use and Management Project is structured to function in an interdisciplinary mode to formulate and demonstrate viable on-farm management alternatives for the typical Egyptian farmer. Although water use and management is emphasized in the project title, it was realized from the formulation of the project that the management of all other resources used in a modern irrigated agricultural system must be considered if the proposed innovations were to be acceptable and of lasting benefit.

Thus, the Egypt Water Use and Management Project constitutes a new strategy for irrigation development both in approach to project activities and in staffing. Project activities are designed to facilitate farmer innovation through an interdisciplinary research and development procedure. This procedure includes problem identification, search for solutions, testing solutions on-site, and diffusion of effective alternatives. The EWUP team includes agronomists, engineers, economists and sociologists from both the United States and Egypt. This team is working with the Egyptian farmer at the field level in an effort to find out what is being done and what viable alternatives given both physical and institutional constraints--exist for improving on-farm management practices.

Problem identification constitutes a major activity of EWUP in this context. For it is the base on which improved on-farm management practices can be formulated and demonstrated. The initial six-month

problem identification activity was carried out in an area representative of current Egyptian agricultural practices. Several case study farms were selected in two study sites. These study farms received intensive attention from all disciplines involved in the project. During efforts at problem identification, both teamwork and actual research activities have been of concern. This dual concern is reflected in the organization of this paper. The first section deals rather exclusively with project organization, procedures and activities while specific on-farm research findings constitute the remainder of the report.

The findings reported reflect the concerns of all the disciplinary contexts but are reported mainly from the perspective of the specific discipline which undertook the investigation. As reflected in the last section of this paper, since project concerns have moved into the on-farm field trials, the need and value of a truly interdisciplinary mode has emerged with full cooperation among all disciplines in these efforts.

INTRODUCTION

The Egypt Water Use and Management Project (EWUP) pilot area research and demonstration programs are designed to assist in improving existing management practices of irrigated agriculture in Egypt. Central to all project activities is the accomplishment of significant social and economic progress for Egyptian farmers. Such achievements depend on the development and demonstration of improved practices suitable for use by the typical Egyptian farmer. Of specific concern to EWUP is the improved management of water, soil, capital and human resources used in agricultural production.

The purpose of this paper is to present some preliminary conclusions from the problem identification phase of the project as it pertains to Mansouria irrigation district. This will be accomplished by presenting the organizational structure of the project and summarizing the innovative research approach that was used to identify problems. Other related project activities will then be presented to acquaint the reader with the full scope of the project. Finally, tentative conclusions will be presented including some possible solutions that seem potentially productive and satisfy project objectives.

PROJECT PLANNING AND DEVELOPMENT

The project was developed from its formulation as an interdisciplinary research activity. Rooted in earlier experiences in Pakistan, EWUP was developed to capitalize on the advantages of combining irrigation engineers, agronomists, agricultural economists and rural sociologists in a unified interdisciplinary team for the development and implementation of the research extension design.

Project Organization

The project has been organized to maximize technical input and support to accomplish improved on-farm management. Implementation of project plans for a given area may be visualized by the organizational chart shown in Figure 1. The Project Directors have an Egyptian Advisory Committee and a U.S. Planning and Coordinating Committee to assist them in all aspects of project implementation. A senior staff of American specialists (discipline leaders) working with a senior staff of Egyptian specialists provide the necessary technical expertise to carry out project objectives in three project areas in Egypt--Mansouria, El Minya and Kafr El Sheikh.

Role of Discipline Leaders: Experienced technical experts from the United States have been brought together to work with experienced Egyptian experts in each discipline. These discipline leaders plan and direct all technical activities in the project areas. The discipline leaders evaluate the technical progress periodically and reassess plans accordingly. They meet with the Project Directors to report technical accomplishments, make evaluations and plan for the achievement of project goals.

These four discipline leaders and Egyptian counterparts act as an interdisciplinary team in planning project goals. To accomplish these goals professionals in the corresponding disciplines, called a field team, carry out work plans developed with their discipline leaders. Team members in the field look to the senior staff for training and assistance in carrying out work assignments. Training and proper technical supervision help assure that quality data and information are collected. The discipline leaders have complete responsibility for monitoring data quality and data analysis within each discipline.

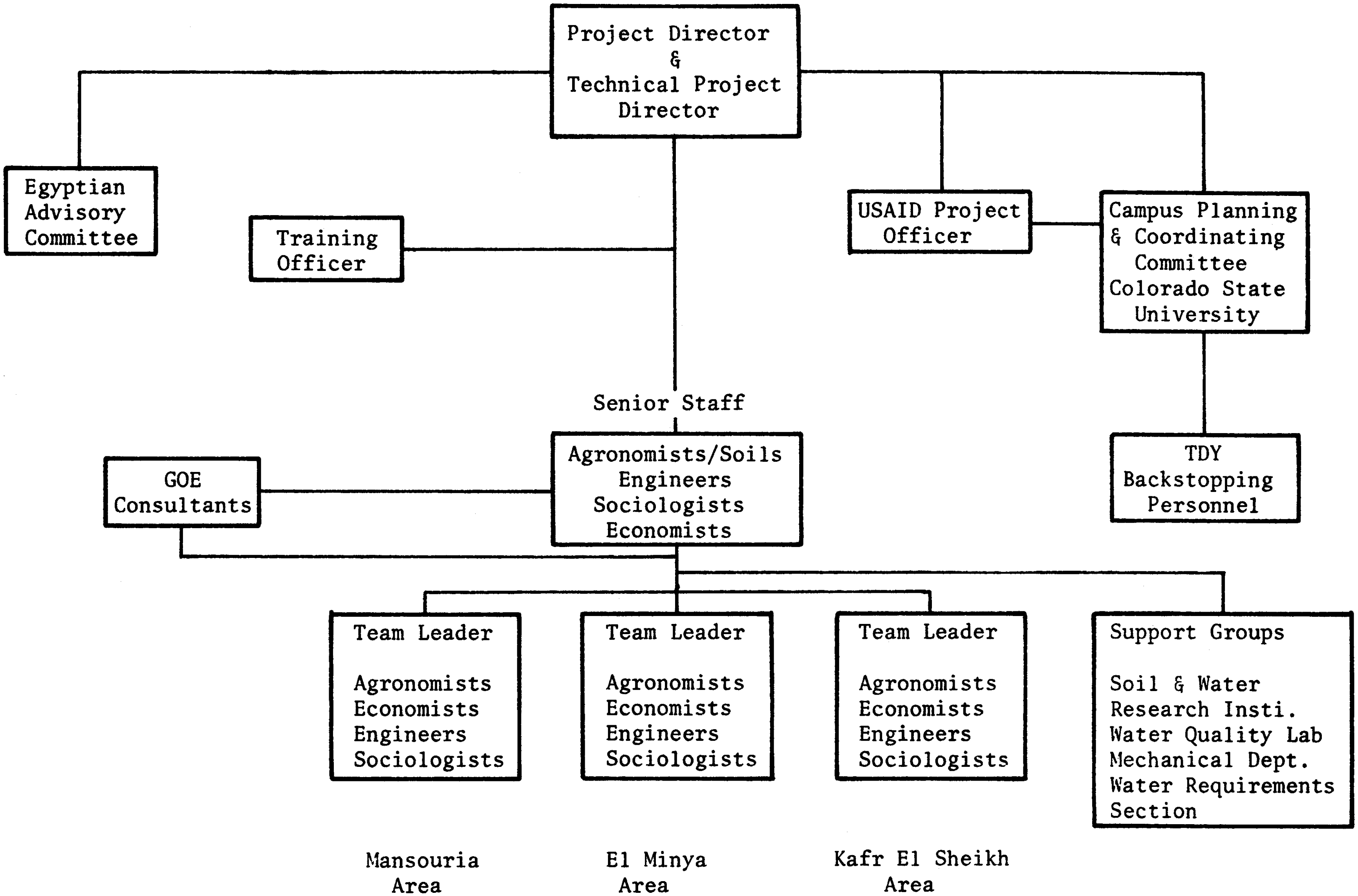

Figure 1. Organizational Chart for Egypt Water Use and Management Project (EWUP).

Role of Team Leaders: The field team leader directs the technical work as a facilitator and motivator so the work is accomplished as outlined by the senior staff in the work plan. The senior staff must work closely with the team leader to communicate work plans and special technical activities. Although the team leader is a trained specialist, the role carries no responsibility for training personnel in other disciplines. However, he should discuss with other discipline leaders the needs for modifying their training programs to best achieve the project goals. As a manager, the team leader facilitates the work by organizing all of the resources available for accomplishing work plans.

Project Procedures for Problem Identification

The relationship of some of the most basic hypothesized potentials for improving agricultural production are summarized in Table 1. By investigating these basic conditions an understanding of present farm system operation can be achieved. Specifically the objective of problem identification is to identify and characterize major physical, hydrological, chemical, biological, economic and organizational factors which constitute significant potentials for increasing crop production.

Detailed Problem Identification Procedures: The Mansouria irrigation district research area was selected to represent one typical set of soils, cropping and irrigation patterns in Egypt. Within the irrigation district, hydrologic units form the major level of analysis. The area was selcted because of its accessibility from project headquarters as well as its resemblance to agricultural and rural life patterns in areas of the country characterized by high population density and proximity to urban centers. In addition, the Water Distribution and Irrigation

TABLE 1. Summary of Hypothesized Potentials for Improvement in Irrigated Agriculture.

BASIC CONDITIONS	FOCAL FACTORS	ENVIRONMENTAL BENEFITS	PRODUCTION BENEFITS	SOCIETAL BENEFITS
Agricultural management knowledge: water, soil, capital and human resource management; motivation and management to realize optimal productivity. Project Emphasis: APPLIED RESEARCH AND DEVELOPMENT	1. Agricultural--production factors including irrigation water, fertilizers, plant populations, labor, capital investment, farmer co-operation patterns etc.	1. Reduced salinity accumulations in soils.	1. Stabilized or increased agricultural productivity.	1. Improved farm family socio-economic well-being.
Cultural patterns (commonly held and socially reinforced behaviors and beliefs) which represent constraints opportunities to effective irrigated agriculture. Project Emphasis: INVESTIGATE IN PROBLEM IDENTIFICATION PHASE; UTILIZE IN TESTING, ASSESSING AND IMPLEMENTING	2. Institutional--timing in delivery or application of production factors; regulations and policy; government and private services; banking and credit, etc.	2. Reduced waterlogging of previously arable land.	2. Increased production efficiencies.	2. Reduced annual labor for on-farm production.
Capital and technological opportunities constraints on farm level management. Project Emphasis: DEVELOPMENT AND APPLICATION OF COST-EFFICIENT ALTERNATIVE TECHNOLOGIES WHICH REPRESENT FEASIBLE FARMER CAPITAL INVESTMENTS		3. Reduced water use.	3. Long-run agricultural productivity both due to increased fertility of crop lands and to saved irrigation water and other production factors which can be used for the development of new lands.	3. Improved national socio-economic well-being.
Institutional organization, including communications and consistency of actions among and between farmers, scientists and government officials. Farm policy constraints and potentials for the effective practice of rational and efficient irrigated agriculture. Project Emphasis: STRENGTHEN INSTITUTIONAL SUPPORT FOR INNOVATIVE AGRICULTURAL PRACTICE				

Systems Research Institute, into which the project has been administratively absorbed, was already working there.

In the Mansouria irrigation district the hydrological units are the Kafret Nasar, Beni Magdoul and El Hammami water courses. They are shown in the general area map in Figure 2. The Beni Magdoul and El Hammami water courses are shown in Figure 3. Each area is bounded by conveyance and drainage channels to form a hydrologic unit. Although there are several villages within each hydrologic area, a village may be served by more than one water course. For the purposes of problem identification all teams focused their surveys on the hydrological units so hydrological, agronomic and socio-economic data could be correlated. The socio-economic disciplines also required some village level data.

Data collected during the problem identification survey provide baseline data. Insights and guidelines for developing programs for transfer of findings to other farmers also result.

On-Farm Agronomic Survey

Agronomic Practices Survey: Field observations were made for plant growth characteristics, soil characteristics, agronomic management and irrigation practices. In addition, field measurements were taken to quantify the soil-plant-water system in the field. Both the soil physical-chemical properties and crop growth factors including yield, plant stands, root system and diseases and pests were measured.

Soil and Land Classification Survey (Beni Magdoul and El Hammami): A general surface and sub-surface texture survey were taken to determine structure, consistency, color, mottling depth and water table location. Soil profiles from representative sites were analyzed for exchange capacity, exchangeable sodium and water soluble salts, pH, gypsum

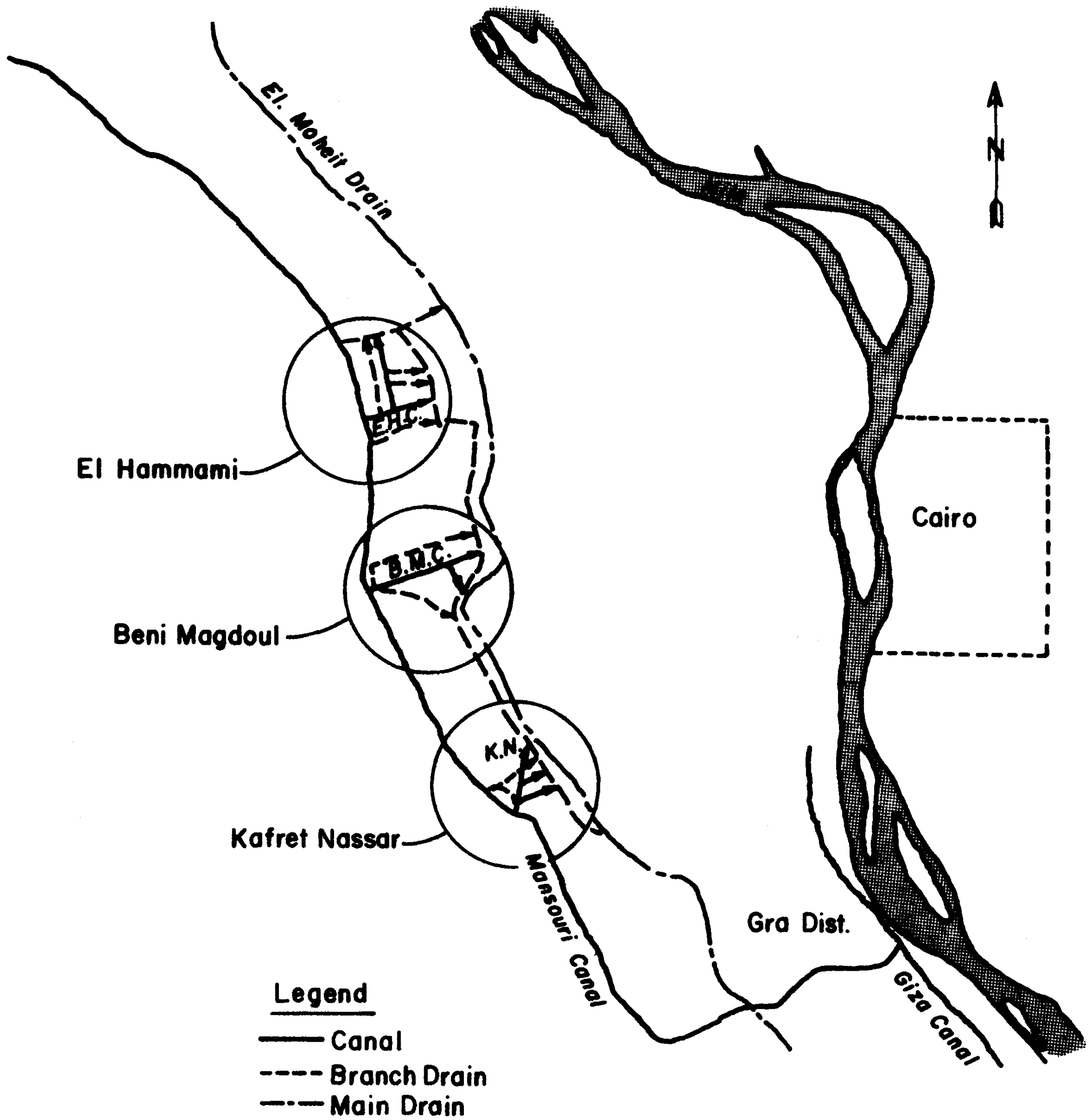

Figure 2. Map of the Mansouria Irrigation District showing the El Hammami, Beni Magdoul and Kafret Nassar study areas.

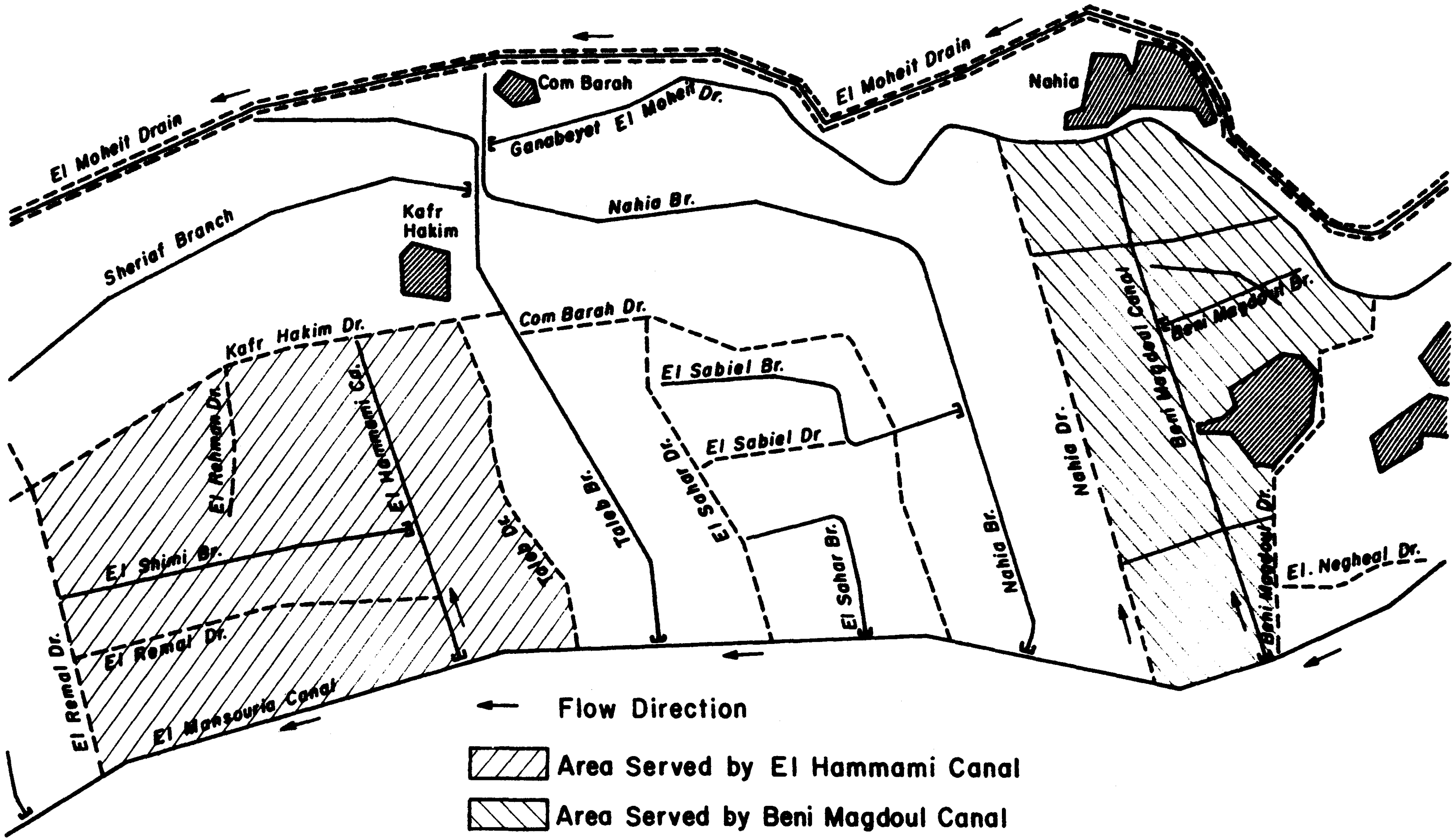

Figure 3. General layout and boundaries of the Beni Magdoul and El Hammami water courses.

requirement, soil organic matter, soil fertility analysis, lime and a moisture curve.

Soil Testing Survey: An extensive soil testing survey was made to identify fertility problems in the village so that sampling procedures can be designed for fertilizer recommendations.

Engineering Survey

The engineering discipline was involved in two major problem identification activities. They were (1) an on-farm water management survey and (2) a water budget study.

On-Farm Water Management Survey: The objectives of this survey was to find out what is happening to irrigation water being applied to selected tracts of land and why and to what degree the irrigation process may be creating an undesirable moisture regime in the normal root zone. The study involves obtaining a complete water budget for selected fields to learn where losses are occurring and the magnitude of such losses. Also, existing irrigation practices, methods, scheduling, physical land features, crops, etc., are analyzed for their correlation with water loss. At the same time a running account is kept of the moisture status in the soil, the depth to water table, and the best available estimate of crop yield. Seven sites were selected in Beni Magdoul, one in Kafret Nassar and eight in El Hammami. In Beni Magdoul and also in El Hammami, only four sites received intensive measurements. For the others, limited measurement of water table and irrigation schedules have been recorded.

Water Budget Survey: The water budget for the Mansouria area consists of measuring surface flows, ground water flows and evapotranspiration. Specific methods for measuring surface flows such as cutthroat flumes were selected for all sites. Exact location of many installations, such as observation wells and flumes, by necessity are determined based upon the available field data as it becomes available.

It is anticipated that these limited measurements can also provide an estimate of seepage losses from the Mansouria Canal. In general, flow in the canal can vary appreciably within a few hours, since the water control is based on maintaining a constant water level instead of a constant discharge. Thus, unless a calibrated control section or measuring device with a recorder is available in the channel, accurate continuous measurement is impractical.

Socio-Economic Survey

This survey provided information about the operational procedures and major types of socio-economic data. The survey consisted of three basic parts given below.

Review of Literature: Literature and available data in English and Arabic were reviewed both in Egypt and the United States. Data were obtained from Egyptian Research Institutes, FAO, Ford Foundation and other organizations working in Egypt. Relevant population and economic statistics from Egyptian and international agencies were obtained whenever available in published form.

Problem Identification Field Surveys: Preliminary field surveys were conducted to provide information for the development of the formal problem identification surveys. Twenty-two farm operators were chosen for socio-economic case studies in the Mansouria Irrigation District; ten of these were in Beni Magdoul and 12 were in El Hammami. The sources of data were key informants from the area including cooperative extension and irrigation personnel plus the decision makers of the case study farms. These farms were chosen to indicate various size holdings, ownership and employment patterns. In addition, field observations of activities were conducted.

Subsequent Research Activities: Data obtained during the problem identification phase has led to the selection of subjects for specialized socio-economic research and detailed continuation research based on results from first-phase investigations. Specialized studies may include such questions as urban encroachment on agricultural lands, joint-family operations, decision making, rural out-migration, socio-economic consequences of mechanization as appears relevant to project objectives.

Socio-Economic Field Trial Activities

Field trial activities are central to project objectives. Solutions are being sought immediately for priority problems already identified in the field surveys. Also some known technologies for problems already identified are being applied and evaluated. For example, changes created within the system by lining water courses ae being evaluated where they appear feasible.

Assessment of Applied Technologies: Each of the technologies applied will be evaluated in terms of farmer acceptability, cost-benefit, social and environmental impacts (using BEFORE and AFTER data). They are developing specific assessment methods in consultation with the engineers and agronomists. The interpretation and the reporting of these findings requires the participation of all team members.

Technology Transfer: When a technical solution to a significant problem is adequately evaluated and there is substantial evidence of its benefit to farmers, plans are developed for its transfer to other farmers in the area. Diffusion of this technological package requires the organization and development of institutional requisites in a communication package. Also, training of agricultural extension workers, village level agriculture advisors and farmers must be planned and implemented. The major responsibility for technology transfer lies on the socio-economic team with assistance from other team members.

The socio-economic team is also responsible for evaluation of the adoption and diffusion rates of the new technologies over time. The infrastructural requirements necessary for widespread diffusion of the technologies need special attention since these technologies may require new or improved agricultural services, organizational changes and incentive systems for farmers.

Procedures for Team Coordination and Cooperation

Continuous collaboration and full communication among team members has proved essential because of the interdisciplinary nature of the project. Since one team collects information that may be needed by other teams, it has been critical that all data be tabulated, summarized and made available for all project members as soon as possible. Also, special meetings have been held in order to review progress and to plan subsequent activities, and preliminary summaries of data have been developed, including this one.

The Project Director and Technical Director have primary responsibility for coordination of efforts and for full cooperation among team members. Each team member, however, must be responsible for full dedication in the cooperative effort to attain the goals of the project.

PROJECT ACTIVITIES

Project operations commenced in September 1977 with a United States training period for most senior Egyptian staff. Remodeling and preparation of a project main office in association with the building occupied by the Water Distribution and Irrigation Systems Research Institute in the Ministry of Irrigation was completed by January 1978. These facilities provided space for the discipline leaders and counterparts as well as the Mansouria field team. As staff members began to gain familiarity with each other's subject matter, the process and problems of interdisciplinary applied research were explored. Finally, a preliminary work plan was developed.

In January 1978 staffing of the Cairo main office team was completed and the Mansouria District problem identification study began with the following activities:

1. Training of junior staff, as well as continued junior staff selection.
2. Continued collection of relevant secondary data and a comprehensive literature search.
3. Acquisition of equipment and familiarization of personnel with the Mansouria District.
4. Selection of two field study areas, Beni Magdoul and El Hammami (see Map 2).

Field Activities

As the study areas were being determined, it became apparent that interdisciplinary planning of field operations was needed. Each discipline had its own set of criteria for site selection, including soil characteristics, size of farm, location of the ditch, operator's personal characteristics. Therefore, some standard sampling procedure suitable to the disciplines was required. Once this was established, a limited number of common case study farm sites were selected, and actual field activities as described below commenced.

Agronomic Team: The agronomic group completed soil sampling in the El Hammami and Beni Magdoul areas. Three hundred and eight samples from 80 farms were obtained from the Beni Magdoul area and an equal number were taken from 90 sites in the El Hammami area. Observations of agronomic practices in the area are still being continuously recorded. The socio-economic group also gathered relevant agronomic data from the individual farmers. An agronomist was often with the socio-economic team during the first round of interviews with the farmer.

Engineering Team: On-farm irrigation methods have been observed and documented to define the irrigation problems of typical farmers. Discharge measurements into small branch ditches and from the branch ditches to field ditches have been made to obtain information on the quantity of water utilized by the farmers. Ground water observation wells were installed and water levels are being recorded daily. Measurements of discharge at the head of all three branch canals have been started also. Four sites of land in Beni Magdoul area are receiving concentrated study on existing water management procedures. Four additional sites in Beni Magdoul are receiving a less intensive study. At El Hammami four sites have been selected for intensive study and two others to receive limited study. The field site locations are noted in Figure 4 for the Beni Magdoul and El Hammami water courses.

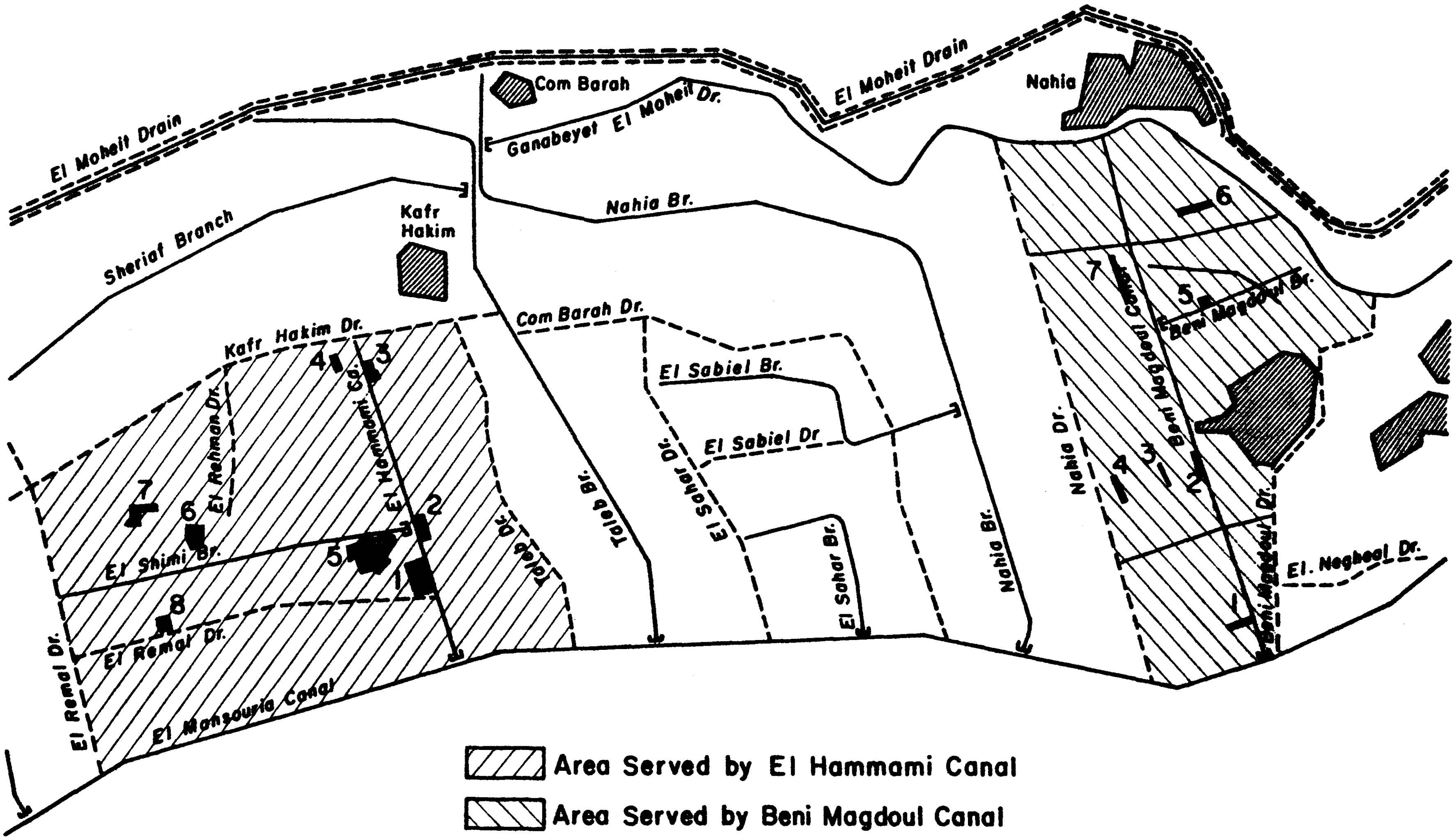

Figure 4. Farm site locations at which more or less intensive studies are made in Beni Magdoul and El Hammami.

On-farm measurements include irrigation scheduling (frequency, amount, duration, time/day), surface disposal of excess water if any, methods of distributing over the land surface, quantity of water applied, degree of land leveling, soil moisture status, and water table level. In addition soil bulk density values have been provided by the agronomy group. This detailed work will permit, for the first time, calculations of the application efficiency and the on-farm water budget. The engineering group also contracted for a local supply of observation wells, cutthroat flumes, infiltrometers, and class A evaporation pans. In addition ground water observations are being continuously recorded by using piezometers and observation wells.

Socio-Economic Team: The socio-economic team developed and field tested farmer interview forms to obtain data on crop production, ownership, population characteristics in the area. Many of the farmers in the area were interviewed.

Preliminary financial analysis of several small farms in the area was made and the study of the economic feasibility of lining the Beni Magdoul and other branch canals was started. Also an analysis of pumping costs was made. Farm budget analysis of one farm was made to test the format and procedures, subsequently further farm budget data was collected.

Training

On-the-job training including water measurement, observation of agronomic practice, soil sampling, soil analysis, socio-economic studies, social and economic surveys, installation of piezometers and observation wells, evaluation of soil bulk density, installation of Parshall and cutthroat flumes, observation of farming practices, continues on a day-to-day basis with project personnel.

THE MANSOURIA IRRIGATION DISTRICT AND RESEARCH SITES

Generally, the Mansouria District is very picturesque. It contains antiquities and the desert at its edge. Lush fields and orchards flourish throughout most of the land unless occupied by modern urban development or villages. Amid the visual appeal, however, there are many needs. Some of these are technical, some economic and some social. These are the aspects which receive attention in the analysis to follow, for they form the focus of both problem identification and subsequent project activities.

The Mansouria Area: An Overview

Two areas were selected as representative of the Mansouria Irrigation District. They are (1) the land along the Beni Magdoul Branch Canal, and (2) the land surrounding the El Hammami Branch Canal as shown in Figure 3. Neither have any administrative status beyond being water command areas of the branch canals. The first, in fact, contains some, but not all, of the land falling in the territory of four separate villages; the second is part of the territory of one village. Both areas fall within the Imbaba District of the Giza Governate. Some physical, agronomic, irrigation and socio-economic characteristics of the area follow.

Physical Geography: (1) The area served by Mansouria District has an elongated strip shape of an average length of 30.000 kilometers from south to north and an average width of 3.500 kilo. (2) The total area of the district is 24,745 feddans (23,838 acres) located mostly west of Mohiet Drain. (3) The extreme western boundary of the Mansouria District extends to the western desert fringe.

The land throughout almost all of the Mansouria irrigation district is a very flat flood plain. Some variation in the elevation of the irrigated fields does exist but mostly within ±0.5 m from the mean of any east-west profile. The overall gradient in the canal system from south to north is about 10 cm per km. The terrain becomes more irregular west of the Mansouria Canal on the edge of the desert.

The climate is warm and sunny, ranging from a daily average maximum of 20°C in January to 36°C in July; night minimum averages are 8°C and 22°C, respectively. Precipitation occurs during a portion of only five days a year, on the average, and measures less than 3 cm total annual accumulation.

Water Resources: The area is mostly fed by Mansouria Canal, a branch of the Giza Main Canal. The Mansouria Canal is 37 kilometers long and discharges about 650,000 m^3/day. Some water is recaptured from the drains by pumping. This water ranges from 800 to 1200 ppm, TDS.

A fairly shallow ground water aquifer, 35 meters or less, is tapped in a few places in the Mansouria District to yield supplemental irrigation water. Usually these wells are located near the end of a canal or ditch or at any other place where the system does not always supply an adequate, dependable stream.

Political Geography: The Mansouria district is an irrigation administrative unit that does not correspond with the boundaries of any other political unit. It is located within the Giza Governate, and contains approximately 180 villages and 7 towns and cities, and 2,419,247 people, many of whom (1,379,277) are part of the Cairo-Giza metropolitan unit. Farmers in this area live in compact villages or sub-villages.

Proximity to Cairo, Giza and Egypt's major pyramid complex has made Mansouria an area of extensive urban encroachment. Land values are extremely high, and farm holdings are small, even by Egyptian averages. A high proportion of part-time and non-farming residents and a relatively high number of non-farm related income opportunities exist. Observers of the agricultural patterns and village life in this district frequently judge it to be a "garden" form of agriculture.

Again, due to proximity to Cairo, the Mansouria district is exempt from the many government crop allocation policies. In addition, certain other national policies including many of the restrictions controlling residential and industrial development on agricultural land are waived. Furthermore, working animals and poultry are more common than in other national areas due to the large, accessible market.

Government services provided at the village level of the district include schools, health care, water supply for domestic use. There are also agricultural cooperative and village bank services, religious centers, roads and some public transportation, and local administrative and law enforcement functions.

Cropping Patterns

Two or three croppings occur annually in this district. The most common winter field crops are berseem clover, flax, vegetables, wheat and beans; summer field crops include maize and vegetables. These variations are determined both by climatic conditions and government regulations which prohibit the cultivation of some crops in the summer. Many orchard crops are grown, including citrus, mangoes and dates. There are vineyards and some specialty crops like flowers are also grown year-round. Intercropping occurs frequently.

Irrigation and Drainage System

Physical and Operational Description: The district irrigation delivery and drainage system is rather typical of the country. The supply canals were laid out earlier in the century. Most are unlined, although a concrete lining program is being carried out at Beni Magdoul. Generally, the canals and drains consist of straight conveyance channels. These are arranged more in a grid pattern than a "snaking" or "branching" pattern. The water is traditionally delivered on a rotation schedule; however, the district contains a few experimental continuous-supply areas including the project's study area at Beni Magdoul.

Specifically, a three-phase rotation system is applied in this district. The rotation in general is a 4-day-on and 8-day-off cycle. However, there is deviation in this rule of rotation in this canal due to the inequity of the region's acreage and the sandy soil in the tail region as compared with the other regions.

To satisfy the standard of fairness in water distribution, during the "on" period of Reach B, a part of the canal discharge is diverted to Reach A during the first two days; during the last two days a part of the discharge is diverted to Reach C. A further complication is that the Beni Magdoul Canal in Reach C is permitted to flow continuously during all rotations. This is shown diagrammatically in Figure 5 below. It should be noted that Beni Magdoul is in Reach C and El Hammami in Reach A.

Government operated and maintained canals take water near the farmers' fields; private ditches operated by groups of farmers take the water the rest of the way to the fields. Only a small part of the land, perhaps ten percent, can be irrigated by gravity; most of it

	12.460 Reach B	16.274 Reach C	28.545 Reach A 37.000
"ON"	4 days -------------	2 days/part ------------------------------------- continuous	2 days/part 4 days/total
"OFF"	8 days	no days	2 days/part 6 days/total

Figure 5. Rotation Schedule in Mansouria Study Area.

requires a lift of less than one meter. Most lifting to field elevation is by sakia (wheel), but many farmers use the tambour (archimedes screw). A few use a mechanical pump, and occasionally the shadoof (counter-balanced pole and bucket) is used for higher lift distances. A few farmers take water from their own wells of from canals or drains by pumps.

A network of second and third class surface drains serves the whole area. The drainage water goes into the El Mohiet Drain (see Figure 4). In addition, the overflow of irrigation water from the canals escapes to this drain.

<u>On-farm Irrigation and Drainage</u>: On-farm irrigation practices in Mansouria district combine two control methods: basins and furrows. Basins are of different sizes, varying between 3 x 6m and 8 x 14m. They do not usually have a common zero level due to inadequate land leveling facilities. In addition, each basin may have a slightly different level. The furrows are built in the basins, thus they have

relatively short lengths. A typical on-farm layout is shown in Figure 6.

Furrows are generally non-uniform and may be classified into two types: (1) narrow furrows, widths between 20 and 40 cm, usually used for main crops such as corn, and (2) wide furrows, widths between 60 and 80 cm, usually used for vegetables. The furrow heights range from 12 to 15 cm. The dikes, which divide the farm into basins are not necessarily high enough to prevent irrigation water from overtopping and causing damage to nearby basins and fields where irrigation is not needed.

The head ditch is always fixed at the edge of a field; however, internal field ditches vary from one crop rotation to another due to farm plowing for the next crop. Farm owners, though sharing one meska, do not plan an irrigation schedule among themselves. Also, it was observed that a fixed irrigation interval is adopted by each farmer. This interval is not varied to correspond with variations in types of crops and stages of growth, climatic conditions, nor working periods.

Farmers' replies to our inquiry regarding "when to irrigate" can be summarized in three points: (1) personal experience and judgment, (2) appearance of surface land cracks, or (3) change of color in the plant. However, in explaining "when to end" irrigation, the farmers agree that they stop irrigation when the water covers the farms to about 5 cm depth.

The farms in the Mansouria district suffer poor drainage conditions due to two predominant factors: (1) most of the lands are not served by field drains, and (2) since field drains are maintained privately without any government control, the drain bed levels become high and actually block water from entering the drains.

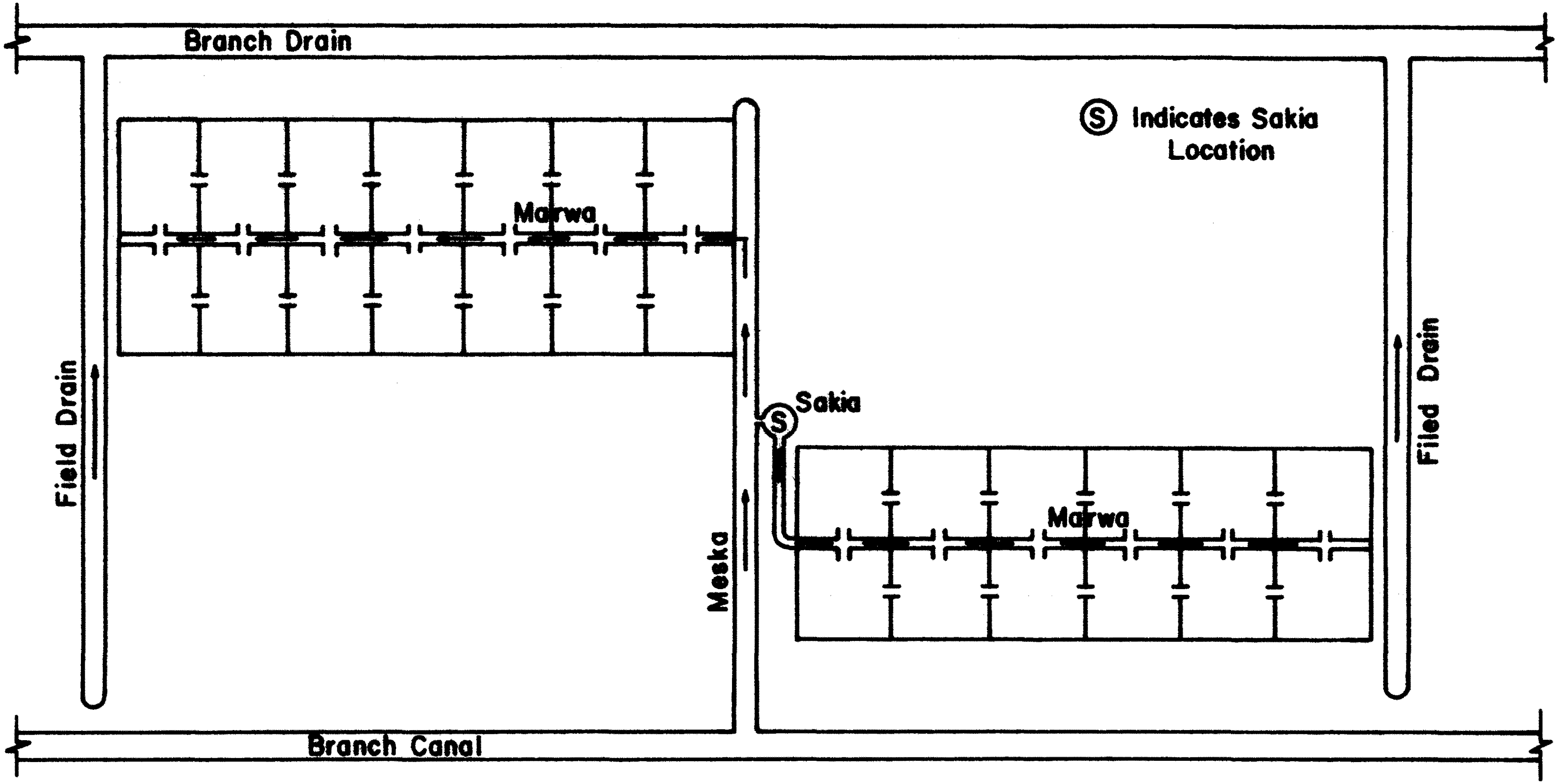

Figure 6. Typical layout of farms using basin irrigation system in Mansouria District.

Current Water Resources Policy: The water policy is intended to ensure the most efficient use possible of the available water resources and to increase the agricultural base and its production in the following ways:

1. Increase efficient use of the water resources by controlling and developing the application system and by limiting flow to the real requirement of the crop.
2. Increase crop production through a developed on-farm water management program.
3. Limit the flow to the removal system by recirculating part of its water to the application system thereby increasing the water use efficiency.
4. Control the water use and alleviate soil waterlogging problems due to excessive seepage from the system and from the excessive irrigation by generally requiring the lifting of irrigation water at the farm level.
5. Evaluate the existing ground water aquifers and use ground water as an additional water resource.
6. Insure better drainage conditions by developing the field tile drainage system.

Economic Features

Macro economic data for the two project study areas in Mansouria are not available. From observation, however, the domination of agriculture as the major economic component of both areas is apparent. It should be kept in mind that people living in both areas can commute to Cairo and have easy access to jobs in industry and commerce. In addition there are some cottage industries, e.g., rug weaving and dress making which provide some non-farm employment opportunities to farm families. As a result there appears to be little unemployment in the study area and the opportunity cost of using farm family labor on the farm is relatively high. About one-third of the farms studied show off-farm family earning for the 1978 agricultural year.

Farm families at Beni Magdoul and El Hammami have access, via oiled road, to the markets of Cairo. The distance to major produce markets is less than 10 km for both areas.

Complexity of farm management decision making in the study area arises as a result of large numbers of reasonably competitive crop alternatives. Farmers experience wide fluctuations in market prices from one year to the next as they attempt to choose profit maximizing cropping systems. Substantial opportunity exists for agricultural production and marketing research and related extension programs to help farmers choose optimal cropping patterns and marketing strategies.

Socio-Cultural Characteristics

The social organization of village life and work patterns appears quite informal and relatively underdeveloped in the villages linked with the two Mansouria study areas. Family and friendship relations seem the pervasive force in indigenous social organization and in existing cooperative coordination patterns. Government services provided by national policy are present and formally organized, of course, but are only functionally viable and integrated into village problem-solving processes when they correspond operationally to informal preferences and social patterns. The personalities and social standing of local functionaries appears a major factor in the services qualifying for popular legitmacy and effectiveness. Generally, one is impressed with the autonomy evidenced within and among village families, and similarly, with the very limited voluntary organization of activities between relatives and neighbors.

In this regard, one suspects that what is referred to in the social science literature as "atomization" and "massification" of village life is taking place in the Mansouria District (that is the tendency for people to go their own separate ways, seeking personal gratification, not wanting to be a "bother" to neighbors or relatives and not interfering in these other people's personal affairs--similar to what often happens in Western nations when undirected suburbanization is in process). This condition has the consequences of depriving residents of a strong sense of community as well as the major social means for acquiring it and managing family and village challenges as well. If this is an accurate impression, it has both adverse consequences and affords some opportunities for the project's field development efforts.

These general impressions of levels of community organization seem to apply to each of the villages in the two Mansouria study areas, but are less apparent in Kafr Hackim, the place of residence for El Hammami study site farmers, than in the Beni Magdoul area villages which are closer to Cairo. The effectiveness of formally organized services likewise seems greater, overall, in the village of El Hammami area farmers.

Cultural Patterns and Values

Turning attention to cultural patterns and values, the early evidence suggests the villages of the study areas are in transition from traditional Egyptian village forms to those more typical of urban centers of nations that have experienced partial modernization. More specifically, many traditional values and behaviors are evident, but exist alongside non-traditional ones, with individuals often shifting cultural modes as they sense circumstances dictate. Generally, it seems the more routine and/or mundane a task is, the more it will follow the traditional pattern, at least superficially. Women are regularly seen wearing traditional outer dresses, carrying loads on their heads or washing dishes with sand on the banks of water courses. Donkeys are ridden to fields being worked, but a truck or taxi will often take the same farmer to a nearby wedding celebration. Recurrent farm tasks like weed control or vegetable harvesting will be done by traditional hand methods, but initial plowing or infrequent applications of insecticides will often be by mechanical means.

A few cultural patterns deserve specific mention, particularly regarding collective values. The residents of the study areas cannot properly be called "folk" or "peasant" people in their life-orientations. They do not display much evidence of agrarian fatalism, although they do often indicate they feel rather powerless to control their destinies in sectors of government policy or regulation. They appear to be contemporary Egyptians in their leisure and recreational pursuits. They are religious (overwhelmingly Moslem in the study villages) and family-oriented people, but they do not seem adverse to accommodating occasional revisions in the practice of either.

In fact, they seem to be as receptive to innovations and changes as urban Egyptians--perhaps more so--when money permits and circumstances justify. Economic and material incentives seem to work well as motivating factors, as do immediate social expectations. In these regards they are atypical of what the social science literature labels "traditional" types. There seem no noticable differences between villages of the study areas with reference to such cultural patterns as these.

Attitudes Toward Assistance

A final matter of socio-cultural relevance deserves consideration in summary. Farmers throughout much of the developed and developing world have a strong desire for independence in thought and action, but also for government support in their agrarian activities. Egyptian farmers are no exception. Perhaps it is this orientation that keeps them on the land despite rigorous labor demands and modest incomes. Whatever the case, farmers in the study areas appear to dislike any exercise of governmental authority, but do look to government agencies for a range of support services. One might hastily conclude that they will not be pleased whatever is done to or for them. Experience in other cultural settings, however, has shown that modest amounts of human consideration, particularly on symbolically significant matters, will yield disproportionate concession from farmers. It is basically a matter of reciprocal responsiveness, which farmers in the study areas seem to evidence at least as much as those in other places.

Case Study Sites

As indicated previously, a small sample of farm operations in the Beni Magdoul and El Hammami study areas were chosen for in depth problem identification research. These sites include seven sites operated by ten farmers in the Beni Magdoul area, and seven sites operated by twelve farmers in the El Hammami area. The location of these sites was shown in Figure 4.

Because most of the problem identification study and analysis is based on our investigation of these case study units, some of their characteristics are summarized in the following graphs, Figure 7.

PROBLEMS IDENTIFIED

Introduction

With the objective of improving existing management practices of irrigated agriculture in Egypt in mind, the problem identification work proceeded as outlined above for the Mansouria irrigation district sites. A summary of the problems identified are presented below in qualitative form. Supporting quantitative data and detailed findings will appear in subsequent reports pertaining to individual disciplines.

Research results vary in some specific details in each of the two specific sites, Beni Magdoul and El Hammami; however, the results presented in this section deal with those identified problems common to all the areas. It is felt by the EWUP staff that these are major problems confronting the farmers in the Mansouria area. The problems outlined herein are clearly defined at this point; other possibly significant ones are being further investigated.

Social and Economic Problems

Social Problems: The social problems in Egyptian agriculture relate both to the farm level organization of agriculture and to national policy and controls:

1. Social Organization Among Farmers. Presently in the Mansouria District there is a virtual absence of formal, voluntary organization among farmers on contiguous lands, and at the village level. Standing cooperative relationships, on a large scale, are not

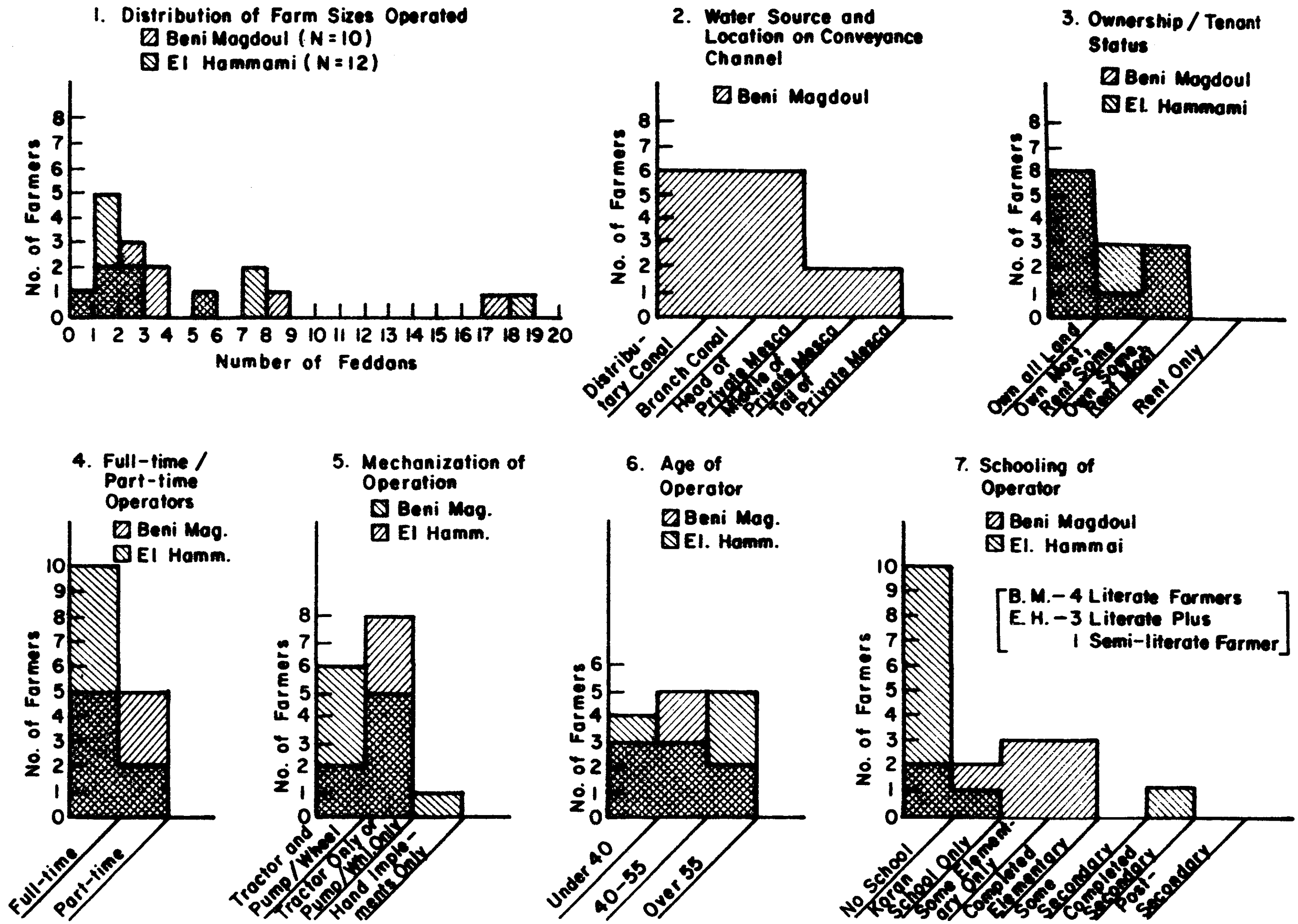

Figure 7. Some comparative farm statistics for Beni Magdoul and El Hammami.

evident. Unquestionably, the project will have to give emphasis to assisting farmers to form voluntary mutual-aid associations, perhaps along the lines of U.S. local water-users associations, but probably broader in function here.

2. Problematic Communications. There exist various problems with inadequate and inaccurate communications among neighboring farmers and with government officials. This situation leads to ineffective decision-making by farmers. It also underlies much of the suspicion and distrust evident between farmers and toward government officials and technical specialists. Such conditions are counter-productive to development processes. Accordingly, improving the frequency and quality of information flow must be implemented as a part of project activities.

3. Low Mutual Understanding and Respect Between Farmers and Official Technical Personnel. Common perceptions of problems, shared knowledge, consistent definitions of abilities, and so forth, are now not an apparent feature of relations between farmers and the government officials nor the technical experts with whom farmers have contact. Such has obviously deleterious consequences for rural development activities which depend upon close working cooperation and trust between these parties to agricultural improvement.

4. Tendency Toward Simple Technical Solutions When More Appropriate, Enduring and Efficient Alternatives Exist. Many examples could be offered; one related to project activities should serve this purpose. Presently there is a tendency to assume that less irrigation water will be applied to fields if the farmer must "work harder" to lift the water a greater distance to field level and if amounts of water supplied are curtailed. Thus, control structures are built and

the levels of ditches are lowered. Hardship is imposed on all farmers but particularly on those at the last reaches of watercourses who, even now, often do not receive the water they need at appropriate times. Demanding more effort from the farmer takes him away from other priority alternative activities which contribute to increased agriculture production. He may even be forced to make heavy expenditures for alternative irrigation methods such as pumps.

If the farmer perceives the crop needs water, observations indicate he will lift the amount of water he thinks is required regardless of the effort. From his knowledge base it is better to over-irrigate, even if it costs him in time and effort, than risk poor yields or loss of crop from not applying enough water.

Education about topics such as efficient water management, farmer-policed local agreements about appropriate water application, scheduling of irrigations, are far more appropriate solutions to the problem of excessive applications of irrigation water, both from the standpoint of the small farmer and for the nation as a whole.

5. Small-Sized Land Holding and Fragmentation of Plots. In addition to problems noted by others of poor economies of scale and difficulties of using many implements and procedures which would improve farming practices, there are socio-political implications. Some of these fall under the general heading of complicating organizational processes and cooperative arrangements among farmers. Others under divided loyalties and commitments, and still others under impeded rationality.

<u>Economic Problems</u>: The economic team presented three problems for consideration in developing EWUP plans:

1. Excessive Costs of Lifting Water. Most farmers in Mansouria lift water with sakias and tambours. Lifting water with a tambour costs three times more than with a diesel or electric pump; a sakia about two times more. Gravity distribution systems should, in some areas, eliminate lifting costs completely. However, one should recognize that changing the present canal systems to a complete gravity system could entail considerable cost in construction of barrages, new canal system, etc. The analysis here deals only with small scale lifting on a meska basis.

The determination of water lifting costs is based on the assumption that human and animal labor has a market value. Our studies indicate that human labor has a value of not less than L.E. 0.15 per hour at Mansouria even during seasons of low labor demand. The market rate for animals is about L.E. 0.32 per hour for turning a medium sized sakia. We assume further that the opportunity cost of power on farms supplying their own labor and animals closely approximates the market rate at the margin.

2. Excessive Slack Time in Crop Rotation. The average slack time in crop rotations for the study farms at Mansouria was 16 percent (58 days per year) for the agricultural years 1977 and 1978. It is our judgment that this can be reduced by better farm planning, cooperation on more capital intensive land preparation methods and improved water distribution systems (some land was idle because water was not available in the meskas).

3. Lack of Data for Farm Planning. Farmers lack the data needed for farm planning and management. They have no farm records and must recall past performance of input-output relationships from memory. Furthermore they have almost no access to secondary sources of input-output information. Substantial increases in productivity and net farm

income could result if farmers were (1) given assistance in establishing record systems, (2) provided access to secondary input-output data, and (3) helped to utilize this information in systematic budgeting and farm planning.

Agronomic and Engineering Problems

The technical problems detailed include both agronomic and engineering concerns. Some of these are overlapping; however, in this section they will be presented separately as this was the mode of their investigation.

Agronomic Problems: The agronomic team identified three problems which are limiting agricultural production in the Mansouria area:

1. Crops Stand Population. The number of plants per unit area of land is low as percent of optimum number of plants per feddan. Table 2 shows the optimum number of plants per feddan for many of the major field crops grown in the Mansouria area. Table 3 summarizes the percent of the optimum stands found on the on-farm work sites in El Hammami and Beni Magdoul. In the case of corn, stands were from 24 to 49 percent below optimum. Beni Magdoul had better stands of corn than did El Hammami farms. However, considerable improvement in both areas can be made. One factor that may explain why stands are better in Beni Magdoul than stands in El Hammami are the differences in soil. The soils in El Hammami being sandy and coarse have a lower water holding capacity and also have higher bulk density values.

2. Fluctuating Ground Water Table. High ground water levels affect crop growth by affecting soil aeration and the crop rooting zone. High crop yields can be obtained under high water table conditions providing there is a low level of salinity in the ground water

Table 2. Optimum Number of Plants per Feddan for Some Field Crops Grown in Egypt.

Wheat	600 fertile heads per m^2 if plant has 6 tillers - $\frac{600}{6}$ = 100 plants m^2 4200 (m^2/feddan) x 100 = 420,000 plants per feddan	
Cotton	60,000 plants per feddan	
Corn	24,000 plants per feddan (10 rows in 7.10 m and 25 cm between plants within plants in a row)	
Rice	33,000 hills per feddan and 3 plants per hill which totals 99,000 plants per feddan	
Berseem	1st cut	5 - 6 tons/feddan on green weight basis
	2nd cut	7 - 8 tons/feddan on green weight basis
	3rd cut	9 -10 tons/feddan on green weight basis
	4th cut	5 - 6 tons/feddan on green weight basis
Vegetables	Squash	4,000 plants per feddan
	Cucumber	3,000 plants per feddan
	Watermelon	2,000 plants per feddan
	Pepper	12,000 plants per feddan
	Eggplant	10,000 plants per feddan
	Tomato	10,000 plants per feddan
Oilcrops	Peanuts	16,000 plants per feddan
	Sunflower	13,000 plants per feddan

Table 3. Percent of Optimum Plants Per Feddan.

Site	Corn	Eggplant	Tomato	Corn + Other Crops*	Pepper
El Hammami	51.4	73.3	--	62.2	--
Beni Magdoul	75.5	--	84.0	79.8	128.0

*Other crops tomato, okra, jew's mallow, cucumber, eggplant and sunflower.

ana that the level of ground water does not fluctuate during the growing season. In the Mansouria area the ground water quality is good but the level fluctuates markedly. Ground water depths on the on-farm work sites in El Hammami and Beni Magdoul were measured during the months of June and July. The data are summarized in Table 4.

Table 4. Ground Water Depth Before and After Irrigation Average Depths of Water Table Below the Soil Surface Before and After Irrigation - cm

Location	Before Irrigation	Range of Depth Values
El Hammami	69.6	55-90
Beni Magdoul	79.8	46-105
	After Irrigation	
El Hammami	58.1	54-65
Beni Magdoul	70.0	43-104

The distribution of water table depths below the soil surface are shown in Figure 8 for Beni Magdoul and El Hammami. In the El Hammami area, the water table is closer to the soil surface on an average than for the Beni Magdoul area. However, the soil texture is significantly different for the two areas as shown in Figure 9. The El Hammami area is characterized by coarse sandy soils while in Beni Magdoul the soils are sandy and clayey loams. Even though the Beni Magdoul area has a water table lower than El Hammami, the potential hazard of a high water table there may be even greater than in El Hammami because of the fine soil texture.

3. Soil Salinity and Sodicity. Soil survey and classification pointed out that salinity is a problem or could be a potential problem

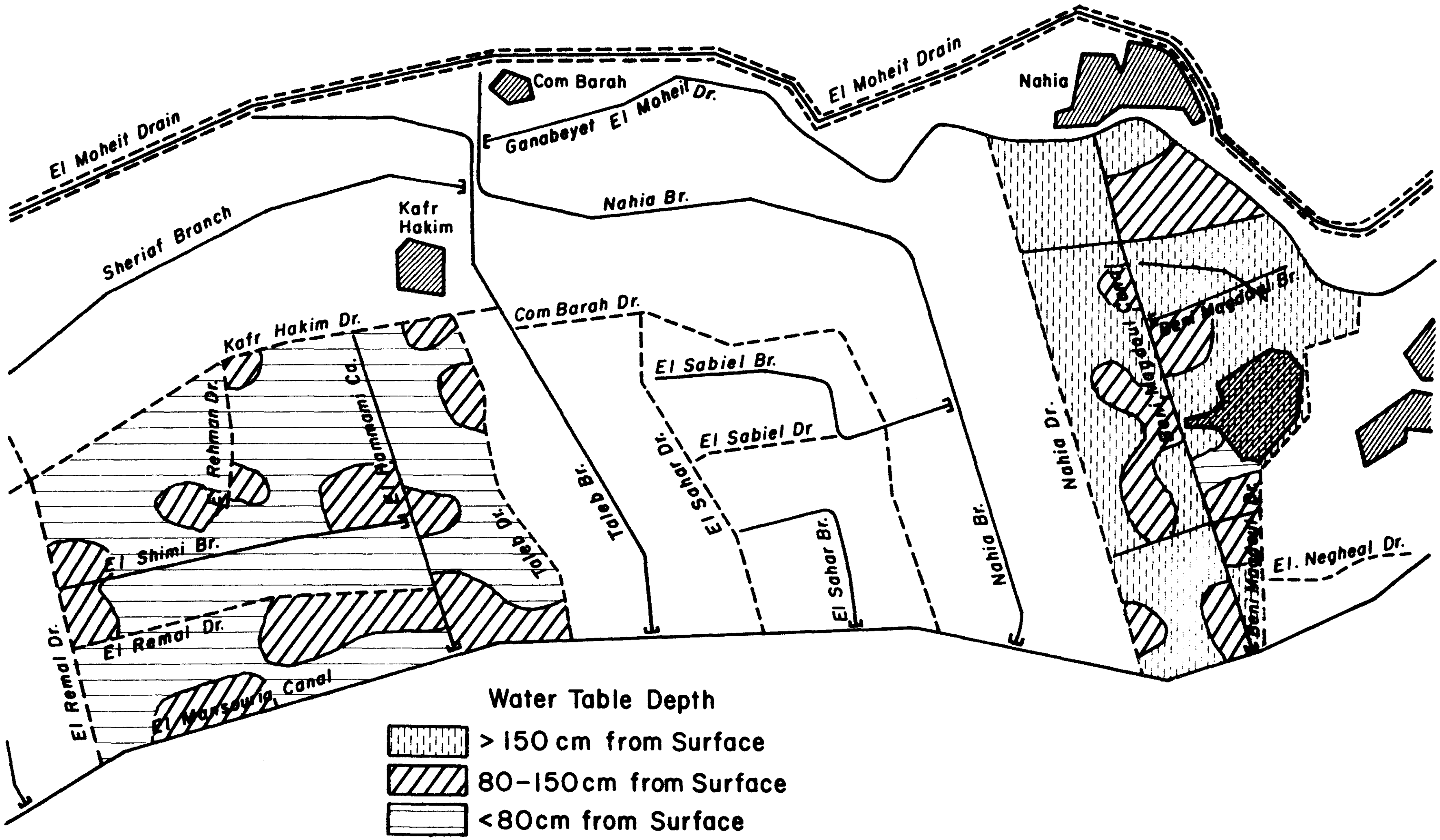

Figure 8. Water table depths below the soil surface in the vicinity of the Beni Magdoul and El Hammami water courses.

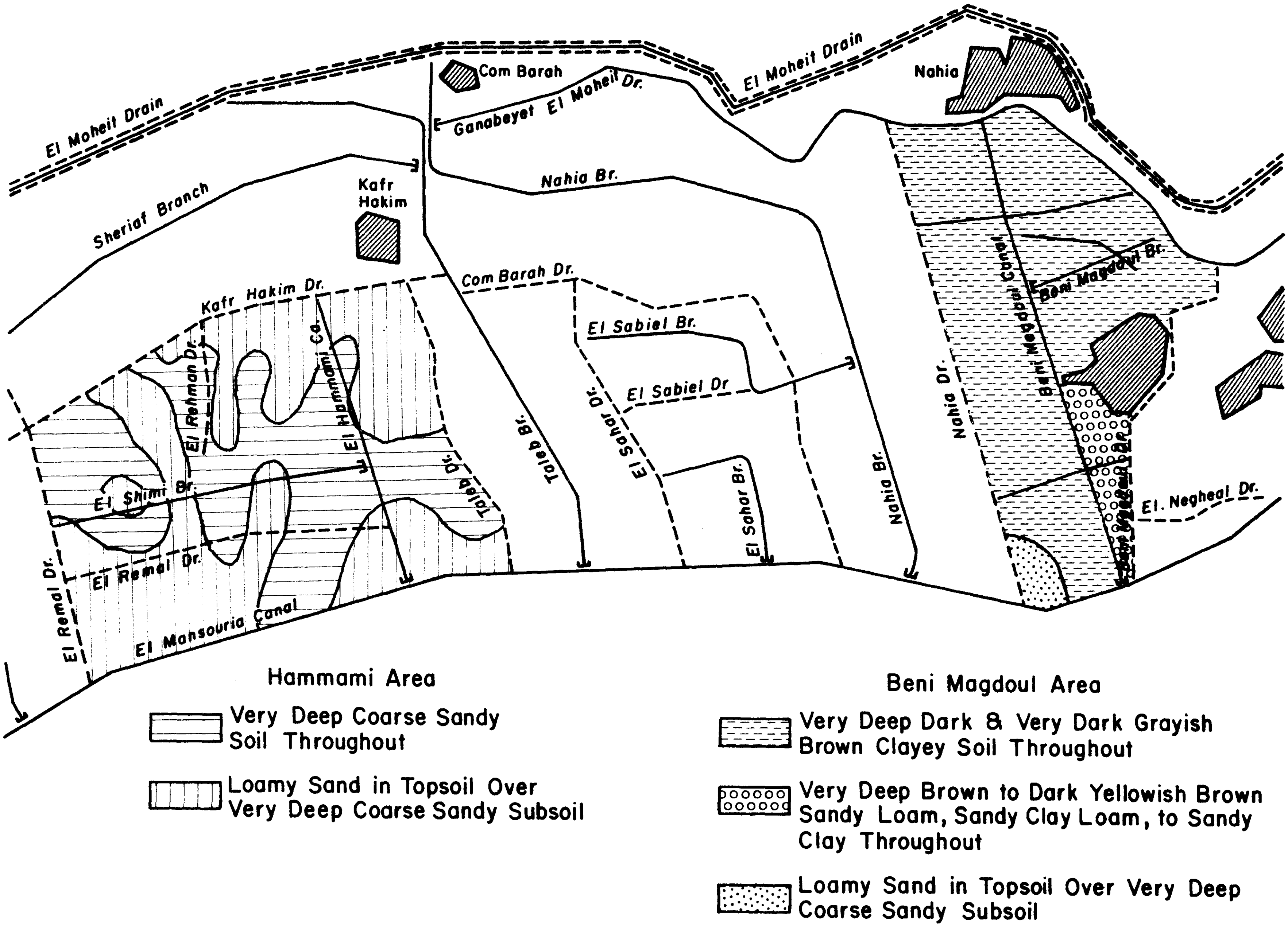

Figure 9. Soil map of Mansouria Project Area.

on 25 percent of the land area in Beni Magdoul and on 17 percent in El Hammami. Soil sodicity as measured by SAR shows that 9 percent of the area in Beni Magdoul and 23 percent in El Hammami pose potential problems if present management practices continue. The extent of the various areas affected in salinity and sodicity is shown in Figures 10 and 11 for these two water courses.

Engineering Problems: The problems identified by the engineering team deal with both the delivery system and on-farm use of irrigation water:

1. Unequal Irrigation Water Distribution Canals. Irrigation water delivered by the Mansouria canal system is not distributed equally among all the lands it serves. The problem is illustrated in Figure 12 where accumulated discharge is plotted as a function of time for the main canal and several of its laterals. Water available per feddan decreases with increasing distance from the intake of a canal or branch. As a result some land receives more water than it needs, while some gets an insufficient amount. Identified reasons include:

a. Extra (illegal) pipe intakes to private ditches have been constructed. Those near the canal intake can rob water from legitimate pipe inlets further down the canal. In El Hammami there are three times as many illegal as legal intakes. The other regions have only a few less.

b. A severe problem of submerged weeds occurred in the concrete-lined Beni Magdoul canal, during the spring and early summer 1978. Apparently the weeds were nourished by an accumulation up to 20 cm of silt in the canal. El Hammami canal was also affected, but it had a severe infestation of emerged weeds as well. Two cleanings

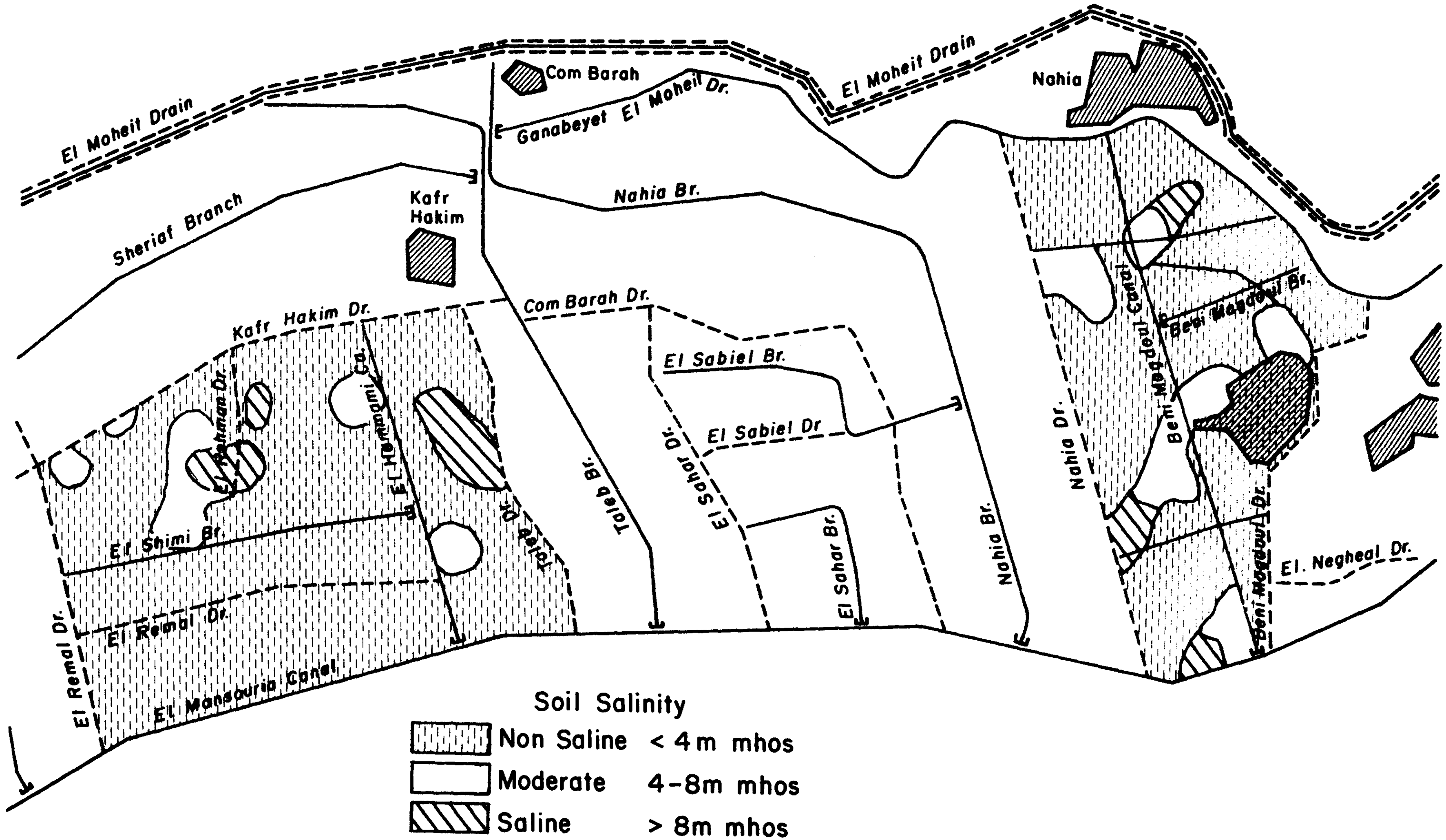

Figure 10. Areas affected by salinity.

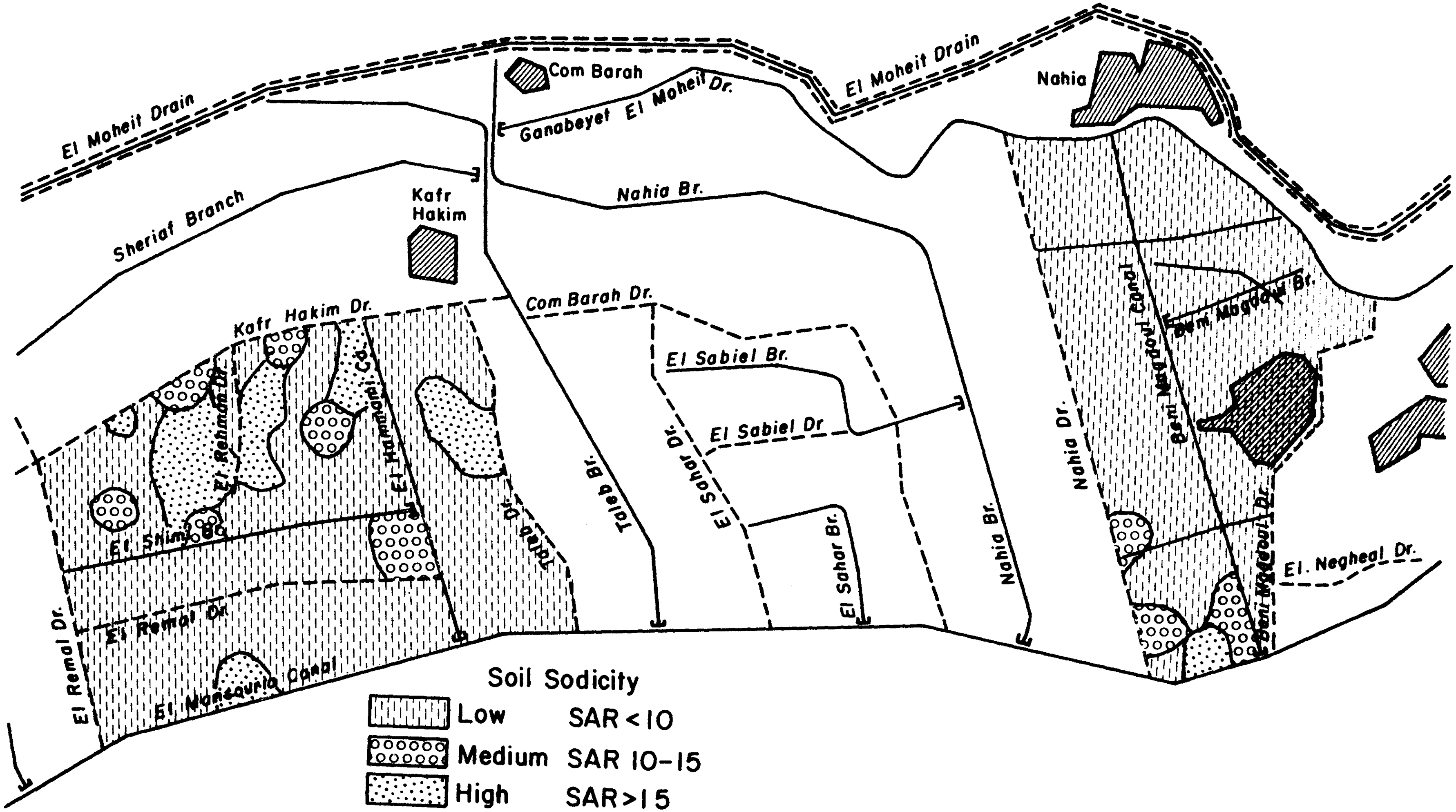

Figure 11. Areas affected with soil sodicity.

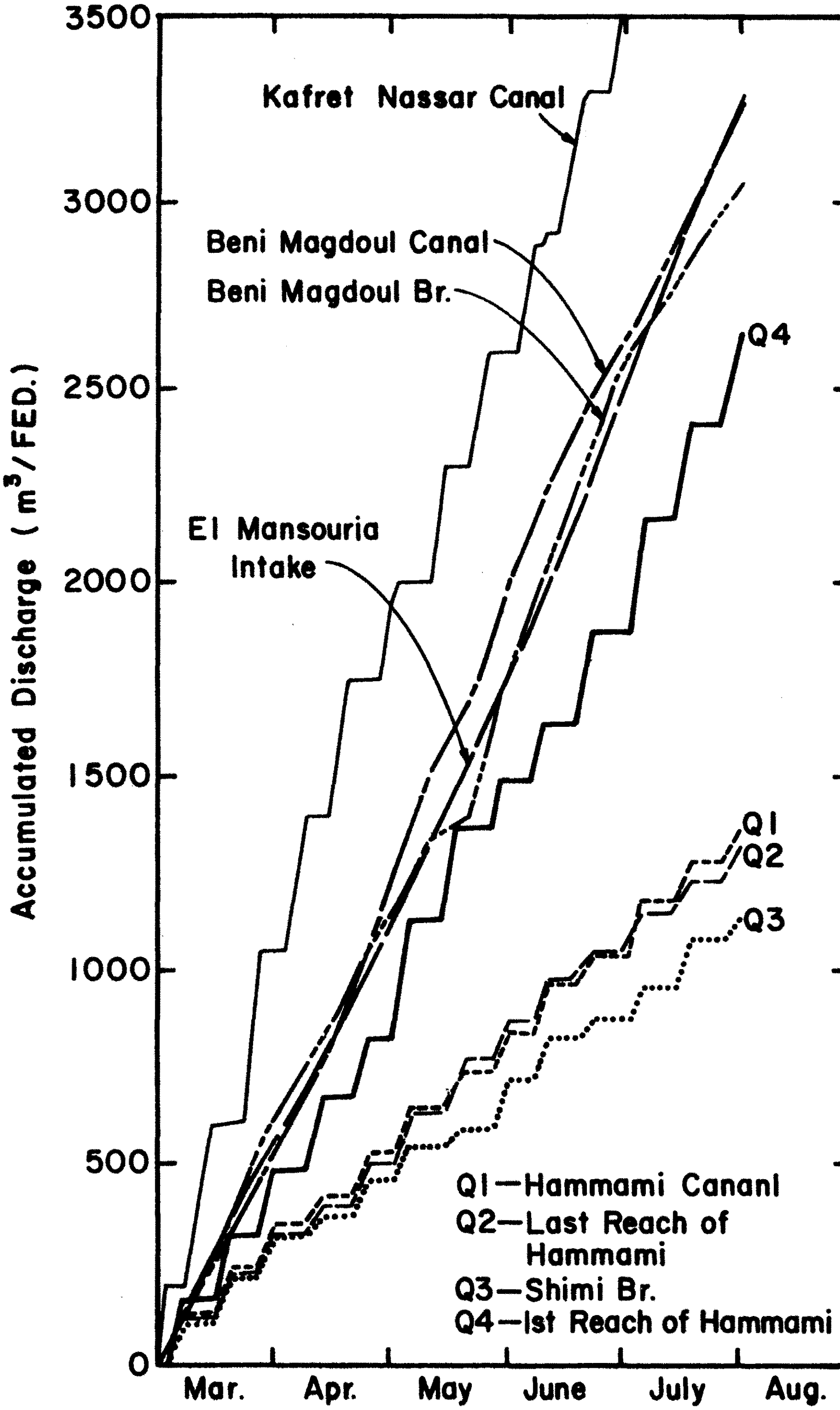

Figure 12. Accumulated discharge as measured at the upstream head gates for the Mansouria Canal and three of its laterals as a function of time for 1978.

were required in each canal during the spring and summer. Prior to cleaning, irrigations were delayed for lack of water.

c. Water delivery to a canal or to a private ditch is not usually measured, but is controlled only by the head at the inlet. Consequently, the users on a branch canal can get more by using more because the gradient is increased. On the other hand, they get less when weeds choke the canal.

d. Those users near the canal intakes, who have more water available, are less inclined to irrigate at night. Consequently, water is more likely to spill over the tail escapes of the first branch canals, due to the diurnal fluctuations, than it is over the last or lower branches. The result is less total water remaining for delivery to the last branches.

2. Uneven Water Distribution in Fields. Irrigation water is often not evenly distributed over a field. High spots and low spots appear as water infiltrates after an irrigation of a basin. One observed consequence is a poor stand in the low spots due to prolonged ponding. A high spot could suffer from too little water absorbed, especially if the low spot receives no excess.

3. Excessive Water Table Fluctuation. The average water table in Beni Magdoul rose to within 0.72 m, 0.80 m, and 0.76 m from the soil surface, respectively, at different times during the spring and summer. Just before the canal closure in January it was observed at only 0.5 m below the ground surface. In an individual field, it usually rises sharply with each irrigation, reaching a level higher than the average, such as 0.37, 0.55, and 0.41 m below the surface in field 1, site 6, during June and July, illustrated in Figure 13. Very little sustained root activity has been observed below these points of highest rise.

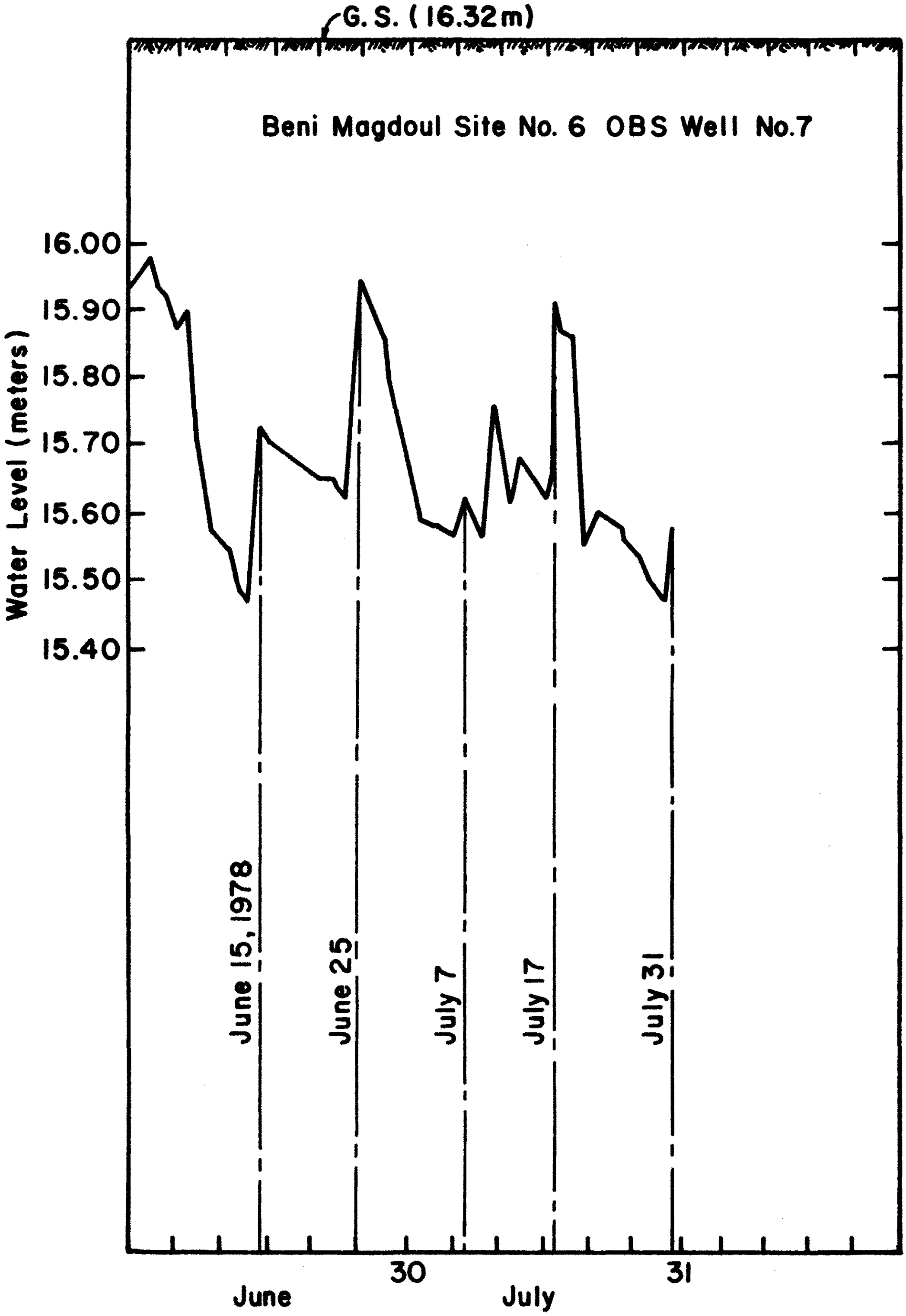

Figure 13. Changes in water elevation with irrigation.

a. Water table fluctuations may result from canal and ditch seepage. Preliminary seepage measurements show considerable variation with location and with depth of water in the ditch or canal.

b. Irrigation applications which exceed the soil moisture deficit contribute to the water table. These are most likely to occur (1) at planting, (2) during a deliberate leaching irrigation, or (3) when two irrigations are applied during "on" period of the rotation. A particular irrigation at another time might also be excessive, but they tend to be much closer to the actual soil moisture deficiency.

4. Irrigation Water Quality. Although water quality in the canals is good (C-2, S-2 by U.S. Salinity Lab classification), salt has accumulated on the ground surface in small areas, due at least in part to a water table close to the surface at those points. Water in drains may have two or three times as much salt (maximum classification C-3, S-3, moderately high), and therefore more restrictions are required when using it for irrigation. Water from wells classifies between these extremes.

5. Land Used for Water Conveyance. The sizeable land area (about 12 percent) occupied by farm ditches is not available for crop production.

6. Seepage Losses. Seepage loss from canals and ditches necessitates designing these structures with larger cross sections. For at least that portion of this water that is pumped back from drains the head is also lost.

7. Weed Growth. Weed growth in drains is sometimes permitted to interfere with the intended performance of the drains.

8. Animal Crossings. Where animals cross canals and drains they tend to break down the banks and raise the bottom.

Interdisciplinary Research

Once the data for the above disciplinary problems were reported and an attempt was made to structure it into a coherent interdisciplinary theme, it became apparent that there were gaps in the data which could best be filled in by an interdisciplinary group. These groups have now been established and research on the following questions is proceeding:

1. Excessive costs of pumping/alternative pumping methods.
2. Crops stand densities.
3. Effect of high, fluctuating water on agricultural productivity and with contribution to crop water requirements.

The problems of excessive pumping costs and poor crop stands were also selected as the areas in which the most gain could be made for small farmers in the next phase of project activities in Mansouria. During the next research phase, field trials will be undertaken. If the field trial results are positive, the proposed alternative solution will be extended throughout the Mansouria area and to other areas in Egypt where similar problems exist.

SUMMARY AND CONCLUSIONS

This report summarizes the activities of the Egypt Water Use and Management Project over approximately the first year of operation. The first expatriates arrived on the project in October 1977. This report represents the status of the project as of October 1978 with particular emphasis on that accomplished in the Mansouria Irrigation district.

The problems identified below seem to be those with solutions which would benefit the farmers the most.

Most farmers in the Mansouria irrigation district lift water with sakias and tambours. An analysis of lifting costs using tambours and sakias has led to the conclusion that one electric or diesel pump located on a Meska serving 50-60 feddans may reduce the lifting costs by one-third. Reducing lifting costs by reducing the number of lifts is relatively easy to accomplish technically and physically. However, this kind of solution requires that the farmers cooperate together and schedule irrigation water. Due to the wide variety of crops, size of farms, and differences in farming habits of individual farmers, reducing the cost of lifting water by reducing the number of lifts which much bring about scheduling will not be particularly easy. For instance, the farmers are not particularly interested in mechanical devices that may require maintenance as in the case of the diesel pump or in the case of an electric pump, a power failure, where they may run the risk of losing some productivity because of the failure of the mechanical system. In addition, they do not feel particularly confident that cooperation can be achieved between so many farm operators. In the Mansouria irrigation district where farm size is relatively small, and where one Meska may serve 30-40 individual farmers, it is not difficult to appreciate their concern.

A second problem appears to be the excessive amount of time that the land is out of production. The average slack time for crop rotations for the study farms at Mansouria was 16 percent for the agriculture year 1977-78. This amount of slack time represents about 58 days per year and it appears that this time could be reduced substantially to increase net-farm income. The reasons for this excessive slack time in crop rotations are not particularly clear. However, interviews with several farmers indicate that for some crops the land must be plowed and exposed to the air and sunshine for a significant period of time before it can be returned into production. Some of these ideas about having the land rest between crops may be a carryover from the annual basin type irrigation used before the Aswan High Dam. Other reasons for slack time may very well be due to inefficient farm operations, e.g., being unable to obtain seeds or equipment for planting or manipulating the soils at the proper time.

Substantial increases in productivity and net farm income also could result if farmers were given assistance in establishing a farm record system and were helped to utilize records and farm data for systematic budgeting in farm planning. A farm planning system would allow decisions to be made in a farm operation that would bring about an opportunity for greater net income.

A few important technical problems identified in the Mansouria irrigation district include: the relatively low percentage of plants per feddan, high water table fluctuations in the plant root zone of the soil profile, and the relatively high percentage of land that may be potentially saline or sodic.

At the time of writing of this report it is not particularly clear the reasons for the low plant stand density. Some preliminary observations indicate that the distribution of water on the land at the time of irrigation and that coupled with low seed quality and hand planting techniques may be responsible for the lower than optimum number of plants per feddan.

The high water table fluctuations in the plant root zone result mostly from irrigation and seepage from Meskas and canals. It is not clear at this point how much each of these contribute to the duration and frequency of fluctuation. In the El Hammami area where the soils are relatively sandy, the water table seems to be higher than those areas in Beni Magdoul where the soil texture is more clayey and finer textured.

Another problem of considerable significance is that irrigation water delivered by the Mansouria canal system is not distributed equally among all the land it serves. Water available per feddan decreases with increasing distance from the intake of the canal or branch canal. As a result some land receives more water than it needs while some gets an insufficient amount.

Some reasons for these inequities in distribution include: illegal extra intake pipes into private ditches, conveyance head losses due to weeds, and excessive seepage in sandy areas.

Perhaps the most pressing social problems that the farmers face in Mansouria, which will have a substantial effect upon improving management practices and making appropriate changes for their well being, is a virtual absence of formal voluntary organization among farmers on contiguous lands and on the village level.

The problem of inadequate and inaccurate communication among neighboring farmers, and with governmental officials lead to ineffective decision making among farmers. Suspicion and distrust between farmers and toward government officials and technical specialists will bring about slow changes in management practices on the farm. However, there is every reason to believe that the farmers will accept change when suspicion and distrust can be eliminated by cooperative and reliable governmental operations. An example situation occurred on the Beni Magdoul branch canal and several of its Meskas when it was planned to line these with concrete. The farmers at first were completely unwilling to accept this change in their water conveyance system and vehemently objected simply because it appeared that the new conveyance cross section would reduce the quantity of flow and cause inadequate water supply for their individual needs.

After completion of construction and about six months of operation of these lined canals and Meskas, the farmers have seen the value of lining and understand that there are factors that control quantity and distribution of water other than the size of the conveyance channel. There is presently a clammering among farmers to have their particular Meskas lined. They see more dependable water distribution: lower water tables adjacent to the Meskas and increased land brought into production due to reduced seepage and reduced cross sections. They are presently ready to accept with great enthusiasm this particular management practice. There is a very good likelihood that other types of management practices which farmers are presently unwilling to accept but when adequately demonstrated they will be acceptable to them.

With these problems identified, EWUP is proceeding to implement some field trials with respect to reducing lifting costs, increasing plant stand density, and other associated on-farm practices such as land leveling for increased water distribution efficiency. Such field trials may help the farmers see, through demonstration, those management practices that will increase production and net income to them. This is being undertaken by: working directly with farmers and their representatives, discussing their problems, offering solutions and assistance, suggesting other solutions to problems that perhaps they may not be aware of.

PRELIMINARY SOIL SURVEY REPORT FOR THE BENI MAGDOUL AND EL HAMMAMI AREAS

EWUP Technical Report No. 2

Prepared under support of
United States Agency for International Development
Contract AID/NE-C-1351
All reported opinions, conclusions or
recommendations are those of the
author and not those of the funding
agency of the United States Government.

By

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March 1979

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Acknowledgment

The assistance of the members of the Soil Survey Section, Soil and Water Research Institute, headed by Dr. A. Serry, in carrying out the field work and the analysis is gratefully acknowledged. Special thanks are given to Dr. W. R. Schmehl, Professor of Agronomy, Colorado State University for valuable help and concern in the preparation and interpretation of the data while on TDY assignment. Also special thanks are given to Drs. M. Abu-Zeid and R. H. Brooks, Project Directors, for their administrative assistance in helping coordinate all efforts to complete the survey.

PRELIMINARY SOIL SURVEY REPORT FOR THE

BENI MAGDOUL AND EL HAMMAMI AREAS

A. D. Dotzenko, M. Zanati, A. A. Abdel-Wahed and A. M. Keleg

INTRODUCTION

This is a preliminary report of the soil survey for the Beni Magdoul and El Hammami areas in Mansouria. The purpose of the report is to supply base data to assist in planning the adaptive research and development phases of the Project. As additional crop production, agricultural engineering and economic data become available, a more comprehensive soil classification will be developed.

The soils in the two pilot areas selected for the Water Use and Management Study in the Mansouria Irrigation District were surveyed during February and March, 1978. The Beni Magdoul area, in the southern part of the District, consisted of approximately 800 feddans and the El Hammami area in the northern part of about 2000 feddans. Fifty-seven profiles were examined and 150 samples were collected for chemical and physical analyses from Beni Magdoul and 88 profiles were examined and 130 soil samples were collected from El Hammami. Maps with a scale of 1:5000 were prepared on the basis of soil profile characteristics and on soil chemical and physical properties. These maps delineated the soil units on the level of soil series and phases of series. Also included is a preliminary evaluation of the effects of the physical and chemical properties of the soils on crop production.

MATERIALS AND METHODS

Field Procedures

The field survey was conducted in Beni Magdoul and El Hammami using cadustral maps of scale 1:2500 prepared by the Soil Survey Department.

Soil profiles representing an area of 10 to 15 feddans per profile were examined to a depth of approximately 150 cm. The morphological features of the profiles were carefully described using the system outlined in the USDA Soil Survey Manual (1951). These features are soil color, texture, structure, consistency in dry, moist and wet conditions, porosity, root distribution, lime and gypsum accumulations, and the horizon boundaries. Other characteristics of the site included crop, relief, topography, salt efflorescence, and depth to ground water table at the time of the survey. Soil samples were taken from each depth and ground water samples were removed from 8 profiles in Beni Magdoul and 22 profiles in El Hammami.

Laboratory Methods

The soil samples collected from the different horizons were air-dried, crushed and passed through a 2-mm sieve. A saturation paste was prepared and the saturation extract was analyzed for electrical conductivity and water soluble cations (Ca^{++}, Mg^{++}, K^{+}, Na^{+}) and anions (Cl^{-}, HCO_3^{-}, $CO_3^{=}$) (U.S. Salinity Laboratory Staff, 1954). Soil pH was determined on the saturation paste. Some samples were selected for the determination of cation exchange capacity and exchangeable sodium. Calcium carbonate was determined on all samples with the Collins calcimeter (Hesse, 1971). Particle size distribution was determined by the pipet method (Black, 1965). Total dissolved solids in the soils were determined gravimetrically after evaporation of the soil extract to dryness (Piper, 1950).

The sodium adsorption ration (SAR) was caluculated using the equation, $SAR = \frac{Na}{(Ca+Mg)^{1/2}}$, where Na and (Ca + Mg) refer to millimoles per liter of these ions in the saturation extract. The exchangeable sodium percentage (ESP) was calculated for samples for which cation exchange capacity and exchangeable sodium has been determined using the equation:

$$ESP = \frac{\text{exchangeable sodium}}{\text{cation exchange capacity}} \times 100$$

The ground water samples were analyzed for soluble cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}), soluble anions (Cl^{-}, HCO_3^{-}), and electrical conductivity. Sulfate was calculated as the difference between the total cations and the sum of Cl^{-} and HCO_3^{-}. Total soluble salts were calculated from the sum of the water soluble cations and anions using their respective molecular weights.

SOILS OF THE BENI MAGDOUL AREA

Soil Morphology

The morphological characteristics of the profiles and the chemical and the mechanical analyses of Beni Magdoul area revealed that most of these soils are Holecene alluvial deposits. These deposits were formed essentially from very dark grayish brown Nile suspended matter consisting of micaceous minerals and hydrated magnetite (Ball, 1952). The soils of the area are classified into the following series:

Series I This series occupies the larger portion of the Beni Magdoul area (Map 1B). The soil is dark to very dark grayish brown throughout, with the clay content generally ranging from 40 to 60% but occasionally with higher levels (Table A-1). The clay content in the topsoil of profiles adjacent to Mansouria canal was less than 40% because of the effect of the wind-blown sand from the near desert. The texture of these soils are classified as sandy clay. The soil is compact and has a strongly developed angular, blocky structure. Wide and deep cracking occurs when the soil dries. Slickensides are very clear in the subsoil to a depth of 60 cm. The lime content is relatively high, and reaches from 2 to 12% in topsoil and decreases gradually with depth to 1 to 5% in the subsoil.

The soils of this series would be classified under the new American soil classification system "Soil Taxonomy" in the order Vertisols, suborder great group Torrerts, and the subgroup Typic Torrerts (Soil Survey Staff, 1967).

Series II This soil series occupies the area located west of Beni Magdoul Village between the canal and the drain. This series is represented on Map 1B by profiles 40, 41, 42, 43, 44. The soil is characterized by a brown to dark yellowish brown color, sandy loam to sandy clay loam, or even sandy clay to a depth of 80 to 150 cm or over. The clay fraction is less than 30%, and sand is the dominant fraction. The lime content is moderate and ranges from 1 to 3.5% and decreases gradually with depth.

This soil is classified under the American classification system in the order Entisols, suborder Fluvents, great group Torrifluvents, and subgroup Typic Torrifluvents (Soil Survey Staff, 1967).

Series III This soil is located in a small area in the corner between the Nahia drain and the Mansouria canal and is represented by profiles 3 and 6 (Map 1B). The soil has a sandy texture except for the topsoil which can be either a loamy sand or sandy clay.

The soil is almost structureless with single grains of pale brown to yellowish brown color. The lime content, which is relatively high, ranges from 3 to 6% and decreases gradually with depth. This soil series under the American System is in the order Entisols, suborder Psamments, great group Torripsamments, subgroup Typic Torripsamments (Soil Survey Staff, 1967).

Soil Salinity

The salinity and SAR levels of irrigated soils are dynamic properties and are related not only to soil properties but also to method and amount of water applied as well as to quality of the water. At the time of the survey surface soils of Beni Magdoul area generally were classed as non-saline when based on electric conductivity values under 4 mmhos (U.S. Salinity Laboratory Staff, 1954). Some scattered sites were moderate saline (4-8 mmhos) as shown for profiles 1, 4, 13, 14, 16, 26, 29, 30, 45, 48, 53 (Map 2B). Three soils were highly saline (8-16 mmhos) in the surface, profiles 12, 25, and profile 2 has an electrical conductivity of 20 mmhos (Table A-2).

The SAR of the surface soil generally was less than 10 and only in profile 2 was it greater than 15. The ESP of the few samples for which it was determined tended to be higher than that calculated from SAR as outlined by the U.S. Salinity Laboratory Staff, 1954.

Water-Table Status

The water table at the time of the survey generally was more than 150 cm below the soil surface. However, in some profiles, the water table ranged from 60 to 140 cm below the surface (profiles 6, 11, 13, 16, 25, 42, 44, 53) and signs of mottling occurred in the fluctuating water-table zone (Map 3B). It should be noted that the water table depth in these soils is not static but is related closely to the irrigation practices prior to measurement.

The analysis of 8 representative ground water samples shows that the total soluble salts ranged from 1060 to 7400 ppm, and reached 11,560 ppm in profile 13, where the soil was moderately affected by salinity (Table A-3). The dominant cation in the ground water of most profiles was sodium. Calcium and magnesium were dominant in the ground water of profiles 20 and 50.

SOILS OF THE EL HAMMAMI AREA

Soil Morphology

The morphological study of 88 soil profiles in Hammami area, together with the chemical and the mechanical analysis of representative soils revealed that: (1) the soil profiles of the entire area are quite uniform, of recent age and were formed from aeolean sand deposits blown from the near western desert; (2) the color of the subsoil ranges from yellow to yellowish brown. The topsoils are darker, being yellowish brown to dark yellowish brown and dark brown; and (3) soil texture generally is sandy throughout the profile. The topsoil in many cases is a loamy sand to depths of up to 30 cm (Table A-4) because of the addition of the suspended matter from previous Nile floods and also because of the application of manure composts during the past 30 years following reclamation. The soil ususally is loose or slightly compact in the topsoil without any developed structure. In addition it is porous and characterized by a high hydraulic conductivity because of the low content of clay and silt which generally does not exceed 10% in subsoils and/or 15 to 25% in topsoils. The lime content is low and ranges from 1 to 2% in the topsoils and less than 1% in subsoil. No gypsum accumulations were observed. Soils of this area according to the American soil classification system "The Soil Taxonomy" are in the order of Entisols, suborder Psamments, great group Torripsamments and subgroup Typic Torripsamments (Soil Survey Staff, 1967). These characteristics place the soils in the Hammami area under one series which is classified into two phases:

Phase I This is a very deep, coarse, sandy soil throughout. The color ranges from brownish yellow (10 YR 6/6) in the subsoil to yellowish brown and dark yellowish brown in the topsoil (10 YR 5/3-5/4-4/4) in moist condition. The coarse sand is the dominant fraction which ranges from 50 to 78% and the silt and clay is less than 10%. The soil is structureless, consisting of loose, single grains. These soils occupy the central part of the area (Map 1A).

Phase II This soil phase is like Phase I, except for the topsoil which is slightly heavier in texture, and is a loamy sand or occasionally a sandy loam. The fine particles of the topsoil range from 15 to 25%. The consistence of the top layer is slightly compact and has a darker color, usually dark gray to dark grayish brown. The soils of this phase are located along the Mansouria canal and Kafr Hakim drain. These areas are considered to be the older cultivated lands in El Hammami (Map 1A).

Soil Salinity

The electrical conductivity of the soils in El Hammami at the time of the survey were usually less than 4 mmhos. Some scattered areas, however, were moderately saline (4 to 8 mmhos) and are represented by profiles 6, 31, 55, 60, 61, 62, 67, 76 and 99 (Map 2A). Some areas of high salinity (from 8 to 16 mmhos) are shown by profiles 12, 14, 47, 54 and 56. The saline areas were located mainly in the eastern part of the area and involved about 300 feddans. There appeared to be a shortage of irrigation water in this area of El Hammami.

Fifteen percent of the surface soils (14 sites) would be classed as sodic, i.e. with an SAR of 15 or greater. Another 7 percent of the soils (6 sites) had an SAR in the range of 10 to 15. Most of the surface soils would be classed as non-sodic (Table A-5).

Water-Table Status

At the time of the survey, water table depths were measured and found to be less than 100 cm from the surface in the entire area (Map 3A). In more than one-half of El Hammami area, water table levels reached 40 to 60 cm from the surface (47 profiles). Because of the presence of water table at shallow depths, mottling occurred in the fluctuation zone and occasionally gleyed layers appeared in the subsoils of many profiles.

The analysis of some water-table samples (22 samples) showed that the total soluble salts usually ranged from 1000 to 2000 ppm (Table A-6). The maximum ground water salinity (3970 ppm) was in profile 47 where the soil was affected by salinity. The lowest total soluble salts in the ground water was in profile 1 (630 ppm) which was adjacent to to Mansouria canal (Table A-6).

PRELIMINARY EVALUATION FOR CROP PRODUCTION

Soil texture, the mineral content of the soil and the cation exchange capacity are fundamental soil properties that are essentially static during man's lifetime. Other properties such as soil salinity, soil sodicity and soil fertility are dynamic properties that change with the farmers' management practices. Thus, in the interpretation of soil analysis, the static or dynamic nature of the parameter must be considered when evaluating management in terms of crop growth. The farmer can modify his cultural practices that influence the dynamic properties, but he must work within the limitations of the fundamental or static soil properties.

Beni Magdoul

Soil texture The principle series described for the area (Series I) is a heavy-textured soil containing from 40 to 60% clay. Soils with this content of clay require good management practices if crop production is to be maintained at high levels. Problems associated with heavy-textured soils are characterized by a) poor aeration during a period of time following irrigation, particularly where a high water table is present, b) difficulty in cultivation or other soil manipulation practices when either too wet or too dry, and c) seedling emergence may be impaired by crusting and cracking.

The soils composing Series I are capable of producing crops from medium to high yield levels with good management systems. Soils composing Series II and III should have medium yield potentials. In all cases, the soils of Beni Magdoul require management practices that encourage good soil-particle aggregation, and careful irrigation is required to prevent poor soil aeration or temporary water-logging in the root zone.

pH and lime The pH of the soils ranged from 7.4 to 8.4 and is that expected in soils containing 2 to 12% lime. These are non-sodic, calcareous soil systems and the pH is determined mainly by the combination of soluble calcium salts and the CO_2 pressure as shown by the following equation (after Cole, 1957):

$$pH = 4.85 + 1/2\ pCa - 1/2 \log pCO_2$$

The pH of the soils are in a favorable range for the nutrition of most crop plants. Few micronutrient deficiencies would be expected, except possibly Fe and Zn for certain crops in areas where soil organic matter is low and where no animal manures or plant residues are returned to the soil.

Saturation percentage (SP) and cation exchange capacity (CEC) The SP of Series I soils averaged 68% in the 0 to 20 or 0 to 30 cm depths and increased to 73% at intermediate depths (30 to 50 cm) and to

77% at 50 to 150 cm depths. The CEC for 9 samples ranged from a minimum of 10 to a maximum of 38. Using the limited data for CEC the following regression equation was developed to calculate the CEC from SP:

$$CEC = 0.80 = 0.45(SP)$$

The equation may be used to estimate the CEC of other soils in Beni Magdoul.

The SP was determined on disturbed soil samples and is not suitable as a single value for soils of these textures to evaluate soil aeration characteristics in the field. With the combination of bulk density and field moisture capacity measurements in the field, good estimates of the aeration characteristics of the soil can be obtained.

Electrical conductivity (EC) The EC of the saturation extract of the 57 surface soils from Beni Magdoul were grouped into 3 categories depending upon the degree of salinity:

a. Non-saline (0-4 mmhos)-only the more sensitive plants are affected.

b. Moderately saline (4-8 mmhos)-growth of most crop plants show reduction in growth. Salt sensitive plants show a considerable reduction in growth while salt insensitive plants show little reduction.

c. Strongly saline (> 8 mmhos)-there is marked reduction in growth of nearly all crop plants.

Electrical conductivity is not a fundamental soil property, but is one that depends largely on soil and water management and on quality of the irrigation water.

Of the 57 soils evaluated, 25% had EC values that were sufficiently high to have an adverse effect on the growth of most crop plants. Only

Salinity scale	No. of soils	% of soils	Average EC per category
Non-saline < 4 mmhos	43	75	2.1
Moderately saline 4 - 8 mmhos	11	19	5.7
Strongly saline > 8 mmhos	3	6	13.9

3 of the soil profiles were classified as strongly saline. With judicious management of irrigation water and possibly with the improvement of drainage and the leaching of excess salts followed by the addition of manure, the salinity problem in these areas could be reduced to the point where reductions in crop yields could be eliminated. The strongly saline areas which encompass only 6% of the total areas were located randomly in the Beni Magdoul (Map 2B).

Soil sodicity Both the exchangeable sodium percentage (ESP) or sodium adsorption ratio (SAR) of the saturation extract are used to characterize the sodicity of a soil. Because of the ease of determination, SAR is most often used. The SAR value is approximately equal to the ESP for values of ESP to about 30 (U.S. Salinity Laboratory Staff, 1954).

The SAR value of 56 surface soil samples are summarized in the following table according to a) low SAR (<10) b) medium SAR (10-15) and c) high SAR (>15).

SAR	No. of soils	% in category	Average per category
Low, <10	52	91	5.6
Medium, 10 - 15	4	7	12.7
High, >15	1	2	23.0

As with EC, if the irrigation water is of good quality the SAR is an indication of the type of soil and water management on the farm. With continued poor management, potential problems could be expected in 4 of the 57 soils (7%), and one soil now has a sodic problem. The combination of high quality irrigation water and high irrigation rates probably are the main factors maintaining the low SAR and salinity values of these soils. Leaching of excess salts from the soil profile, providing adequate drainage exists, and then followed by the applications of gypsum and manure would preclude the development of sodic conditions.

Ionic composition and the saturation extract Certain ionic ratios in the saturation extract can give insights to potential nutritional problems. The SAR values summarized in the preceding section indicate no calcium nutrition problems at the present time. Should the SAR of profile site 2 continue to increase (SAR = 23), nutritional problems could develop although detrimental soil physical conditions probably would appear first.

The Ca/Mg and SO_4/Cl ratios were calculated for the saturation extracts of the surface soils. The average Ca/Mg ration was 1.9 $\pm$ 0.5 and the average SO_4/Cl ratio was 1.6 $\pm$ 0.5. The value for the Ca/Mg ratio is satisfactory and a Ca/Mg imbalance would not be expected unless the ratio becomes very high or very low. The SO_4/Cl ratio indicates that it is a sulfate dominated system in most profiles. This is desirable because at comparable electrical conductivity levels in the soil, salinity effects on plant growth generally are less severe in sulfate systems.

Groundwater analysis Groundwater samples were analyzed from under 8 soil profiles and are summarized in the following table.

Factor	Average	Range
Electrical conductivity, mmhos	5.9	1.4 to 13.7
Sodium adsorption ratio	10.1	5.7 to 14.9
Total soluble salts, ppm.	4690	1065 to 11,100
SO_4/Cl ratio	0.84	0.6 to 4.0
Ca/Mg ratio	0.81	0.5 to 1.1

Six of the water samples had conductivity levels of greater than 4. None of the water samples had SAR values that exceeded 15, but one-half fell in the range of 10 to 15. Sodium chloride is the predominate salt in most of the ground water samples.

In general, the ground water samples indicate that problems could be encountered in crop production if irrigation practices allowed continued upward movement of salts from the ground water. This could be quite serious, particularly in areas where a high water table and high rates of evaporation occur simultaneously.

El Hammami

Soil texture The soils are largely loamy sands in the surface and sands in the subsoil. They have very low water holding capacities and low cation exchange capacities. Problems associated with light textured soils such as these are a) droughtiness, b) low fertility, and c) subject to severe leaching of nutrients. These soils should have no aeration problems but careful management of irrigation and fertilization will be required. In contrast to the heavier soils in Beni Magdoul, a relatively high water table may be advantageous if salinity can be controlled. Deeper rooted crops, such as tree crops, should be well suited in this area as the intervals between irrigations would be lengthened thus reducing the build up of the water table and reducing the loss of plant nutrients by leaching.

pH The pH of the soils in El Hammami ranged from 7.9 to 8.8 and most of the soils were non-sodic. Some of the pH values of 8.4 or so were not as high as might be expected for SAR values in excess of 15. The soil pH values of the surface soils generally were in a favorable range for the growth of most crop plants, but micronutrient deficiencies could be expected, particularly with Fe or Zn for certain crops because of the combination light texture and low organic matter content of these soils.

Saturation percentage (SP) and cation exchange capacity (CEC) The SP percentages averaged 25.5% for the surface areas and 22.9 for the subsurface. This indicated a low water holding capacity of these soils. The field moisture capacity of most soils was 12 to 15 percent. With bulk density measurements reasonably good estimates of cover soil aeration, under field conditions can be calculated for these light textured soils.

Cation exchange capacity levels were also quite low as surface soils (0 to 20 and 0 to 30 cm) had values of 6.8 while subsurface soil layers (30 to 150 cm) averaged about 4.6 meq. per 100 g. The available water holding capacity estimated from SP indicates that the soils in El Hammami are not well suited for maintaining good soil moisture without frequent irrigation or subsurface water supplies. The low CEC values indicate the possibility of extensive leaching when the soils are heavily irrigated. Excellent management of both water and fertilizer is of prime importance in these soils so that adequate moisture can be maintained without excessive leaching of plant nutrients.

Soil salinity The electrical conductivity of the saturation extract of 86 samples that were sampled were grouped into 3 categories.

Salinity Scale	No. of Soils	% of Soils	Avg. EC per category
Non-saline, <4 mmhos	71	83	1.8
Moderately saline, 4 - 8 mmhos	9	10	5.6
Strongly saline, >8 mmhos	6	7	11.4

Of the 86 samples evaluated , 19% had EC values that were sufficiently high to have an adverse effect on crop production. This was in contrast to the 25% of the soils in the same category in the Beni Magdoul area. Only 6 sampled areas were classed as strongly saline. With proper use of water to facilitate the removal of excess salts from the root zone, the salinity of these areas could be controlled so that there are no detrimental effects on crop growth.

Soil sodicity The sodium absorption ratios (SAR) of 86 surface soil samples are summarized into 3 categories in the following table:

SAR	No. of Soils	% in Category	Avg. per Category
Low, <10	66	77	3.6
Medium, 10 - 15	7	8	12.5
High, >15	13	15	31.1

Potentially serious problems can be expected in 8 percent of the soils where SAR values range from 10 to 15, particularly if present farm management practices continue. Sodic problems have already developed in 15 percent of the area where SAR values are now above 15. Judicious irrigation practices combined with the addition of gypsum and animal manure will help remedy the salt-affected areas. The growing of tree crops in these areas should be encouraged.

Ionic composition of the saturation extract The Ca/Mg and SO_4/Cl ratios were calculated for the saturation extracts of the surface soils. The Ca/Mg ratio averaged 1.8 and the SO_4/Cl ratio averaged 2.0. Both ratios are satisfactory and no nutritional problems normally would be expected.

Groundwater analysis Groundwater samples were analyzed from under 22 soil profiles and the major factors are summarized in the following table.

Factor	Average	Range
Electrical conductivity, mmhos	2.05	0.7 to 4.5
Sodium Absorption ratio	5.85	1.0 to 15.84
Total Soluble salts, ppm.	1658	630 to 3970

Only one of the samples (No. 47) had a conductivity level over 4 and it also had the highest total soluble salt content. One sample had an SAR value that exceeded 15 and 4 other samples fell into the range between 10 and 13. The levels of salt in El Hammami groundwater samples generally were not excessively high, but if water table levels continued to rise, some surface soils could become saline or sodic if proper irrigation practices are not followed.

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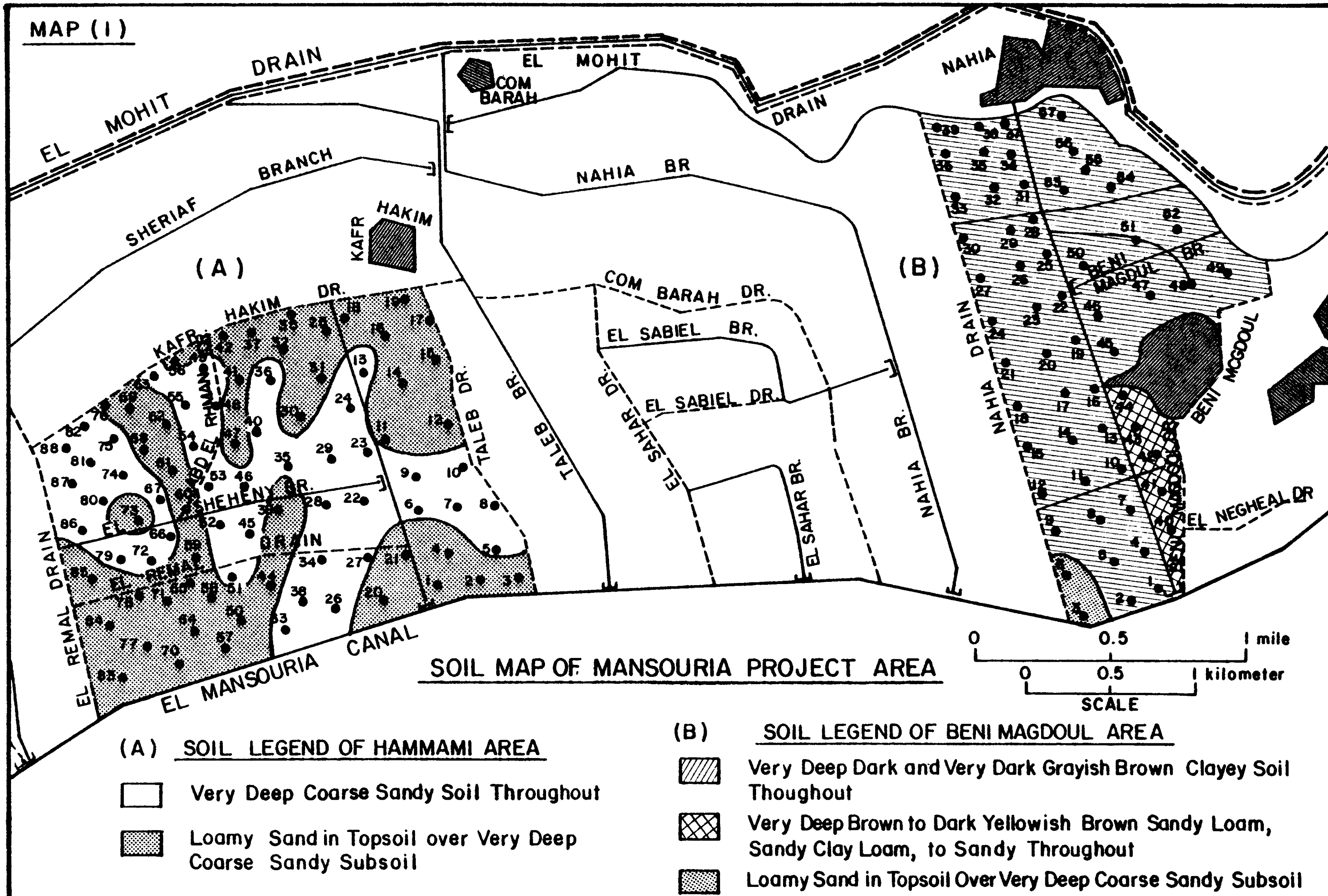
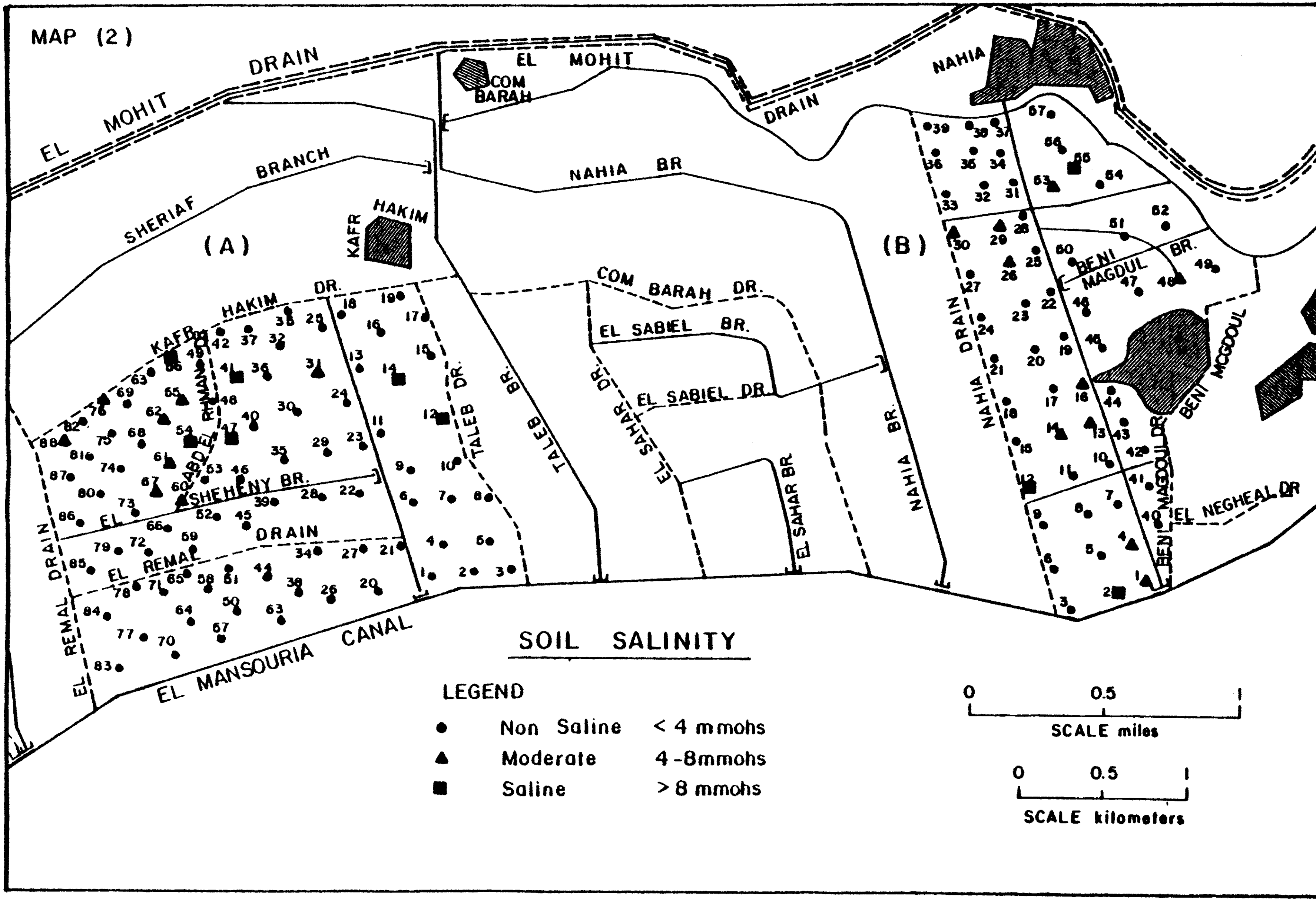
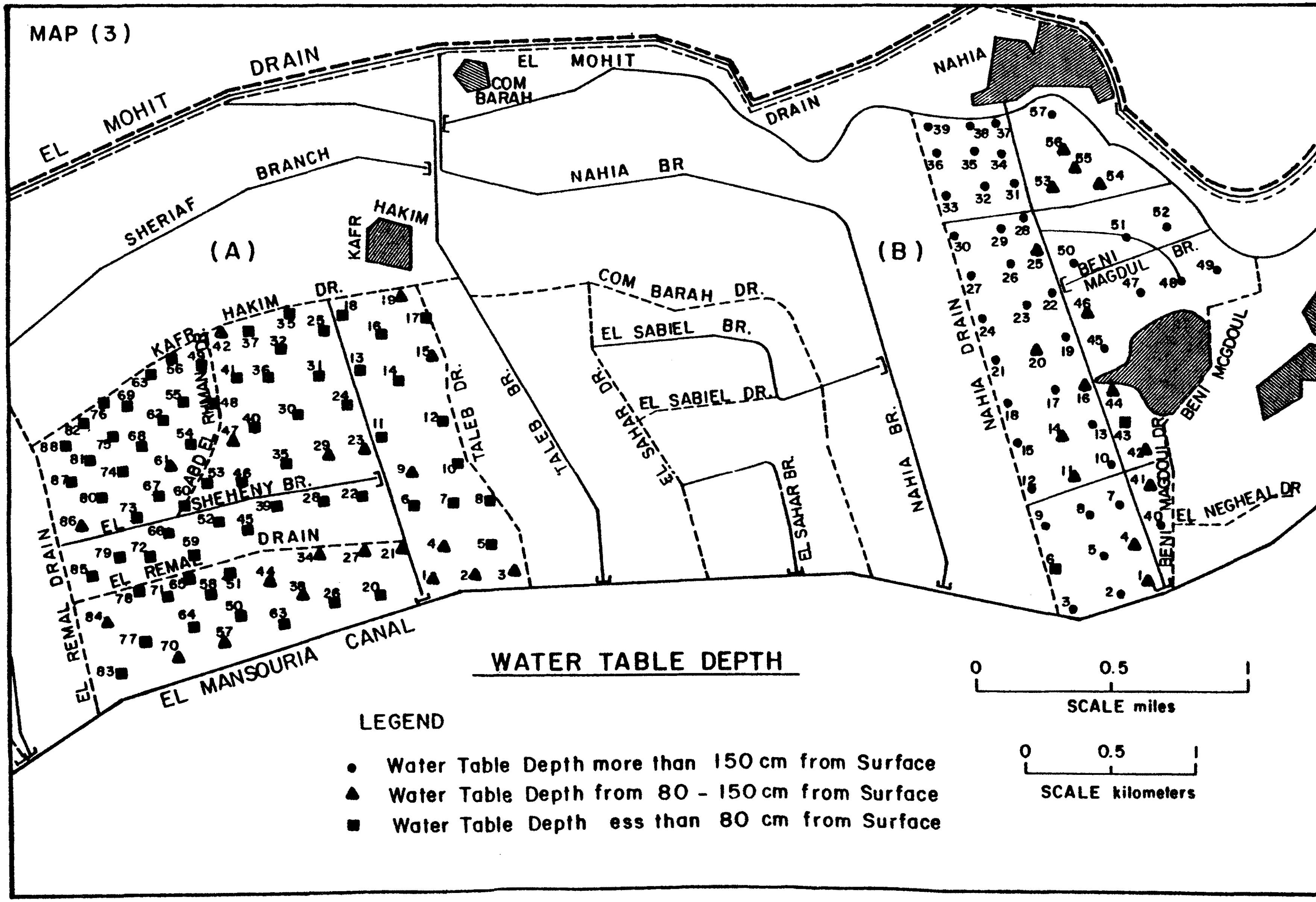
Appendix A


MAP (1)
EL MOHIT DRAIN
SHERIAF BRANCH
KAFR HAKIM
COM BARAH
EL MOHIT DRAIN
NAHIA BR
NAHIA
NAHIA DRAIN
(A)
(B)
HAKIM DR.
KAFR
ABD EL RHMAN
EL SHEHENY BR.
EL REMAL DRAIN
DRAIN
TALEB DR.
TALEB BR.
COM BARAH DR.
EL SABIEL BR.
EL SABIEL DR.
EL SAHAR DR.
EL SAHAR BR.
NAHIA BR.
BENI MAGDOUL BR.
BENI MAGDOUL
EL NEGHEAL DR
EL MANSOURIA CANAL
SOIL MAP OF MANSOURIA PROJECT AREA
0 0.5 1 mile
0 0.5 1 kilometer
SCALE
(A) SOIL LEGEND OF HAMMAMI AREA
Very Deep Coarse Sandy Soil Throughout
Loamy Sand in Topsoil over Very Deep Coarse Sandy Subsoil
(B) SOIL LEGEND OF BENI MAGDOUL AREA
Very Deep Dark and Very Dark Grayish Brown Clayey Soil Thoughout
Very Deep Brown to Dark Yellowish Brown Sandy Loam, Sandy Clay Loam, to Sandy Throughout
Loamy Sand in Topsoil Over Very Deep Coarse Sandy Subsoil


MAP (2)
EL MOHIT DRAIN
SHERIAF BRANCH
EL MOHIT
COM BARAH
NAHIA BR
NAHIA DRAIN
KAFR HAKIM
(A)
(B)
KAFR HAKIM DR.
COM BARAH DR.
EL SABIEL BR.
EL SABIEL DR.
EL SAHAR DR.
EL SAHAR BR.
TALEB BR.
TALEB DR.
NAHIA BR.
NAHIA DRAIN
BENI MAGDOUL BR.
BENI MAGDOUL DR.
BENI MCGDOUL
EL NEGHEAL DR
ABD EL RAHMAN
EL SHEHENY BR.
EL REMAL DRAIN
EL REMAL DRAIN
EL MANSOURIA CANAL
SOIL SALINITY
LEGEND
Non Saline < 4 mmohs
Moderate 4 -8mmohs
Saline > 8 mmohs
0 0.5 1
SCALE miles
0 0.5 1
SCALE kilometers


MAP (3)
EL MOHIT DRAIN
EL MOHIT
COM BARAH
NAHIA
DRAIN
SHERIAF BRANCH
NAHIA BR
KAFR HAKIM
(A)
(B)
KAFR HAKIM DR.
COM BARAH DR.
EL SABIEL BR.
EL SABIEL DR.
ABD EL RHMAN DR.
EL SHEHENY BR.
EL REMAL DRAIN
EL REMAL DRAIN
TALEB DR.
TALEB BR.
EL SAHAR DR.
EL SAHAR BR.
NAHIA BR.
NAHIA DRAIN
BENI MAGDUL BR.
BENI MCGDOUL
BENI MAGDOUL DR.
EL NEGHEAL DR
EL MANSOURIA CANAL
WATER TABLE DEPTH
LEGEND
Water Table Depth more than 150 cm from Surface
Water Table Depth from 80 - 150 cm from Surface
Water Table Depth ess than 80 cm from Surface
0 0.5
SCALE miles
0 0.5
SCALE kilometers

Appendix B

Table A-1. Particle Size Distribution Calcium Carbonate Content and Total Soluble Solids of Selected Soil Profiles (Beni Magdoul Location)

		Particle size distribution 1/				Percentage of Total Soil		
Profile No.	Depth cm.	Clay %	Silt %	Fine Sand %	Coarse Sand %	$CaCO_3$	T.D.S. 2/	Texture
1	0-17	35.0	7.2	27.9	28.0	8.1	0.7	Sandy clay
	17-60	44.8	9.2	26.1	20.0	8.0	0.4	Clay
	60-150	54.6	10.7	23.1	11.6	6.2	0.4	Clay
3	0-25	6.9	5.8	17.8	69.5	5.0	0.2	Loamy sand
	25-135	4.8	7.0	15.3	72.8	6.1	0.1	Sand
5	0-15	43.0	15.5	11.1	30.3	6.4	0.3	Clay
	15-50	63.6	12.3	10.8	13.6	6.0	0.4	Clay
	50-90	59.4	7.9	20.1	12.6	4.0	0.9	Clay
	90-150	50.3	19.3	20.3	10.2	3.1	0.8	Clay
6	0-15	30.0	14.4	12.0	43.6	8.0	0.3	Sandy clay
	15-50	22.4	10.9	19.3	47.4	3.6	0.3	Sandy clay
	50-130	4.6	5.5	21.1	68.8	2.8	0.2	Sand
12	0-15	49.8	8.4	22.9	18.9	4.8	0.9	Clay
	15-50	55.7	15.8	12.8	15.8	4.2	0.6	Clay
	50-150	51.3	7.4	28.2	13.1	2.7	0.9	Clay
16	0-25	53.5	10.5	32.8	3.1	4.2	0.5	Clay
	25-75	44.1	10.3	43.5	2.2	2.0	0.5	Clay
	75-130	56.0	22.4	16.0	5.6	1.2	0.6	Clay
18	0-15	44.2	9.8	45.7	0.3	3.7	0.2	Clay
	15-150	61.8	14.5	18.0	5.7	3.4	0.3	Clay
23	0-25	66.0	15.6	13.9	4.5	3.4	0.4	Clay
	25-50	58.5	23.1	15.2	3.2	2.2	0.4	Clay
30	0-30	49.0	12.4	37.3	1.2	4.4	0.6	Clay
	30-150	44.9	19.0	34.0	2.1	1.2	0.8	Clay
37	0-25	39.8	24.1	33.3	2.8	4.2	0.2	Clay
	25-80	57.5	23.9	17.9	0.6	1.6	0.2	Clay
	80-150	50.7	30.4	18.2	0.7	1.2	0.2	Clay
40	0-30	16.5	12.7	13.4	57.3	3.2	0.1	Sandy loam
	30-100	18.5	9.7	12.6	59.2	2.4	0.1	Sandy loam
	100-150	2.1	1.0	18.1	78.8	2.8	0.1	Sand
41	0-60	18.2	7.8	10.9	63.1	3.6	0.1	Sandy loam
	60-70	1.0	0.5	2.7	95.7	3.5	0.1	Sand
	70-100	15.8	8.2	16.8	59.2	2.0	0.1	Sandy loam
	100-150	3.1	2.6	0.9	93.4	3.0	0.1	Sand

Table A-1. Particle Size Distribution Calcium Carbonate Content and Total Soluble Solids of Selected Soil Profiles (Beni Magdoul Location)

		Particle size distribution 1/				Percentage of Total Soil		
Profile No.	Depth cm.	Clay %	Silt %	Fine Sand %	Coarse Sand %	$CaCO_3$	T.D.S.2/	Texture
42	0-30	26.3	13.8	4.1	55.7	3.0	0.1	Sandy clay
	30-60	10.6	5.0	9.1	75.3	1.6	0.1	Loamy sand
	60-110	5.6	5.6	7.1	81.7	1.7	0.1	Sand
43	0-25	23.9	14.3	8.4	53.4	5.5	0.2	Sandy clay loam
	25-75	12.0	18.2	12.5	57.4	3.7	0.1	Sandy loam
44	0-20	32.5	9.8	15.7	42.0	3.0	0.2	Sandy clay
	20-80	50.1	8.7	17.4	23.8	2.0	0.2	Clay
	80-110	8.7	5.4	16.3	69.7	1.7	0.1	Loamy sand
48	0-20	47.0	18.2	21.5	13.3	3.4	0.4	Clay
	20-75	45.7	21.4	21.3	11.5	1.0	0.5	Clay
	75-150	52.0	23.8	19.7	4.4	0.9	0.2	Clay
50	0-20	40.0	20.3	18.1	21.6	3.6	0.2	Clay
	20-75	44.7	25.6	23.1	6.6	1.6	0.3	Clay
	75-130	43.7	17.8	32.9	5.6	1.3	0.3	Clay
54	0-15	43.7	29.1	14.4	12.8	3.8	0.1	Clay
	15-100	40.5	28.1	20.5	10.9	2.4	0.1	Clay
	100-150	42.3	27.8	26.0	3.9	0.8	0.1	Clay
57	0-30	42.7	21.9	29.1	6.3	3.8	0.1	Clay
	30-85	47.6	25.3	21.3	5.9	1.1	0.1	Clay

1/Based on lime-free soil.
2/Total dissolved solids determined gravimetrically.

Table A-2. Chemical characteristics of soil profiles sampled - Beni Magdoul Area.

Profile No.	Depth cm	pH[1/]	SP[2/]	E.C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l							SAR[3/]	CEC[4/]	ESP[5/]
					Ca	Mg	Na	K	CO_3	HCO_3	Cl			
1	0-17	7.8	59	7.5	23.1	13.3	56.5	0.95	0.0	2.0	52	13.2	--	--
	17-60	7.8	67	5.4	15.5	11.7	42.5	0.8	0.0	2.5	32	11.5	--	--
	60-150	7.8	75	4.5	10.7	11.8	34.3	0.4	0.0	2.0	26	10.2	--	--
2	0-15	7.5	51	20.3	48.6	62.7	171.2	1.4	0.0	2.5	202	23.0	--	--
	15-65	7.6	55	15.7	41.4	51.7	171.2	1.4	0.0	2.0	142	25.1	--	--
	65-150	7.5	61	13.5	43.0	42.6	103.7	1.1	0.0	1.5	124	15.9	--	--
3	0-25	7.8	30	3.5	16.2	12.7	18.0	1.1	0.0	4.0	12	4.7	--	--
	25-130	7.9	26	2.9	12.3	6.5	14.1	0.55	0.0	4.0	13	4.6	--	--
4	0-15	7.7	62	6.7	20.2	18.8	50	0.8	0.0	3.5	46	11.3	--	--
	15-90	7.7	80	6.5	15.7	11.0	53	0.55	0.0	3.0	34	14.5	--	--
	90-150	7.7	95	7.5	19.0	16.8	55	0.55	0.0	2.0	34	13.0	--	--
5	0-15	7.6	62	3.8	13.4	9.1	26.5	0.4	0.0	3.0	20	7.9	--	--
	15-50	7.7	70	4.8	16.4	10.3	35.2	0.4	0.0	3.0	22	9.6	--	--
	50-90	7.4	76	6.8	26.3	23.9	47.0	0.55	0.0	2.5	24	9.4	--	--
	90-150	7.5	75	8.0	30.2	29.9	51.5	0.45	0.0	2.5	38	9.4	--	--
6	0-15	7.8	46	3.8	9.2	10.1	25.0	0.65	0.0	3.0	16	8.0	18.0	14.0
	15-50	7.9	47	4.5	8.5	9.8	36.2	0.3	0.0	3.5	22	12.0	18.0	14.0
	50-130	8.0	25	5.1	12.3	11.4	37.2	0.45	0.0	3.0	26	10.8	10.0	10.0
7	0-17	7.8	62	3.4	10.1	9.6	19.2	0.20	0.0	3.0	14	6.1	--	--
	17-150	7.8	75	3.5	5.6	6.9	25.0	0.20	0.0	3.0	18	9.1	--	--
8	0-17	7.7	63	1.5	5.6	3.0	7.8	0.40	0.0	3.0	7	3.8	--	--
	17-150	7.7	79	3.2	5.6	6.8	24.2	0.15	0.0	3.0	18	9.7	--	--

Table A-2. Chemical characteristics of soil profiles sampled - Beni Magdoul Area (continued).

Profile No.	Depth cm	pH[1/]	SP[2/]	E.C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR[3/]	CEC[4/]	ESP[5/]
9	0-17	7.7	65	3.3	8.4	7.6	20.0	0.20	0.0	3.0	17	3.8	--	--
	17-50	7.7	61	3.1	5.6	6.1	23.0	0.20	0.0	2.5	14	9.5	--	--
	50-120	7.5	69	4.6	12.6	10.7	32.2	0.20	0.0	2.0	30	9.4	--	--
10	0-20	7.6	68	2.2	6.7	6.2	10.6	0.10	0.0	3.5	10	4.2	--	--
	20-150	7.5	85	4.4	12.9	9.4	35.2	0.10	0.0	2.0	11	10.5	--	--
11	0-30	7.6	73	3.9	10.6	9.7	28.2	0.20	0.0	4.5	19	8.9	--	--
	30-120	7.4	83	5.0	15.1	12.3	37.2	0.25	0.0	2.0	34	10.1	--	--
12	0-15	7.5	69	10.5	36.9	21.9	80.5	0.25	0.0	3.0	78	14.8	32.0	18.0
	15-50	7.4	79	5.9	16.8	13.8	47.7	0.20	0.0	2.0	45	12.2	35.0	15.0
	50-150	7.4	86	7.5	24.6	22.8	45.5	0.25	0.0	2.0	42	9.4	36.0	15.0
13	0-15	7.6	64	5.9	17.9	15.3	40.0	0.80	0.0	3.5	41	9.8	--	--
	15-130	7.5	69	6.8	17.4	21.1	45.5	0.55	0.0	2.0	37	10.4	--	--
14	0-30	7.5	60	6.0	19.6	17.2	40.0	0.80	0.0	3.0	43	9.3	--	--
	30-150	7.6	85	4.8	14.0	13.4	36.2	0.45	0.0	2.0	31	9.8	--	--
15	0-10	7.7	65	2.0	5.0	4.1	12.0	0.25	0.0	4.0	9	5.6	--	--
	10-150	7.5	75	5.8	15.7	15.5	43.3	0.20	0.0	2.0	27	11.6	--	--
16	0-25	7.6	69	4.1	11.7	9.7	23.0	0.45	0.0	2.5	18	7.0	--	--
	25-75	7.5	72	4.9	12.9	13.8	36.2	0.10	0.0	2.5	19	9.9	--	--
	75-130	7.4	79	5.8	16.8	15.3	41.5	0.55	0.0	3.0	32	10.4	--	--
17	0-20	7.5	68	2.2	5.6	5.6	14.6	0.20	0.0	3.5	8	6.2	--	--
	20-90	7.4	81	5.8	16.8	15.3	45.0	0.55	0.0	2.2	24	11.2	--	--
	90-150	7.4	73	5.8	14.6	13.2	42.5	0.40	0.0	2.2	28	11.4	--	--

Table A-2. Chemical characteristics of soil profiles sampled - Beni Magdoul Area (continued).

Profile No.	Depth cm	pH[1/]	SP[2/]	E.C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR[3/]	CEC[4/]	ESP[5/]
18	0-15	7.6	68	1.9	7.8	4.5	10.6	0.28	0.0	3.0	7	4.3	--	--
	15-150	7.6	84	2.3	5.5	3.1	17.6	0.20	0.0	2.5	10	8.5	--	--
19	0-30	7.6	67	2.2	7.8	5.6	12.1	0.30	0.0	3.5	8	4.7	--	--
	30-150	7.6	87	4.1	8.3	8.1	32.0	0.30	0.0	3.0	16	11.2	--	--
20	0-25	7.6	69	2.2	6.7	5.1	14.0	0.2	0.0	3.0	10	5.8	--	--
	25-80	7.6	79	3.3	7.3	8.2	24.2	0.4	0.0	3.0	11	8.7	--	--
	80-150	7.5	83	4.7	12.9	13.8	31.2	0.4	0.0	3.0	21	8.5	--	--
21	0-20	7.6	62	2.0	7.3	5.0	11.2	0.4	0.0	3.5	10	4.5	--	--
	20-75	7.6	79	2.6	5.6	4.0	21.2	0.4	0.0	3.0	8	9.5	--	--
	75-150	7.6	79	2.6	3.9	4.1	20.7	0.4	0.0	3.0	10	10.4	--	--
22	0-30	7.6	63	1.7	5.0	3.0	11.7	0.4	0.0	3.5	5.0	5.9	--	--
	30-150	7.6	78	2.7	4.5	4.1	20.7	0.4	0.0	3.5	12	10.0	--	--
23	0-25	7.6	74	3.8	12.3	9.1	23.7	0.45	0.0	3.5	22	7.2	--	--
	25-150	7.4	80	5.5	16.8	13.2	37.2	0.4	0.0	3.0	36	9.6	--	--
24	0-15	7.6	70	2.2	7.8	6.6	10.9	0.4	0.0	3.0	10	4.1	--	--
	15-150	7.6	79	2.7	10.1	9.2	11.4	0.4	0.0	3.0	14	3.7	--	--
25	0-25	7.6	69	3.7	15.6	7.4	22.2	0.45	0.0	3.5	26	6.5	--	--
	25-130	7.5	78	3.7	10.1	6.5	26.5	0.45	0.0	3.0	18	8.9	--	--
26	0-30	7.7	72	4.3	15.6	11.7	28.2	0.45	0.0	3.5	28	7.6	--	--
	30-150	7.6	84	4.7	18.4	10.5	40.2	0.4	0.0	2.5	28	10.6	--	--

Table A-2. Chemical characteristics of soil profiles sampled - Beni Magdoul Area (continued).

Profile No.	Depth cm	pH[1/]	SP[2/]	E.C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l: Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR[3/]	CEC[4/]	ESP[5/]
27	0-30	7.8	104	1.3	6.1	2.5	7.05	0.30	0.0	3.5	4	3.4	--	--
	30-90	7.7	80	1.3	2.8	2.5	10.0	0.15	0.0	3.0	3	6.1	--	--
	90-150	7.8	72	3.1	7.3	6.1	25.0	0.40	0.0	3.0	14	9.7	--	--
28	0-25	7.5	64	2.6	14.0	5.8	11.7	0.45	0.0	4.0	11	3.7	--	--
	25-80	7.8	74	1.9	6.1	2.5	13.2	0.25	0.0	3.5	6	6.4	--	--
	80-150	7.7	75	2.2	3.9	3.6	18.5	0.25	0.0	3.0	7	9.6	--	--
29	0-30	7.8	74	4.8	15.6	13.3	31.2	0.45	0.0	3.5	27	8.2	--	--
	30-75	7.6	75	5.9	15.1	11.1	39.2	0.40	0.0	3.0	31	10.8	--	--
	75-150	7.6	78	6.9	20.1	18.9	42.5	0.95	0.0	2.5	41	9.5	--	--
30	0-30	7.6	75	7.4	26.3	18.1	41.5	0.95	0.0	3.5	51	8.8	--	--
	30-150	7.7	70	8.0	30.7	21.2	48.5	0.80	0.0	2.5	45	9.5	--	--
31	0-30	7.8	72	1.5	6.1	3.5	9.2	0.40	0.0	3.5	5	4.2	--	--
	30-85	7.9	73	1.3	4.5	3.5	8.5	0.25	0.0	3.0	6	4.3	--	--
	85-150	7.9	75	1.3	2.8	2.0	10.0	0.45	0.0	3.0	7	6.5	--	--
32	0-35	7.8	80	3.8	9.5	8.7	28.2	0.55	0.0	4.0	14	9.3	--	--
	35-80	7.9	78	3.5	9.0	8.6	22.0	0.40	0.0	3.5	15	7.4	--	--
	80-150	7.7	78	3.2	8.4	7.6	22.7	0.40	0.0	2.0	14	8.0	--	--
33	0-25	7.6	64	3.0	14.0	6.3	11.7	0.45	0.0	4.0	8	3.7	--	--
	25-80	7.7	70	1.5	3.9	5.1	7.9	0.15	0.0	2.5	3	3.7	--	--
	80-190	7.9	78	2.3	3.7	3.8	18.5	0.40	0.0	3.0	4	9.6	--	--
34	0-25	7.6	70	2.3	7.8	5.6	13.7	0.75	0.0	3.0	8	5.3	--	--
	25-85	7.8	73	3.8	9.0	8.1	25.0	0.40	0.0	2.0	9	8.6	--	--
	85-150	7.8	68	2.9	6.7	4.0	23.0	0.65	0.0	2.0	10	9.9	--	--

Table A-2. Chemical characteristics of soil profiles sampled - Beni Magdoul Area (continued).

Profile No.	Depth cm	pH[1/]	SP[2/]	E.C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l: Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR[3/]	CEC[4/]	ESP[5/]
35	0-20	7.9	64	1.0	3.4	3.6	5.2	0.15	0.0	4.0	2	2.8	--	--
	20-80	8.1	70	2.2	5.0	4.6	15.0	0.40	0.0	3.5	4	6.8	--	--
	80-150	7.7	73	2.6	3.9	5.7	19.2	0.55	0.0	2.0	8	8.8	--	--
36	0-17	8.0	67	1.1	3.9	2.5	6.3	0.20	0.0	4.0	3	3.5	--	--
	17-150	7.8	77	1.6	3.4	3.0	12.5	0.25	0.0	3.0	5	7.0	--	--
37	0-25	7.9	74	1.2	5.0	2.5	6.7	0.30	0.0	3.5	4	3.4	--	--
	25-80	7.9	77	1.2	2.2	1.5	10.5	0.40	0.0	3.0	3	7.7	--	--
	80-150	7.8	74	1.4	2.8	3.6	10.0	0.45	0.0	3.0	3	5.6	--	--
38	0-17	7.9	69	0.9	3.9	2.5	5.0	0.20	0.0	4.5	2	2.8	--	--
	17-150	8.0	75	1.6	3.4	4.6	10.5	0.40	0.0	3.0	3	5.3	--	--
39	0-30	7.8	75	1.9	9.5	3.9	7.2	0.45	0.0	3.5	7	2.8	--	--
	30-75	7.9	78	1.3	2.8	5.8	7.5	0.15	0.0	3.5	3	3.9	--	--
	75-150	7.6	77	1.1	1.7	2.6	8.3	0.10	0.0	3.0	3	5.7	--	--
40	0-30	7.8	27	1.2	5.6	3.4	5.2	0.65	0.0	3.5	3	2.4	--	--
	30-100	7.7	27	1.3	6.7	1.8	7.7	0.65	0.0	3.5	4	4.0	--	--
	100-150	8.3	27	1.1	5.6	1.4	6.5	0.45	0.0	2.0	4	3.4	--	--
41	0-60	8.4	34	0.8	3.9	0.9	4.3	0.65	0.0	3.5	2	2.7	--	--
	60-70	8.3	27	0.9	3.2	2.2	4.9	0.25	0.0	2.5	4	2.9	--	--
	70-100	8.1	42	1.2	3.4	1.9	8.5	0.20	0.0	3.0	6	5.2	--	--
	100-150	8.1	24	2.1	6.7	7.2	10.0	1.00	0.0	3.0	6	3.8	--	--
42	0-30	8.0	42	0.7	4.5	0.8	2.7	0.35	0.0	3.5	2	1.7	--	--
	30-60	8.0	27	0.8	2.8	2.1	4.6	0.35	0.0	3.0	2	2.9	--	--
	60-110	7.9	20	0.9	5.0	0.9	5.3	0.25	0.0	2.5	2	3.1	--	--

Table A-2. Chemical characteristics of soil profiles sampled - Beni Magdoul Area (continued).

Profile No.	Depth cm	pH1/	SP2/	E.C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR3/	CEC4/	ESP5/
43	0-25	8.3	41	1.4	5.6	1.9	9.2	0.45	0.0	3.5	2	4.8	--	--
	25-75	8.3	32	1.5	2.2	2.1	13.1	0.15	0.0	3.5	5	8.9	--	--
44	0-20	8.2	53	1.2	3.9	1.4	9.2	0.35	0.0	3.5	3	5.7	28.0	16.0
	20-80	8.3	80	2.2	2.2	2.1	20.0	0.15	0.0	3.5	6	13.6	35.0	17.0
	80-110	7.8	30	3.0	5.0	2.0	25.5	0.40	0.0	3.0	10	13.6	16.0	13.0
45	0-15	7.7	65	5.5	17.9	11.0	36.7	0.55	0.0	3.5	28	9.7	--	--
	15-150	7.4	80	6.0	17.3	13.2	42.0	0.25	0.0	2.0	40	10.8	--	--
46	0-25	8.0	75	2.4	6.1	4.1	18.5	0.25	0.0	4.0	11	8.2	--	--
	25-150	7.9	87	2.0	5.6	0.8	17.0	0.25	0.0	2.5	10	9.5	--	--
47	0-20	8.1	69	1.0	3.9	1.4	5.5	0.15	0.0	3.0	4	3.4	--	--
	20-80	8.0	81	3.1	8.4	6.0	22.2	0.45	0.0	2.0	14	8.2	--	--
	80-150	7.8	88	3.7	13.4	10.7	24.2	0.45	0.0	1.5	15	7.0	--	--
48	0-20	8.0	65	5.5	16.8	15.6	32.5	0.95	0.0	3.0	27	8.1	--	--
	20-75	7.7	65	5.8	17.3	18.5	35.5	0.55	0.0	2.0	42	8.4	--	--
	75-150	7.9	64	2.8	9.5	6.0	15.7	0.40	0.0	1.5	19	5.6	--	--
49	0-15	7.9	58	1.3	4.5	3.0	7.7	0.25	0.0	2.5	4	4.0	--	--
	15-80	7.9	61	1.3	2.8	2.5	11.2	0.25	0.0	2.0	2	6.9	--	--
	80-150	7.8	67	2.7	6.7	3.5	20.7	0.25	0.0	1.5	12	9.2	--	--
50	0-20	7.9	61	2.2	7.3	4.5	13.2	0.55	0.0	2.5	9	5.4	--	--
	20-75	7.8	70	4.5	10.1	8.6	35.2	0.45	0.0	3.0	18	11.5	--	--
	75-130	7.7	78	3.3	6.7	6.7	25.7	0.25	0.0	2.5	12	9.9	--	--

Table A-2. Chemical characteristics of soil profiles sampled - Beni Magdoul Area (continued).

Profile No.	Depth cm	pH1/	SP2/	E.C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l: Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR3/	CEC4/	ESP5/
51	0-25	8.0	62	1.1	2.8	2.5	7.3	0.15	0.0	3.5	4	4.5	--	--
	25-75	7.8	68	2.0	3.9	2.5	15.7	0.25	0.0	3.5	8	8.8	--	--
	75-150	7.5	75	5.4	22.3	15.1	32.5	0.40	0.0	2.5	15	7.5	--	--
52	0-25	7.8	70	3.2	7.8	7.2	21.2	0.45	0.0	3.5	15	7.7	--	--
	25-80	7.8	71	3.3	6.1	5.5	24.2	0.45	0.0	3.0	14	10.0	--	--
	80-150	7.6	70	5.7	17.3	13.2	38.2	0.40	0.0	2.0	31	9.9	--	--
53	0-25	7.8	72	5.1	21.2	12.5	31.2	0.40	0.0	3.8	17	7.6	--	--
	25-75	7.8	73	3.9	10.6	10.8	28.2	0.40	0.0	3.0	14	8.6	--	--
	75-140	7.8	84	2.3	4.5	4.1	17.7	0.25	0.0	3.0	5	8.5	--	--
54	0-15	8.5	61	1.1	3.4	0.3	9.2	0.20	0.0	3.5	4	6.8	--	--
	15-100	8.2	68	1.5	3.4	6.2	8.7	0.15	0.0	3.5	5	4.0	--	--
	100-150	7.9	64	1.3	2.2	2.6	9.8	0.10	0.0	3.5	4	6.3	--	--
55	0-25	7.7	79	10.9	44.8	33.3	71.0	0.80	0.0	3.0	57	11.4	--	--
	25-150	7.8	81	4.9	16.8	13.1	34.2	0.40	0.0	3.0	23	8.8	--	--
56	0-25	8.0	67	1.1	4.5	0.8	7.2	0.25	0.0	3.5	3	4.4	--	--
	25-60	7.9	75	3.9	9.0	10.0	30.2	0.25	0.0	3.0	8	9.8	--	--
	60-150	8.0	67	2.0	3.9	4.1	13.5	0.40	0.0	3.5	5	6.8	--	--
57	0-30	8.0	63	1.5	7.8	2.9	7.2	0.25	0.0	3.5	7	3.1	--	--
	30-150	7.8	70	1.4	4.5	3.0	8.5	0.15	0.0	3.0	3	4.4	--	--

1/pH of the saturation paste

2/SP - Saturation percentage

3/SAR - Sodium adsorption ratio

4/CEC - Cation exchange capacity

5/ESP - Exchangeable sodium percentage

Table A-3. Analysis of Ground Water in Beni Magdoul Area.

Profile Sample Number	pH	E.C. mmhos/cm at 25 c	Total Soluble Salts ppm*	meq per liter							SAR
				HCO_3	Cl	SO_4	Ca	Mg	Na	K	
1	7.8	4.0	3100	4.5	28.0	17.4	8.5	11.3	30.1	0.02	9.6
6	7.6	2.7	2170	6.3	10.0	16.1	4.0	6.4	21.9	0.02	9.6
13	7.8	13.7	1108	5.2	119.2	59.8	43.3	42.7	97.5	1.00	14.9
20	7.6	9.2	7400	5.0	63.2	52.4	26.9	34.2	58.5	1.00	10.6
25	8.0	5.2	4370	7.9	27.2	32.4	9.4	15.1	42.5	0.5	12.1
43	7.8	1.4	1060	5.1	2.0	7.9	2.8	2.7	9.4	0.02	5.7
46	7.6	4.7	3540	6.6	32.0	17.4	11.4	10.3	34.2	0.02	10.3
50	7.6	6.5	5300	6.8	33.2	44.2	14.4	30.3	38.5	1.00	8.1

*Calculated by using molecular weight
**Calculated by difference

Table A-4. Particle Size Distribution Calcium Carbonate Content and Total Soluble Salts of Selected Soil Profiles (El Hammami location)

		Particle size distribution 1/				Percentage of total soil	
Profile No.	Depth cm.	Clay %	Silt %	Fine Sand %	Coarse Sand %	$CaCO_3$	Texture
1	0-30	19.4	1.0	24.7	54.9	1.9	Sandy loam
	30-170	4.6	5.6	4.7	85.2	1.1	Sand
12	0-35	13.1	6.1	12.8	68.0	0.2	Loamy sand
	35-100	5.1	4.1	13.2	77.6	1.7	Sand
18	0-20	9.7	11.7	2.0	76.6	1.6	Loamy sand
	20-55	4.1	6.1	21.3	68.5	1.9	Sand
	55-150	6.0	8.6	4.6	80.8	0.6	Sand
26	0-30	4.6	0.7	11.1	83.6	1.2	Sand
	30-150	4.0	0.5	18.3	77.1	0.6	Sand
28	0-40	7.1	3.0	9.0	80.9	0.9	Loamy sand
	40-150	6.0	3.5	4.7	85.7	0.4	Sand
33	0-15	14.4	9.8	7.4	68.5	2.5	Loamy sand
	15-150	11.2	5.6	12.0	71.3	1.3	Loamy sand
35	0-20	7.1	1.0	6.4	85.5	1.0	Sand
	20-150	2.0	6.1	6.6	85.3	1.1	Sand
41	0-20	9.8	14.4	8.7	67.1	2.8	Loamy sand
	20-150	5.6	6.6	9.2	78.6	1.2	Sand
44	0-30	14.7	12.7	4.1	68.6	1.3	Loamy sand
	30-150	5.0	4.5	15.7	74.7	0.6	Sand
56	0-15	7.6	10.6	0.7	81.1	0.8	Loamy sand
	15-45	6.1	4.1	1.4	88.4	1.5	Sand
	45-150	4.1	6.6	5.2	84.2	1.3	Sand
61	0-20	11.2	6.6	0.3	81.9	1.5	Loamy sand
	20-60	7.6	3.6	6.5	82.3	2.3	Sand
	60-150	3.6	4.6	2.2	89.6	2.3	Sand
62	0-20	7.7	11.3	0.6	80.4	2.2	Loamy sand
	20-150	6.1	1.0	7.2	85.6	1.9	Sand
69	0-25	11.3	5.1	1.1	82.5	2.2	Loamy sand
	25-150	5.0	1.5	7.7	85.8	0.6	Sand
70	0-25	27.9	12.2	20.3	39.7	1.3	Sandy clay loam
	25-150	3.0	1.5	12.7	82.7	1.6	Sand

Table A-4. Particle Size Distribution Calcium Carbonate Content and Total Soluble Salts of Selected Soil Profiles (El Hammami location)

		Particle size distribution 1/				Percentage of total soil	
Profile No.	Depth cm.	Clay %	Silt %	Fine Sand %	Coarse Sand %	$CaCO_3$	Texture
72	0-20	7.1	2.5	11.0	79.4	0.7	Sand
	20-150	6.1	1.5	6.6	85.8	1.1	Sand
73	0-30	7.4	6.0	12.3	74.3	0.2	Sand
	30-150	6.1	1.0	15.5	77.3	1.9	Sand
81	0-20	6.1	4.1	8.5	81.3	2.1	Sand
	20-150	4.5	1.5	16.3	77.7	1.0	Sand
83	0-25	19.5	6.2	14.7	59.7	2.4	Sandy loam
	25-150	1.5	4.5	7.9	86.1	0.6	Sand
87	0-30	3.6	2.5	5.0	88.9	1.4	Sand
	30-150	2.0	4.1	7.0	86.9	1.5	Sand

1/Based on lime free soil.

Table A-5. Chemical characteristics of soil profiles sampled in the El Hammami Area.

Profile No.	Depth cm	pH[1/]	SP[2/]	E.C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l: Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR[3/]	CEC[4/]	ESP[5/]
1	0-30	7.9	25	0.7	4.6	3.0	2.0	0.10	0.0	2.5	2	1.0	--	--
	30-170	8.3	21	0.8	5.0	0.3	4.2	0.40	0.0	2.5	4	2.6	--	--
2	0-40	7.9	27	2.0	8.5	4.4	8.5	0.80	0.0	4.0	12	3.3	--	--
	40-150	8.4	23	1.0	4.5	0.3	6.9	0.20	0.0	3.0	6	4.4	--	--
3	0-35	8.1	27	0.9	5.0	2.5	3.2	0.55	0.0	3.0	2	1.6	--	--
	35-150	8.1	23	1.9	7.3	1.7	5.0	0.20	0.0	3.5	8	2.4	--	--
4	0-30	8.1	28	0.8	5.6	2.4	3.4	0.40	0.0	3.0	2	1.7	--	--
	30-150	8.25	21	1.3	5.6	2.4	6.7	0.55	0.0	3.0	8	3.4	--	--
5	0-30	8.1	21	0.9	5.6	2.4	2.9	0.25	0.0	3.5	2	1.4	--	--
	30-150	8.2	22	1.4	6.1	2.5	6.2	0.40	0.0	3.5	8	3.0	--	--
6	0-35	7.8	22	6.1	24.6	21.4	27.5	0.35	0.0	3.0	24	5.7	--	--
	35-150	7.8	24	5.0	20.1	17.3	23.5	0.20	0.0	3.0	34	5.4	--	--
7	0-30	8.0	23	1.8	8.1	3.8	7.7	0.55	0.0	3.0	12	3.1	--	--
	30-150	8.2	22	1.3	6.7	3.5	5.5	0.75	0.0	3.5	6	2.4	--	--
8	0-40	8.4	23	1.0	5.6	0.8	4.7	0.45	0.0	3.5	5	2.6	--	--
9	0-40	8.3	23	0.9	6.1	0.9	3.7	0.65	0.0	3.5	4	2.0	--	--
	40-150	8.4	23	0.70	3.9	1.4	3.25	0.20	0.0	3.0	3	2.0	--	--
10	0-20	8.2	25	1.5	6.7	4.5	5.5	0.45	0.0	3.5	4	2.3	--	--
	20-150	8.3	23	1.5	6.1	2.5	7.7	0.55	0.0	3.5	7	3.7	--	--

Table A-5. Chemical characteristics of soil profiles sampled in the El Hammami Area.

Profile No.	Depth cm	pH[1]	SP[2]	E. C. mmhos cm^{-1} 25° C	Composition of the saturation extract, meq/l Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR[3]	CEC[4]	ESP[5]
11	0-30	8.0	26	3.8	16.8	9.4	17.7	1.15	0.0	3.0	13	4.9	--	--
	30-150	8.4	22	0.9	3.4	1.4	5.0	0.40	0.0	2.5	3	3.2	--	--
12	0-35	8.3	30	10.9	14.0	11.1	104.5	2.90	0.0	3.5	58	29.5	10.0	9.0
	35-100	8.3	22	5.7	7.8	24.3	36.2	1.70	0.0	3.5	23	13.2	5.0	12.8
13	0-20	8.2	24	1.6	7.4	3.9	6.7	0.65	0.0	3.0	4	2.8	--	--
	20-150	8.4	23	1.3	4.5	0.8	7.7	0.25	0.0	3.5	6	4.7	--	--
14	0-45	8.6	28	13.2	7.8	9.3	185.0	3.10	0.0	5.0	115	65.2	7.5	13.3
	45-150	8.2	23	3.0	7.3	2.9	23.5	0.35	0.0	3.5	18	10.4	6.0	9.0
15	0-35	7.9	25	3.4	16.2	8.9	11.2	0.80	0.0	3.0	10	3.2	--	--
	35-150	7.9	23	4.2	18.4	12.1	18.5	0.70	0.0	2.5	29	4.7	--	--
16	0-27	8.1	25	2.0	7.6	5.1	10.5	0.45	0.0	3.0	8	4.2	--	--
	27-150	8.4	24	1.5	5.6	3.0	8.5	0.55	0.0	3.5	4.0	4.1	--	--
17	0-30	8.2	27	2.5	7.3	5.0	15.7	0.65	0.0	3.0	10	6.3	--	--
	30-120	8.3	25	1.5	3.9	3.6	9.2	0.55	0.0	4.0	8	4.8	--	--
18	0-20	8.2	29	1.4	5.6	3.4	6.7	0.45	0.0	3.5	4	3.2	--	--
	20-55	8.1	27	1.6	5.6	5.8	6.7	0.45	0.0	2.5	6	2.8	--	--
	55-150	8.3	24	2.6	5.6	15.9	6.7	0.70	0.0	3.0	13	2.3	--	--
19	0-20	7.7	35	1.5	7.4	6.6	3.0	0.70	0.0	3.0	4	1.1	--	--
	20-70	8.1	25	1.0	3.9	4.1	2.8	0.30	0.0	2.5	4	1.4	--	--
	70-83	8.0	47	0.9	2.8	3.1	3.7	0.40	0.0	2.5	2	2.2	--	--
	83-150	8.2	22	1.4	5.6	6.2	4.2	0.55	0.0	2.5	8	1.7	--	--

Table A-5. Chemical characteristics of soil profiles sampled in the El Hammami Area.

Profile No.	Depth cm	pH[1/]	SP[2/]	E.C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l: Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR[3/]	CEC[4/]	ESP[5/]
20	0-30	7.9	24	1.7	8.9	4.4	5.5	0.80	0.0	3.5	5	2.2	--	--
	30-150	8.1	22	1.7	6.7	5.6	8.5	0.65	0.0	3.0	10	3.4	--	--
21	0-35	8.0	25	1.6	8.1	3.8	4.2	0.75	0.0	2.5	4	1.7	--	--
	35-150	8.3	22	0.6	2.8	2.0	2.4	0.20	0.0	3.5	2	1.5	--	--
22	0-35	8.4	23	2.7	3.9	3.1	22.8	1.00	0.0	4.0	10	12.2	6.0	9.3
	35-150	8.6	21	2.8	3.4	1.9	25.0	1.10	0.5	4.5	15	15.4	2.5	5.6
23	0-15	8.1	23	1.0	5.1	3.5	3.4	0.35	0.0	3.5	4	1.6	--	--
	15-150	8.0	22	1.6	7.4	3.9	6.7	0.45	0.0	3.0	11	2.8	--	--
25	0-15	8.7	27	2.4	3.4	0.3	22.7	1.15	3.6	5.5	7	16.7	6.0	8.0
	15-150	8.8	22	5.1	2.8	3.6	53.5	1.70	2.0	5.5	24	29.9	6.0	14.3
26	0-30	8.0	23	1.8	6.7	4.5	8.5	0.45	0.0	3.5	9	3.6	--	--
	30-150	8.3	21	1.1	3.4	4.6	5.5	0.25	0.0	3.0	4	2.8	--	--
27	0-35	8.3	24	1.1	2.8	3.6	7.7	0.55	0.0	3.5	3	4.3	--	--
	35-110	8.4	23	3.3	7.3	6.6	21.2	1.15	0.0	3.0	10	8.0	--	--
	110-150	8.2	23	2.1	7.3	6.6	7.7	1.35	0.0	2.5	10	2.9	--	--
28	0-40	8.2	33	0.7	3.4	1.9	2.4	0.35	0.0	3.5	2	1.4	--	--
	40-150	8.3	23	1.1	5.0	3.6	3.6	0.90	0.0	3.5	4	1.7	--	--
29	0-20	8.2	24	1.7	8.1	5.4	4.2	0.80	0.0	3.5	6	1.6	--	--
	20-150	8.3	24	1.3	5.1	2.9	6.7	0.80	0.0	3.0	10	3.4	--	--

Table A-5. Chemical characteristics of soil profiles sampled in the El Hammami Area.

Profile No.	Depth cm	pH[1/]	SP[2/]	E.C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l: Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR[3/]	CEC[4/]	ESP[5/]
30	0-20	8.5	27	2.3	2.2	2.6	20.0	0.55	0.0	4.5	10	12.0	10.0	5.4
	20-150	7.9	24	3.9	13.1	13.6	19.0	1.10	0.0	3.5	12	5.2	6.0	13.3
31	0-20	7.9	28	4.9	5.6	6.2	5.3	2.55	0.0	4.5	14	21.8	7.5	14.0
	20-150	8.1	24	1.1	3.3	3.1	5.5	1.30	0.0	2.5	4	3.1	6.0	13.3
32	0-20	8.1	30	2.9	6.3	6.7	20.5	0.90	0.0	4.5	4	8.0	--	--
	20-150	8.3	25	3.9	7.8	5.0	31.5	0.90	0.0	3.5	16	12.5	--	--
33	0-15	7.8	37	1.9	5.0	5.2	12.0	0.55	0.0	4.0	2	5.3	--	--
	15-150	8.0	20	1.7	6.1	3.5	10.3	0.30	0.0	2.5	4	4.7	--	--
34	0-35	8.0	23	2.0	8.4	5.5	8.7	0.65	0.0	3.0	6	3.3	--	--
	35-150	8.0	20	1.5	4.2	5.6	5.9	0.65	0.0	2.5	3	2.6	--	--
35	0-20	8.2	25	1.8	5.0	5.2	9.0	0.80	0.0	4.0	8	4.0	--	--
	20-150	8.5	24	1.9	5.8	4.5	10.3	0.80	0.0	4.0	4	4.5	--	--
36	0-20	8.1	23	2.5	3.4	3.6	20.0	0.65	0.0	3.5	15	10.7	6.0	11.5
	20-150	8.4	24	3.8	2.3	3.3	43.5	1.10	0.0	4.5	18	26.0	7.5	13.8
37	20-150	8.2	29	3.9	7.2	7.9	35.2	1.35	0.0	3.5	12	13.1	--	--
38	0-40	8.7	23	0.8	2.8	1.5	3.7	0.35	0.0	4.0	2	2.5	--	--
	40-150	8.2	23	1.4	3.4	3.6	7.7	0.60	0.0	3.5	8	4.1	--	--
39	0-35	8.1	26	0.9	3.9	3.6	3.3	0.60	0.0	3.0	2	1.7	--	--
	35-150	8.4	22	1.0	3.4	3.6	5.5	0.40	0.0	3.5	2	2.9	--	--

Table A-5. Chemical characteristics of soil profiles sampled in the El Hammami Area.

Profile No.	Depth cm	pH[1/]	SP[2/]	E. C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l: Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR[3/]	CEC[4/]	ESP[5/]
40	0-15	8.2	22	1.2	3.4	3.0	5.5	0.65	0.0	3.0	4	3.1	--	--
	15-150	8.1	21	2.8	6.1	3.5	20.5	1.65	0.0	3.0	16	9.4	--	--
41	0-20	8.1	31	9.0	16.2	18.6	85.5	1.45	0.0	3.5	45	20.5	7.5	14.4
	20-150	8.2	25	3.5	2.8	3.6	32.5	1.15	0.0	3.5	16	18.2	5.0	8.0
42	0-35	8.3	28	2.8	3.9	4.7	20.5	0.80	0.0	4.0	11	9.9	6.0	10.0
	35-150	8.2	25	2.3	4.5	6.2	15.5	0.40	0.0	2.5	9	6.7	4.3	9.0
43	0-30	7.8	23	1.9	3.9	4.7	10.4	0.85	0.0	3.5	13	5.0	--	--
	30-150	8.0	22	1.2	4.5	3.5	4.0	1.35	0.0	3.0	4	2.0	--	--
44	0-30	7.9	24	1.1	3.6	4.2	4.3	0.40	0.0	3.0	5	2.2	--	--
	30-150	8.1	24	1.0	5.0	3.0	4.8	0.90	0.0	3.0	6	2.4	--	--
45	0-20	7.8	23	1.5	3.9	3.6	8.5	1.50	0.0	3.0	6	4.4	--	--
	20-150	8.1	25	1.2	4.5	3.5	5.3	0.40	0.0	3.0	5	2.7	--	--
46	0-25	8.0	24	1.0	3.4	3.0	4.7	0.45	0.0	3.5	6	2.6	--	--
	25-150	8.1	19	2.4	12.3	7.0	6.9	0.20	0.0	3.0	6	2.2	--	--
47	0-40	8.2	28	15.4	3.9	2.5	17.1	3.10	0.0	3.5	69	9.6	6.0	13.3
	40-60	8.5	24	3.2	6.1	6.7	31.2	1.35	0.0	3.5	8	12.3	4.5	8.8
	60-150	8.2	25	3.9	5.0	5.7	43.5	1.25	0.0	2.0	16	18.3	5.0	4.0
48	0-35	8.3	24	2.9	7.3	5.5	20.5	0.75	0.0	4.0	11	8.1	--	--
	35-150	8.6	24	5.5	5.0	2.5	56.5	1.85	0.0	4.0	25	29.2	--	--
49	0-25	8.4	24	1.3	2.2	1.5	10.3	0.25	0.0	3.5	5	7.5	5.0	12.4
	25-150	8.3	24	2.5	6.1	4.6	16.8	0.20	0.0	3.0	8	7.3	5.0	12.4

Table A-5. Chemical characteristics of soil profiles sampled in the El Hammami Area.

Profile No.	Depth cm	pH[1/]	SP[2/]	E. C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l: Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR[3/]	CEC[4/]	ESP[5/]
50	0-35	8.0	28	1.2	4.1	4.6	5.9	0.30	0.0	3.0	7	2.8	--	--
	35-150	8.0	21	1.2	2.8	5.2	6.3	0.30	0.0	3.5	5	3.1	--	--
51	0-30	8.0	23	3.4	10.1	10.2	20.0	1.15	0.0	3.0	21	6.3	--	--
	30-150	8.1	22	1.3	5.0	2.5	7.7	0.25	0.0	2.5	4	4.0	--	--
52	0-25	8.3	23	1.9	3.4	3.0	15.1	0.30	0.0	4.0	5	8.4	7.5	12.0
	25-150	8.3	22	2.3	3.9	3.1	17.7	0.75	0.0	3.0	8	9.5	4.8	10.4
53	0-20	8.2	23	0.9	3.9	3.1	4.2	0.40	0.0	3.5	6	2.2	--	--
	20-150	8.1	23	1.04	3.9	2.5	5.5	0.35	0.0	4.0	5	3.1	--	--
54	0-20	8.0	24	11.4	30.2	24.9	89.0	4.55	0.0	2.5	42	17.0	--	--
	20-150	8.4	22	1.6	2.8	2.0	13.1	1.65	0.0	4.0	8	8.5	--	--
55	0-25	7.9	22	5.6	28.5	16.4	34.0	1.30	0.0	3.5	13	7.2	--	--
	25-150	7.9	22	2.6	8.4	5.5	15.7	0.55	0.0	3.5	11	6.0	--	--
56	0-15	7.8	31	8.8	26.8	23.5	68.5	1.15	0.0	3.0	62	13.7	--	--
	15-45	8.2	24	3.7	5.6	6.7	30.2	0.45	0.0	2.5	18	12.2	--	--
	45-150	8.2	26	3.9	7.8	6.6	31.2	0.55	0.0	2.5	18	11.5	--	--
57	0-20	8.8	35	2.0	2.2	2.3	28.2	1.15	trace	5.0	13	18.8	6.0	10.0
	20-150	8.0	26	1.2	4.5	3.0	6.3	0.35	0.0	2.5	8	3.2	1.8	8.3
58	0-30	8.1	24	2.4	6.1	6.2	15.1	0.45	0.0	3.0	6	6.1	--	--
	30-150	8.0	21	1.8	5.0	3.6	11.2	0.40	0.0	3.0	7	5.4	--	--
59	0-25	7.8	24	2.8	16.2	9.5	15.0	0.65	0.0	3.0	5	4.6	--	--
	25-150	8.0	21	1.5	5.0	3.6	7.9	0.30	0.0	2.5	6	3.8	--	--

Table A-5. Chemical characteristics of soil profiles sampled in the El Hammami Area.

Profile No.	Depth cm	pH[1]	SP[2]	E. C. mmhos cm^{-1} 25° C	Composition of the saturation extract, meq/l: Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR[3]	CEC[4]	ESP[5]
60	0-20	8.1	27	5.7	14.0	7.4	48.0	0.40	0.0	4.5	13	14.7	10.0	8.0
	20-150	8.5	19	1.4	3.4	2.5	8.3	0.35	0.0	3.5	6	1.5	5.0	7.5
61	0-20	8.4	23	6.6	5.0	4.6	68.5	2.35	0.0	3.5	21	31.3	6.0	8.5
	20-60	8.2	21	4.9	3.3	4.2	47.5	1.70	0.0	3.0	18	24.5	5.0	8.0
	60-150	8.3	21	3.8	5.6	4.0	40.2	1.40	0.0	3.0	15	18.3	3.2	6.5
62	0-20	8.4	23	5.9	7.3	7.1	60.6	1.40	0.0	4.0	18	22.1	5.0	11.0
	20-150	8.4	22	5.8	10.6	10.8	52.2	1.90	0.0	3.5	14	16.0	2.8	10.0
63	0-20	8.5	23	2.8	5.0	1.4	22.8	0.90	0.0	3.5	5	12.7	6.0	12.0
	20-150	8.9	23	4.8	5.0	3.0	54.5	1.00	0.0	5.5	17	27.3	5.0	9.5
64	0-25	7.6	35	2.5	13.4	5.9	8.5	1.30	0.0	3.0	5	2.7	--	--
	25-150	8.1	19	1.4	5.6	3.4	7.0	0.30	0.0	2.0	7	3.3	--	--
65	0-20	7.7	36	1.4	6.1	5.1	4.9	0.50	0.0	3.5	5	2.0	--	--
	20-150	8.3	19	0.9	4.5	3.5	4.2	0.30	0.0	2.5	3	2.1	--	--
66	0-30	8.0	22	1.7	6.7	5.6	6.1	0.45	0.0	4.0	8	2.4	--	--
	30-150	8.4	19	0.8	3.9	3.6	2.9	0.45	0.0	2.5	2	1.5	--	--
67	0-35	8.8	23	4.4	2.8	3.1	43.5	0.45	2.0	6.0	16	25.3	6.0	13.0
	35-150	8.7	19	1.9	5.0	3.6	13.7	0.30	1.5	5.5	4	6.6	2.0	18.0
68	0-20	8.6	26	3.9	3.9	4.7	39.2	0.75	0.0	3.5	11	18.9	6.0	11.0
	20-150	8.6	20	2.2	3.9	3.1	15.7	0.45	0.0	3.0	7	8.4	5.0	9.0
69	0-25	8.1	24	2.3	7.8	6.1	11.7	0.86	0.0	3.5	5	4.4	--	--
	25-150	8.2	23	1.6	6.1	3.5	7.5	0.70	0.0	3.0	6	3.4	--	--

Table A-5. Chemical characteristics of soil profiles sampled in the El Hammami Area.

Profile No.	Depth cm	pH[1/]	SP[2/]	E. C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l: Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR[3/]	CEC[4/]	ESP[5/]
70	0-25	7.9	23	1.1	5.0	3.6	3.0	0.40	0.0	3.0	3	1.40	--	--
	25-150	8.4	23	0.8	3.4	3.0	2.9	0.30	0.0	3.0	4	1.60	--	--
71	0-20	8.0	27	1.2	6.7	3.5	3.4	0.40	0.0	4.0	4	1.5	--	--
	20-150	8.2	20	1.2	4.5	3.5	5.0	0.15	0.0	3.5	5	2.5	--	--
72	0-20	8.3	22	1.7	3.9	4.7	8.3	2.50	0.0	4.0	5	4.0	--	--
	20-150	8.1	21	1.3	3.9	4.1	5.5	1.10	0.0	4.0	7	2.8	--	--
73	0-30	8.0	26	1.3	5.0	4.6	4.7	0.35	0.0	3.0	7	2.2	--	--
	30-150	8.3	19	0.9	4.5	2.5	4.5	0.20	0.0	2.5	8	2.4	--	--
74	0-25	8.1	17	2.0	8.9	6.1	7.9	0.60	0.0	4.0	9	2.9	--	--
	25-150	8.4	18	2.0	5.6	6.7	11.0	0.50	0.0	4.0	9	4.4	--	--
75	0-30	8.2	22	2.5	6.1	7.8	15.0	0.65	0.0	3.0	9	5.7	--	--
	30-150	8.5	22	1.2	4.5	1.4	8.7	0.45	0.0	3.5	4	5.1	--	--
76	0-30	7.9	27	6.9	27.9	15.4	51.2	1.15	0.0	3.5	21	21.2	--	--
	30-150	8.3	22	2.7	3.9	4.1	25.0	0.55	0.0	3.0	7	12.5	--	--
77	0-15	8.1	25	2.0	6.1	6.7	8.9	0.55	0.0	3.0	9	3.5	--	--
	15-150	8.2	23	1.4	4.5	4.5	6.9	0.45	0.0	3.5	5	3.2	--	--
78	0-25	7.8	28	1.9	8.4	6.0	6.3	0.60	0.0	4.0	8	2.3	--	--
	25-150	8.2	21	1.5	6.1	5.7	6.1	0.45	0.0	3.5	7	2.5	--	--
79	0-20	8.1	23	1.6	8.4	3.9	6.1	0.60	0.0	3.0	9	2.4	--	--
	20-150	8.3	21	1.6	4.5	5.1	7.9	0.35	0.0	2.5	9	3.6	--	--

Table A-5. Chemical characteristics of soil profiles sampled in the El Hammami Area.

Profile No.	Depth cm	pH 1/	SP 2/	E. C. mmhos cm^{-1} 25°C	Composition of the saturation extract, meq/l Ca	Mg	Na	K	CO_3	HCO_3	Cl	SAR 3/	CEC 4/	ESP 5/
80	0-20	8.2	22	3.7	7.8	7.6	29.2	0.65	0.0	3.0	16	10.5	--	--
	20-150	8.3	20	2.2	4.5	6.2	14.0	0.40	0.0	2.5	12	6.0	--	--
81	0-20	8.1	25	1.1	5.6	3.0	2.8	0.75	0.0	3.0	3	1.3	--	--
	20-150	8.3	24	1.0	2.8	2.5	6.7	0.30	0.0	3.0	4	4.1	--	--
82	0-20	8.4	21	1.4	3.4	2.5	10.3	0.85	0.0	3.5	3	6.0	--	--
	20-150	8.5	21	1.6	2.8	1.5	14.5	0.60	0.0	3.5	7	9.9	--	--
83	0-25	7.7	33	1.2	6.7	2.9	3.0	0.30	0.0	3.0	3	1.4	--	--
	25-150	8.2	24	0.8	2.8	3.1	3.6	0.35	0.0	1.5	5	2.1	--	--
84	0-25	7.8	29	1.8	8.4	6.0	5.5	0.55	0.0	4.0	9	2.0	--	--
	25-150	8.0	22	1.6	5.6	5.1	7.5	0.30	0.0	3.5	7	3.2	--	--
85	0-10	8.1	33	0.9	4.5	3.0	3.4	0.60	0.0	3.0	3	1.8	--	--
	10-30	8.1	26	1.1	3.9	4.1	3.7	0.60	0.0	3.0	4	1.9		
	30-150	8.3	23	0.8	3.9	2.0	3.2	0.50	0.0	2.5	4	1.8	--	--
86	0-20	7.8	23	1.8	8.4	2.8	8.7	0.90	0.0	2.0	9	3.7	--	--
	20-150	8.0	22	2.2	8.4	6.0	8.7	0.60	0.0	3.0	16	3.2	--	--
87	0-30	8.6	25	1.3	3.4	0.3	11.0	0.25	0.0	3.0	5	8.1	--	--
	30-150	8.4	22	3.5	3.9	3.1	32.2	0.45	0.0	3.0	16	17.2	--	--
88	0-30	7.7	23	4.8	25.7	14.9	17.7	2.15	0.0	2.5	29	3.9	--	--
	30-150	8.3	22	1.6	2.8	5.2	10.0	0.55	0.0	3.0	9	5.0	--	--

1/pH of the saturation paste

2/SP - Saturation percentage

3/SAR - Sodium adsorption ratio

4/CEC - Cation exchange capacity

5/ESP - Exchangeable sodium percentage

Table A-6. Analysis of the Ground Water in El Hammami Area.

Profile Sample Number	pH	E.C. mmhos/cm 25 C	Total Soluble Salts ppm*	meq per liter							SAR
				HCO_3	Cl	SO_4	Ca	Mg	Na	K	
1	7.9	0.7	630	5.3	1.8	1.8	3.5	3.5	1.9	0.05	1.0
2	7.7	0.8	670	4.5	2.0	3.2	3.4	3.2	2.8	0.05	1.5
6	8.2	2.6	2060	7.0	5.6	16.9	5.7	6.5	15.3	2.05	6.2
12	8.1	3.7	2980	6.8	16.4	21.9	6.8	8.7	28.4	1.15	10.2
13	7.4	2.7	1860	5.2	7.6	19.9	6.7	5.1	18.7	2.15	7.7
16	7.7	1.8	1410	4.5	2.8	13.4	5.7	5.9	9.1	0.02	3.8
19	7.8	1.3	1140	4.5	2.4	9.9	7.9	6.0	2.9	0.10	1.1
22	7.7	3.0	2480	6.0	10.8	19.8	3.4	5.3	27.9	0.01	13.4
26	8.3	1.3	1100	8.6	2.0	4.2	1.6	3.4	9.8	0.10	6.3
30	7.7	2.7	2180	6.0	11.6	15.4	5.3	8.1	19.1	0.60	7.4
33	7.9	1.8	1390	5.6	4.0	10.8	3.5	6.6	10.3	0.02	4.6
41	7.8	3.3	2860	6.6	11.4	24.4	5.9	7.7	28.4	0.35	10.9
47	8.2	4.5	3970	5.7	21.2	33.7	9.1	11.7	39.0	0.85	12.1
55	8.3	1.1	870	8.2	2.0	1.5	3.2	3.2	5.3	0.02	3.0

Table A-6. Analysis of the Ground Water in El Hammami Area.

Profile Sample Number	pH	E.C. mmhos/cm 25 C	Total Soluble Salts ppm*	meq per liter							SAR
				HCO_3	Cl	SO_4	Ca	Mg	Na	K	
59	8.0	1.5	1090	7.4	2.4	5.7	7.9	4.7	2.9	0.02	1.2
64	7.5	1.5	1010	5.3	4.4	7.6	5.5	3.3	6.5	0.02	3.1
67	8.2	3.0	2480	8.5	8.4	18.2	1.6	4.2	27.2	2.05	15.8
68	8.1	2.4	1920	8.4	8.8	10.8	5.5	4.5	17.8	0.15	8.0
74	7.8	1.7	1190	6.9	4.0	5.6	6.1	3.2	7.1	0.15	3.2
77	7.8	1.4	1080	4.9	3.6	7.5	4.9	5.8	5.0	0.25	2.2
80	7.8	1.6	1200	4.4	5.6	7.6	5.7	2.2	9.4	0.25	4.8
88	8.0	0.9	910	7.7	3.0	2.3	4.4	5.6	3.0	0.01	1.3

*Calculated by using molecular weight

**Calculated by difference

PRELIMINARY EVALUATION OF MANSOURIA CANAL SYSTEM
GIZA GOVERNORATE, EGYPT

EWUP Technical Report No. 3

EGYPT WATER USE AND MANAGEMENT PROJECT

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March 1979

Prepared under support of the United States Agency for International Development Contract AID/NE-C-1351.

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Preface

This report was prepared by the staff of the Egyptian Water Use and Management Project. Principal authors were John Wolfe, Farouk Shahin and M. Saif Issa. The project is funded by the U. S. Agency for International Development, under a grant agreement between the United States of America and the Arab Republic of Egypt. Dr. D. S. Brown is the Mission Director USAID and Mr. Niel Dimick is Project Manager USAID.

The project is in the Water Management and Irrigation Technologies Research Institute, Dr. M. Abu-Zeid, Director, Ministry of Irrigation but the Ministry of Agriculture has a collaborative role with the Soil and Water Research Institute, Dr. A. Serry, Director and Agricultural Economics Institute, Dr. G. Hindy, Undersecretary, providing personnel and services.

The Consortium for International Development with executive offices in Logan, Utah is the contractor with Colorado State University as the lead university for the project. American personnel on the project are from Colorado State University, Oregon State University and Montana State Universit_

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PRELIMINARY EVALUATION OF MANSOURIA CANAL SYSTEM GIZA GOVERNORATE, EGYPT

By John W. Wolfe, Farouk Shahin, and M. Saif Issa

Egypt Water Use Project*

Irrigation began in Egypt more than 5000 years ago. Through the centuries the "basin system" was developed in the flood plain of the Nile. It was a system to trap water on the land during flood, thus providing one irrigation and one crop each year.

A system of canals and drains gradually developed to provide more control. During the 19th century additional canals and barrages were constructed to provide perennial irrigation for some lands. Since the Valley is narrow, these canals tend to parallel the Nile for hundreds of kilometers. The drains are also generally parallel. Since construction of the High Aswan Dam, all of the land on the valley floor is supposed to have an adequate share of water available to support crops during all the year.

During a recent investigation it was discovered that at least one major canal system is not making equal delivery of water to all the land it serves. The reasons seem to be related to many factors, including the design of the system, and especially to the traditional practices and procedures followed by the irrigation district and by the farmers. This paper briefly describes the favorable climate and the principal water resource, describes in more detail the general mode of operation of Egyptian canal systems, and explains the physical characteristics and the operational procedures, policies, and practices that contribute to unequal water distribution within one particular canal system near Cairo. It also lists a few field trials now contemplated that may reveal some possible solutions to these and related problems.

Climate

Egypt lies in a hydrologically arid zone where the average rainfall ranges between 180 mm on the northern Mediterranean coast and nil in the southern region. The mean monthly temperature ranges from 13.5 ^{o}C in January to 26.7^{o}C in August at the northern coast, and from 16.8^{o}C to 42^{o}C in the southern region near Aswan.

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*Prepared under support of United States Agency for International Development, Contract AID/NE-C-1351. All reported opinions, conclusions or recommendations are those of the author and not those of the funding agency of the United States Government.

Water Resources

Agriculture in Egypt depends almost entirely on the River Nile, which flows from the equatorial lake plateau in Central Africa and from the Ethiopian Heights in East Africa. The River Nile water is shared among the Nile countries. Its course extends almost 6000 km to reach Egyptian territory and its flow is controlled by a series of dams and barrages.

The Major Irrigation System

A typical irrigation system in Egypt consists of major canals, and main and secondary branch canals. Irrigation water is distributed by the main canals on a rotational basis.

Under the rotational method, the area served by one main canal is divided either into two equal regions and called a double rotational system, or into three regions and called a triple rotational system. In each of these rotations, water is admitted to only one of the regions (during the so-called on-period) and the intakes of all the other regions are closed (so-called off-period). To insure more control of water distribution, a series of regulators are constructed along the main canals.

Different allocations in space and time are applied on this system according to the location, climate and cropping pattern. Examples are:

Two-rotation systems
4 days on and 4 days off
7 days on and 7 days off

Three-rotation systems
4 days on and 8 days off
5 days on and 10 days off
7 days on and 14 days off

The canals are normally designed to maintain a water level that requires the farmer to lift the water up to a maximum of 75 cm. This range allows the farmer to use lifting tools manufactured in the villages. An Archimedes screw is powered by hand, and a water wheel by animal.

Canal cross sections are designed to carry enough water for the crop requirements of the land it serves. The designed canal flow has two limits. The maximum flow occurs in the summer period during maximum evapotranspiration. The minimum flow occurs during the winter when the crops have the lowest water requirement.

The canal is designed to permit the discharge to be controlled by changing the canal water level at its intake.

The job of the irrigation district engineers and their gate operators is to fulfill the water distribution schedules by maintaining the specified water levels in the main irrigation system. With the help of the head regulators in the main canals, each one just below a group of branch intakes, they can close and open sluice gates to control the water levels, both in the main canals and just behind the branch intakes. They must adjust these gates according to the rotation schedules.

Figure (1) is a diagrammatic representation of the designed distribution operation in the main canals where:

When the water is appointed to the first reach; i.e. it is the on-period for the first reach:

The intake (a) is adjusted to have the specified water level in the main canal just downstream from its intake.

The regulator (b) is closed to maintain the required water level at its upstream side.

All the intakes (d) between regulators (a) and (b) are adjusted to pass the quantities of water that keep their downstream levels at those specified.

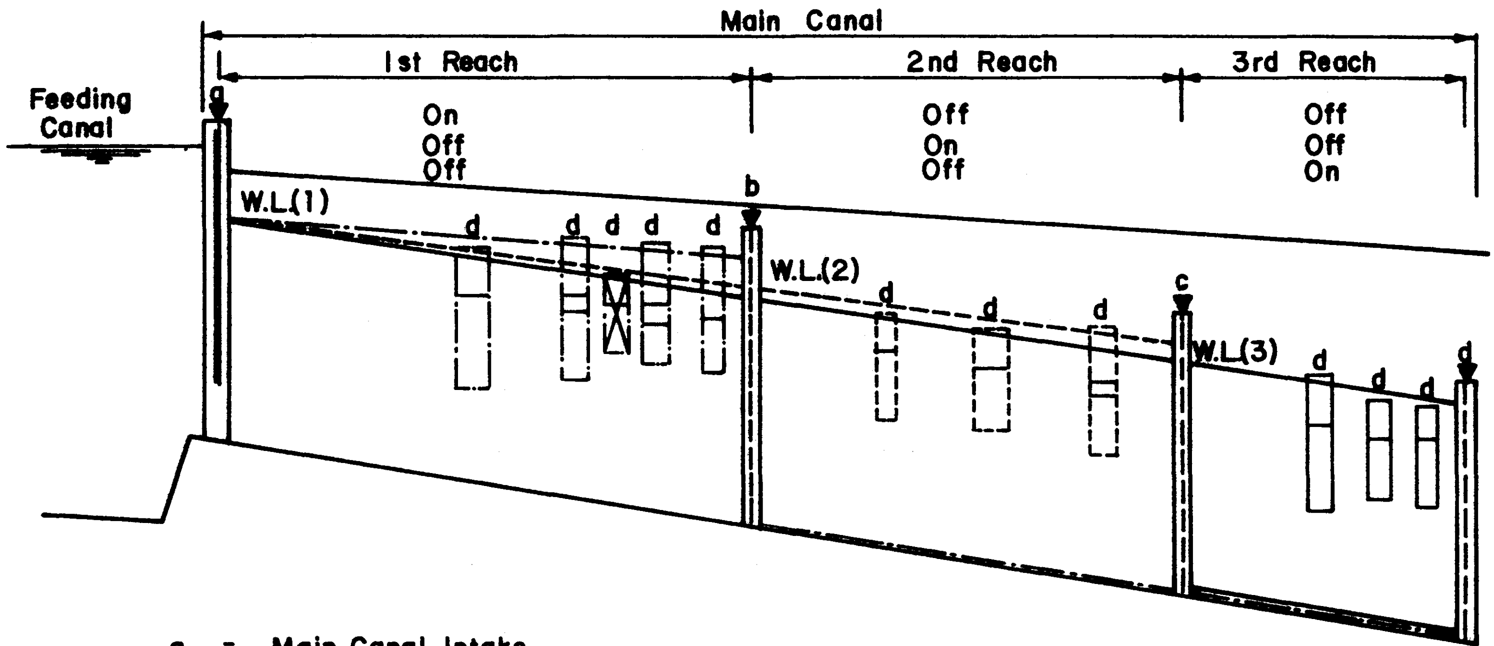
No water is allowed to the second or third reaches.

When water is scheduled for the second reach, the first and third are off and:

The intake (a) is regulated to have the required water level at its downstream side, while the regulator at (b) is fully opened and that at (c) is closed to keep water from flowing to the third reach.

The water at the upstream side of (c) is maintained at a specified level to make adequate head available for the intakes between points (b) and (c).

The intakes between (b) and (c) are regulated to maintain the water levels of the branches downstream from those intakes at the designed levels for the rotation.



a. = Main Canal Intake

b & c = Water Controll Regulators along the Main Canal for Rotation Operations

d = Branch Canal Intakes

e = Tailend Regulator or Spillway

—·—·— Water Level in the Ist Reach On-period

------ Water Levels in the 2nd Reach On-period

——— Water Levels in the 3rd Reach On-period

W.L.(I) is Water Level when the Water is Appointed to the Ist Reach and 2nd and 3rd Reaches are Off

Fig. 1 Operation of a typical main canal on a triple rotation system.

During this period, the water still has adequate head available for the intakes on the first reach, but they must be closed to provide enough water for the second reach.

When the water is appointed to the third reach the first and second reaches are off while:

The intake (a) is regulated the same as before, regulators at (b) and (c) are fully opened and the water level on the upstream side of the tail end of the main canal is maintained as specified.

The intakes (d) of the third reach are regulated to maintain the designed water levels in the branch canals.

During this period, the water is still available at only slightly reduced heads at the intakes in the first and second reaches. They must be officially closed to convey the water to the last reach. Otherwise the last reach will not have its fair share of water.

While the internal distribution within one or more irrigation districts is accomplished only by the maintenance of the adopted water levels in their main and secondary canals, most of the intakes of the major canals and the main distribution sites between Governorates are calibrated, and the water flow through them quantitatively measured.

The Minor Irrigation System

While the major irrigation system is operated and maintained by the government, the minor system, beginning from the canals and extending to individual farms, is in private ownership and is maintained by the farmers themselves.

The canal outlets to the private ditches are normally steel or concrete pipes laid through the canal banks, with their crests 25 cm lower than the designed canal water levels. The hydraulic pressure is thus approximately equal on them. The pipe diameters are chosen to supply adequate water to each private ditch according to its length and the area served by it. Pipe outlets are used in all Governorates except Fayoum where the water is distributed quantitatively by free flow weirs. In Fayoum all the weir crests are installed at the same vertical distance below the designed water levels in the canals and only widths are changed according to the area served.

One private ditch may serve up to 75 farmers, or even more, depending on the size of farms, the size of fields, and the total area served. The area served usually ranges between 20 and 150 feddans (8 to 63 hectares). The farmers are allowed to lift water directly from this ditch to their fields. Fortunately the small fields tend to be long and narrow, with one end touching a ditch. The irrigation scheduling along a ditch is arranged by the farmers. On some ditches, the next turn is given to the one who has been waiting beside his field the longest time. If problems arise between farmers concerning either scheduling irrigation turns or maintainance of ditches, the district irrigation engineer has the legal responsibility to solve them by designing an irrigation scheduling program along the ditch, or by arranging for and supervising a ditch cleaning operation at the farmers expense.

Irrigation Water Rights

Egyptian water legislation is based mainly on Moslem water law. It involves the system of control and administrative mechanisms. The basic Moslem laws provide that water be delivered in the most equitable manner possible. All irrigators receiving water from a particular canal have an equal right to the water according to the size of their holdings. They must not take more than their share or deprive anyone else of his right to a turn. The relationship between man and water results from the infusion of two basic Moslem principles:

Water is common property for use by the entire community.

Water should be shared equally.

From these basic rules, the Egyptian water law has fixed the rights of both the farmers and the government concerning irrigation water management. The following points are included in the law:

The Ministry of Irrigation is responsible for the operation and maintenance of the main and secondary canals and drains, while the private field ditches and distributaries must be operated and maintained cooperatively by the farmers.

The safety of the canals, drains, and their embankments is public responsibility and secured.

A strip of land 20 m on each side of the canals and drains is to be kept free from construction unless the approval of the Ministry of Irrigation is first obtained.

The Ministry of Irrigation has the right to do any kind of work along this right-of-way, even taking the soil that may be required for the maintenance of the irrigation works, but the land owners are adequately compensated.

All land owners whose land is supplied from one private ditch have the right to take their irrigation water equally according to their land holdings. Although farmers are encouraged to schedule irrigation turns on the ditch, the final authority for planning, scheduling, and administering the delivery of water to each feddan is the inspectorate, a subdivision of the district.

The maintenance, cleaning, and weed control in the private ditches are responsibilities of the farmers.

The Ministry of Irrigation can clean those ditches when required, at the expense of the farmer, either by request of the farmers or if recommended by the irrigation officials.

The lands that are irrigated from one private ditch or drain have water rights on its course. This right is secured.

Any construction on the public canals or drains has to be approved by the Ministry of Irrigation.

The Ministry of Irrigation has the right to supply the lands with field drains at the farmers' expense. Those expenses can be either collected directly or by installment within a 20-year period at most.

The Ministry of Irrigation is responsible for quoting unit fixed prices for lifting irrigation water by each type of device. Thus a farmer with a pump cannot overcharge another farmer for his service.

Current Water Resources Policy of Egypt:

Because rainfall is scarce and other water resources are limited, and because of the rapid increase in the population, the water policy is intended to ensure the most efficient use possible of the available water resources and to increase the agricultural base and its production in the following ways:

Increase efficient use of the water resources by controlling and developing the application system, and by limiting its flow to the irrigation requirement of the crop pattern.

Increase the farm crop production through a developed on-farm water management program.

Limit the flow to the removal system by recirculating part of its water to the application system, thus increasing the water use efficiency.

Control the water use, and prevent a high water table due to excessive seepage from the system and excessive irrigation, by generally requiring the lifting of irrigation water at the farm level.

Evaluate the existing ground water aquifers and use ground water as an additional water resource.

Insure better drainage conditions by expanding the area served by field tile drainage.

The Mansouria Irrigation Canal System

The Mansouria Irrigation District is in the Giza governorate extending mostly north from the pyramids. It contains 24,745 feddans (10,400 hectares). Rather long and narrow, it is bounded by the desert on the west and by a deep drain, Ganabiet El-Mohiet, on the east.

This district is served by the Mansouria Canal (a branch of Giza Canal, km 101.00 left hand side). The Mansouria Canal is 37 kilometers long and has about 650,000 m^3 daily discharge. It works only as a carrier in its first reach of 12.460 kilometers. Its inlet is a 2-vent sluice gate, each vent 3.0 m wide. The canal is also supplied by three regulators, first at km 16.274 (2-vent sluice gate, 3.0 m wide each), second at km 28.545 (2 vents, 2 m wide each, controlled by timber blocks) and the last as km 37.00 (one vent, 3.80 m wide, controlled by timber blocks). The Mansouria Canal supplies 24 secondary canals (8 to the left side and 16 to the right side) with an average length of 3.0 kilometers, besides 121 intakes to single farms.

The designed cross section of Mansouria canal is as follows:

Reach	Bed Width	Side Slopes	Bed Slopes	Water Depth
from	m		cm/km	m
0.0 - 16.274	13	3:2	6	1.55
16.274 - 28.545	12	3:2	2	1.55
28.545 - 37.00	9	3:2	8	1.05

In addition to the Mansouria canal, three of its branch canals with the following descriptions were chosen for study.

	Branch Canals		
	Kafret Nassar	Beni Magdoul	El Hammami
Intake location	km 14.500, R.S.	km 21.475, R.S.	km 25.850, R.S.
Area served	476 Fed (200 ha)	860 Fed (361 ha)	780 Fed (328 ha)
Length	1465 m	2910 m	1660 m
Branches (laterals)	1) Galal	1) Beni Magdoul	1) El Shemi
Intake location	km 0.465, R.S.	km 1.850, R.S.	km 0.775, L.S.
Area served	90 Feddans (38 ha)	140 Feddans (59 ha)	400 Feddans (168 ha)
Length	783 m	900 m	1,970 m
	(2 Kafret Nassar		
Intake Location	km 1.340, L.S.		
Area Served	290 Feddan (122 ha)		
Length	1482m		

Note:
R.S. = right side
Fed = feddans
1 feddan = 1.038 ac. = 0.42 ha.

Designed hydraulic properties just downstream for the intake are:

	Kafret Nassar	Beni Magdoul	El Hammami
Bed width	0.75 m	3.00 m before lining	2.00 m
Side slopes	1:1	1.25:1 after lining	1:1
Hydraulic gradient	13 cm/km	11 cm/km	13 cm/km

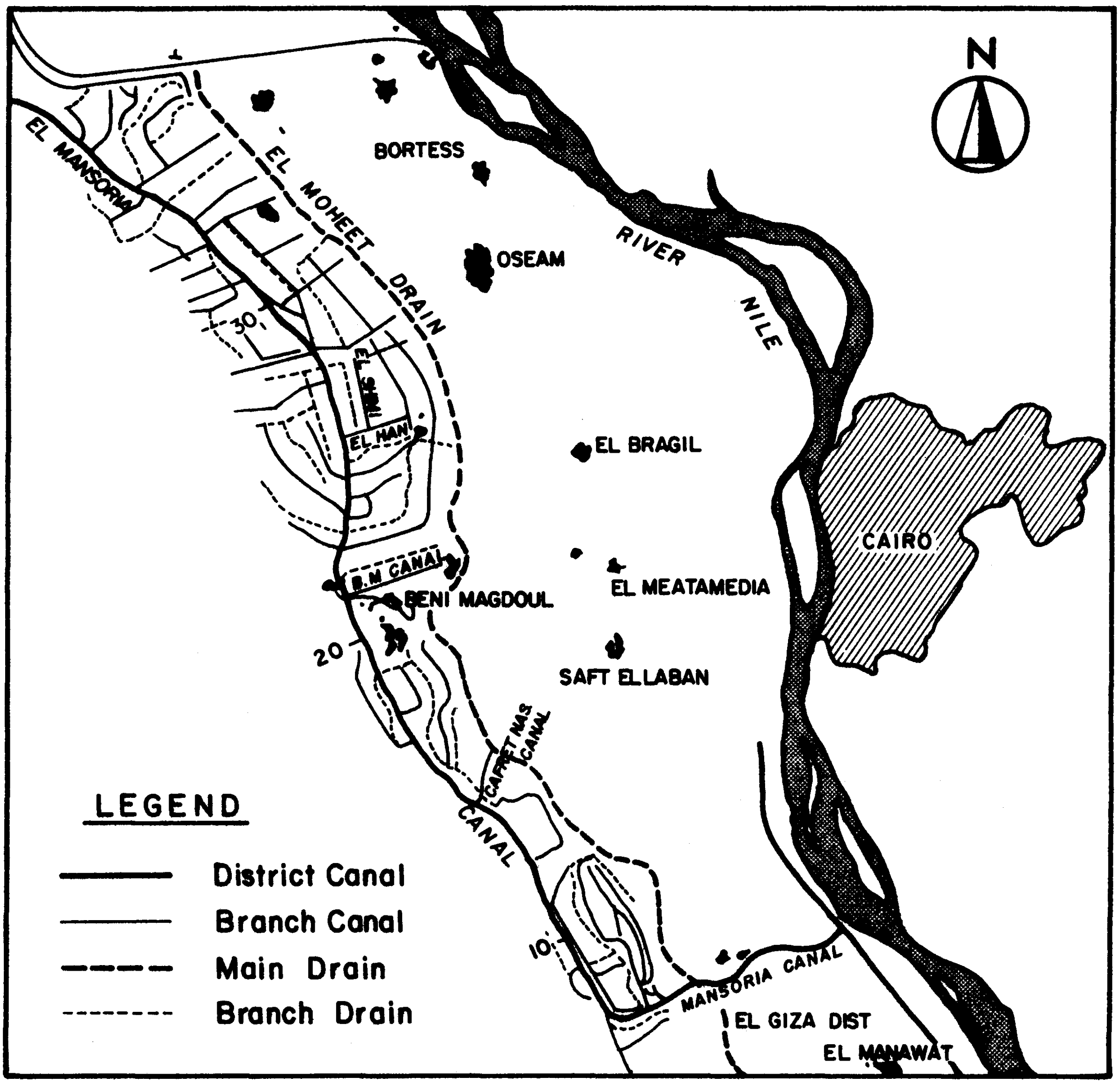


Fig. 2 The area served by the Mansouria Canal and three selected branches.

Irrigation Water Regulation in Mansouria

The Ministry of Irrigation, through the Giza Irrigation district, releases into the Mansouria canal a quantity of water calculated to meet the irrigation requirement of all the land served by this canal. The water is distributed by the triple rotation method where the canal is divided into 3 reaches. The area of the first reach is 6,288 feddans (2640 ha), the second 12,763 feddans (5360 ha), and the third 5,694 feddans (2390 ha). The schedule is 4 days on and 8 days off (Figure 2).

Because the three reaches are unequal in size, and the second reach has an area of more than double that of the others, a part of the water is diverted to the second reach from the on-periods of the first and third reaches. The second reach receives a full flow for four days. During each of the other four-day periods it receives partial flow, but for two of those days in each period the water level remains high, then drops to a lower stage. This procedure helps to equalize the water shares. Figure 3 shows a diagrammatic representation of the applied rotations.

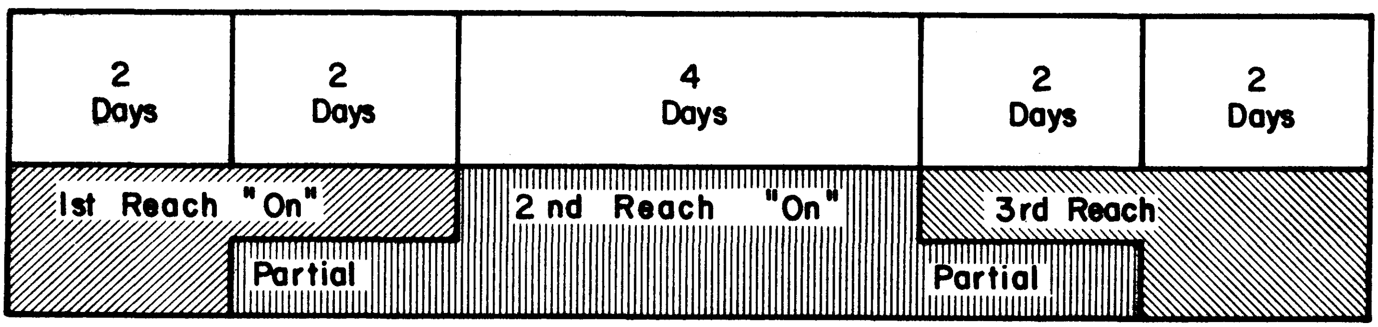


Fig. 3. Irrigation rotation schedule in the Mansouria Canal.

During the on-periods, water is controlled in the main and secondary canals by maintaining the water levels just upstream from the main regulators and just downstream from the branch canal intakes, according to the levels specified in the initial designs.

The Mansouria Canal and its branches are unlined except Beni Magdoul, which received a cast-in-place concrete lining in 1977. Also, this branch canal receives a continuous flow, as part of a comparison study for evaluation of the rotation system.

A study by the Water Distribution and Irrigation System Institute in August and September 1975 on the main Mansouria canal found that while the daily average water share at Mansouria intake was 23.5 m^3/feddan (5.6 mm/day) during a full rotation period, it was 41.7 m^3/feddan (9.9 mm/day) in the first reach, 19 m^3/feddan (4.5 mm/day) in the second, and 27 m^3/feddan (6.4 mm/day) in the third. This water share includes both water use and water losses within each reach.

Objectives of This Study

The data reported in this paper represent only a portion of the effort of the Egypt Water Use Project (EWUP). The long range objective of EWUP is to raise the economic and social standing of the Egyptian farmer by improving water management, agronomic practices, farm management, and social structure. The objectives of this portion were to:

1. Determine the variability of the water shares delivered within the Mansouria District.

2. Determine the conveyance losses in the Mansouria Canal.

Procedure

1. To determine the variability of the water shares, the following discharges were measured:

    a. The inflow to the Mansouria District at the Mansouria Canal intake.

    b. The inflow to the Kafret Nassar Canal.

    c. The inflow to the Beni Magdoul Canal and to its branch.

    d. The inflow to the El Hammami Canal and to each of its branches.

    The inflow to the Beni Magdoul Canal was obtained from a calibrated sluice gate known as a Nyrpic gate. It served as a free-flow orifice with the width adjustable. The inflow to the Beni Magdoul branch was obtained from a 9-inch Parshall flume. All other discharges were obtained from frequent current meter measurements plus at least daily staff gage readings. In addition to a staff gage, the Kafret Nassar intake was fitted with a water stage recorder. The measurement sites were thus calibrated, and this calibration up-dated every two or three months. One staff gage reading was assumed to be representative of a 24-hour period. Thus the relative values of water shares are assumed valid.

The five-month period between March 1, 1978, when the discharge measurement in El Hammami area began, and July 31 was chosen for the comparative water shares calculations.

2. To determine conveyance losses in the Mansouria canal.

   a. Six sites were chosen along the Mansouria Canal for measuring discharge. They are numbered consecutively from one to six. The first four of these are along the first reach, where there are no authorized outlets. They are at km 0.200, 4.700, 8.380, and 11.980, respectively. The others are at km 24.890 and 27.450 respectively. Figure 2 shows the location of km 10, km 20, and km 30.

   b. All measurements were made by current meter. Two sites were measured simultaneously, each measurement being conducted by a trained crew and supervised by an experienced engineer. Farmers were requested not to take water from the reach being measured. Technicians patrolled the canal banks to insure compliance with this request. The conveyance loss in the reach between the two measurement sites was assumed to be the difference between the two discharge measurements.

<u>Results of the Water Shares Study</u>

Comparing the three chosen canals it was found that:

The share of each feddan served by the Mansouria intake was 3281 m^3 in the period with an average of 21.4 m^3/day (5.09 mm/day).

The share of each feddan served from the Kafret Nassar canal that lies on the first reach where water is given under the rotation method was 4700 m^3 in the period with an average of 30.7 m^3/day (7.31 mm/day).

The share of each feddan under Beni Magdoul canal where the water is given continuously without rotation was 3283 m^3 in the period with an average of 21. 4 m^3/day (5.09 mm/day).

The share of each feddan served from the Hammami canal on the second reach, under rotation, was 1370 m^3 in the period with an average of only 9.1 m^3/day (2.17 mm/day).

A similar comparison on a smaller scale was made for the El Hammami canal, using the discharges from both the Shimi and El Hammami branches. The discharge distributed by each of the three reaches of the canal, and for the canal as a whole, were obtained as follows:

The first discharge (Q_1) was measured at the intake of El Hammami and was used to calculate the average share of the canal serving 780 feddans.

The second discharge (Q_2) was measured just downstream from the head works of the Shimi branch and was used to calculate the share for the last reach of El Hammami serving 298 feddans.

The third dischare (Q_3) was measured at the intake of the Shimi branch and was used to calculate its share of water for 400 feddans.

The fourth discharge (Q_4) was the calculated differences (Q_1-Q_2-Q_3) and was used to estimate the shares for the 81 feddans area served by the first reach.

For the measurements collected from March to July it was found that:

The average share of each feddan in the entire Hammami area served by Q_1 was 1370 m^3 in the period, with an average daily rate of 9.1 m^3 (2.17 mm/day).

The average share of each feddan in the last reach served by Q^2 was 1321 m^3 in the period, with an average daily rate of 8.8 m^3 (2.09 mm/day).

The average share of each feddan in Shimi branch served by Q_3 was 1139 m^3 in the period with an average daily rate of 7.5 m^3 (1.79 mm/day).

The average share of each feddan in the first reach of Hammami canal served by Q_4 (where the water is readily available during the "on" periods) was 2642 m^3 in the period with an average daily rate of 17.5 m^3 (4.17 mm/day). This latter figure is twice the quantity available to the two branches.

"A comparison of water delivered to these branch canals during this five month period is shown in figure 4".

Conveyance Losses Measured

In the first reach between sites (1) and (2), there was more gain than loss. There were small losses at the higher discharges. The gain increases with a decrease of canal flow. It appears to begin at zero at a flow of about 6 m^3/s and increases to about 6% at a flow of 3.5 m^3/s. The gain is almost certainly due to seepage from the surrounding water table.

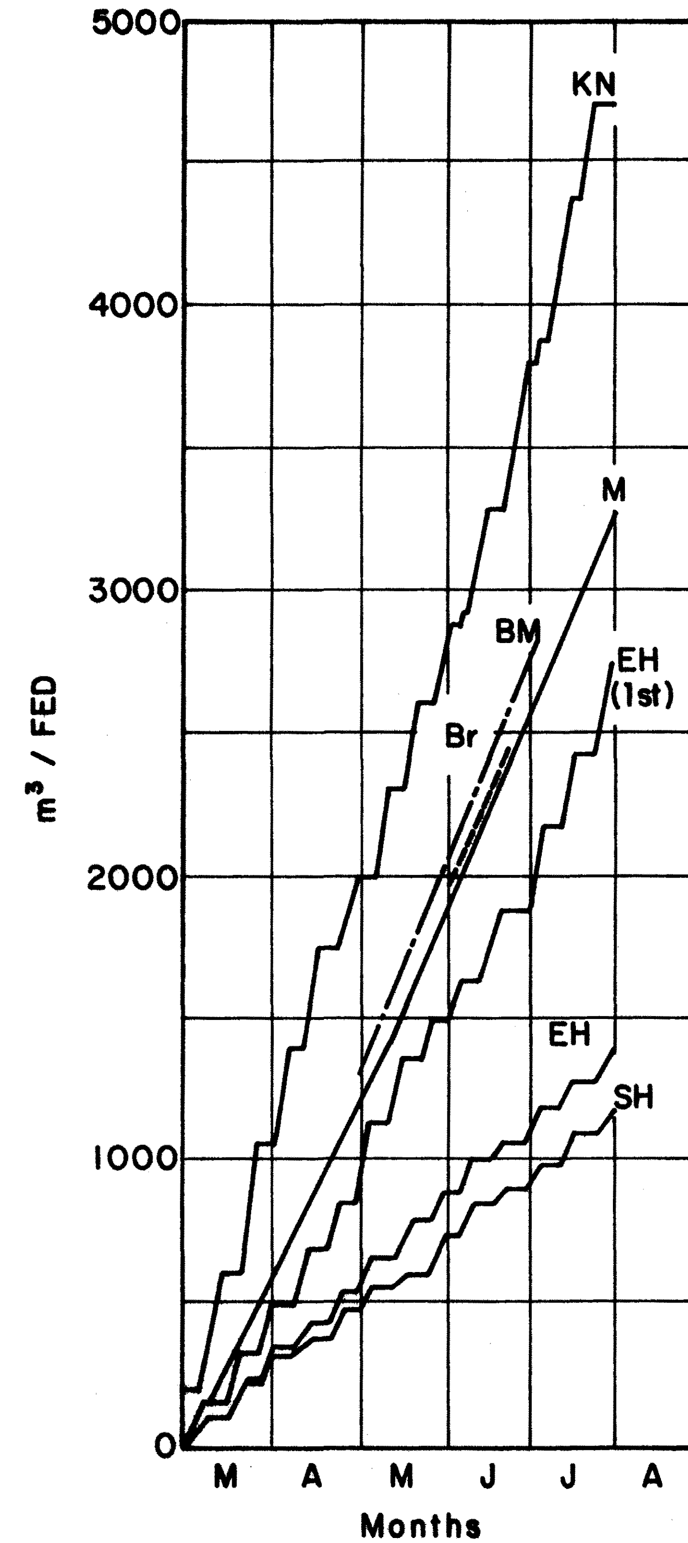


Fig. 4 Accumulated water delivery shares to various branch canals from the Mansouria Canal during a five month period in 1978.

In the rest of the first reach, losses were dominant. Between sites 2 and 4, a total length of 7.28 km, the losses increased with an increase in flow, and ranged between 5% and 13%, with an average of 9.7% of the entering discharge at site 2. This is a loss of 1.3% per km length. These results may be representative of all losses in that first reach.

The second reach, between sites 5 and 6, is near the Hammami area. It may be representative of the middle reach of the canal. The measured discharges show a higher rate of loss than appeared in the first reach. They also show an increase in water loss with an increase in flow. From the limited number of readings (3) it appears that the loss ranges between 7.9% at a flow of about 4.2 m^3/s and 12.9% at 4.41 m^3/s, with an average of about 10.1%. This is a loss of about 3.9% for each km. Table 1 shows the calculated values for this reach.

Table 1. Conveyance losses from the Mansouria Canal between site 5 and site 6

Date of Measurement	Site 5 at km 24.89		Site 6 at km 27.45	Loss in reach		
	Water Level elevation m	Discharge m^3/s	Discharge m^3/s	m^3/s	$m^3/km/s$	%
June 13,1978	17.275	4.212	3.879	0.333	0.129	7.9
June 14,1978	17.28	4.309	3.903	0.406	0.159	9.4
June 25,1978	17.285	4.408	3.839	0.569	0.222	12.9

Discussion of the Problem Identified

Among the three branch canals chosen for study, it appears that progressively less water per unit land area is delivered to those branches which are farther from the Mansouria intake. The figures are 7.31, 5.09, and 2.17 mm/day delivered by the canals located at kilometer 14.5, 21.5, and 25.9, respectively. These values compare with 5.09 mm/day delivered by the entire Mansouria Canal system during the chosen five-month period.

The same kind of relationship appears to exist within the area served by the El Hammami Branch Canal and its Shimi Branch. The figures are 4.17, 2.09, and 1.79 mm/day, respectively, for the first reach before the final branching, for the shorter Hammami Branch, and the longer Shimi Branch. These compare with 2.17 mm/day per day for the entire Hammami area. In addition, it has been observed that farms near the end of a private ditch receive less water than those near the intake, and that some farmers can only find water in the ditch at night.

All of these water delivery measurements include whatever conveyance loss there is within the area served. Estimates of these losses are not yet available. However, because a high water table exists in the region, it is assumed that at least a part of the seepage from the canals is available for consumptive use. Perhaps some idea of the conveyance losses in the branch canals can be obtained from the measurements that were made in the Mansouria Canal. These ranged from a slightly negative loss for one short section to 1.3% per km through most of the clay soil, and reached the very high value of 3.9% per km through sandy soil. If we assume that these percentage losses can be applied to the smaller canal cross sections in the clay soil of Kafret Nassar and in the sandy soil of El Hammami, respectively, the total loss in Kafret Nassar's 3.73 km would be 5%, and in El Hammami's 3.63 km, 14%. If these losses are not all recoverable as consumptive use, they make the disparity among the water shares even greater. All figures are based on one year measurements.

Since both the Beni Magdoul Canal and its brancn are lined, it is assumed that their conveyance losses are less. A separate paper is being prepared on the combined effect of the canal lining, the slightly lower designed water level in these canals, the change from rotation to continuous flow (delivery on demand), and the extension of the lining to many of the private ditches served by these canals.

During this test period, engineers for the Egypt Water Use Project were permitted to regulate the inflow to the Beni Magdoul Canal. It was somewhat comforting to learn that the 5.09 mm/day distributed by the Beni Magdoul Canal was identical with the amount delivered by the entire Mansouria system.

It is apparent from the foregoing that the shares of water are not equally distributed, and that some regions receive more than they need and others less than they need for maximum production.

The area served by the Kafret Nassar Canal receives more than three times as much water as that served by El Hammami Canal and more than four times that supplied by the Shimi Branch. Several reasons for these differences have been identified. Some of them relate directly to the practice of using water levels to regulate discharge rather than water measurement, and to the physical characteristics of the system. Among them are:

1. The water level near the intake of any canal is maintained up to the design level most of the time, making water available when it is supposed to be. This becomes less true toward the end of the canal.

2. Intakes to private ditches, especially near the intake of a canal, will discharge more water if the users lift more out onto their lands. This results from the reduced head on the downstream side of the pipe inlet, thus increasing the total head causing flow through the pipe. The same effect is transmitted back to the sluice gate at the intake of the canal, increasing the flow there also.

3. Since the water level in the Mansouria canal remains fairly high at the initial end during all rotations, there is more opportunity for water to be obtained during the off-period of a particular branch canal through a leaky gate, or by direct diversion to a field.

4. Weeds in unlined canals, including submerged weeds are very prolific in this climate. In spite of frequent cleaning, they can increase the required hydraulic gradient in a canal so much that essentially no water reaches the end until they are removed.

5. Silt deposits give nourishment to weeds even in lined canals, greatly restricting flow. In unlined canals the silt builds up with the weed growth in just a few months, even to the point of causing a reverse gradient in the bottom of the canal, especially near the end. Some of this silt is blown into the canals, especially during the windy period in the spring. The weeds tend to trap both the wind-borne and water-borne silts.

6. When a canal passes by or through a village, it may receive enough trash to restrict flow. Sand and gravel used to scour dishes and pans accumulate in the bottom. Garbage, including broken glass, not only restricts flow but makes the hand-cleaning operation more difficult. During 1978, Beni Magdoul Canal had to be drained and cleaned twice, and El Hammami three times. Some of the material discovered in the

cleaning included bricks and concrete blocks that may have been illegally placed to raise the water level behind them, at the expense of users farther down the canal.

7. Illegal pipe intakes to private ditches probably constitute one of the most important factors causing unequal shares. In the first reaches, where a good head of water is available most of the time, an extra pipe through the canal bank will double the flow, thus providing enough water so night irrigation is not required. When there is not night irrigation, the unused portion of the flow may be lost over the canal spillway directly to the drain at night, or perhaps from the end of a private ditch. Farther downstream near the ends of the canal system, illegal intakes can then become almost a necessity to get enough water to supply a sakia (water wheel for lifting water usually driven be animal power) even when irrigating with the water level that reaches a maximum at night. The night water level, even though higher, may still be below the design level for that reach.

The Search for Solutions

The Egypt Water Use Project is now beginning a search for solutions to the problems identified in the Mansouria district. A number of different trials are being considered. Among those which may have a beneficial effect on the problems identified in this paper are:

1. Lining of canals and ditches

   A full-scale trial is already underway in Beni Magdoul under the auspices of the Water Distribution and Irrigation System Institute. It is hoped that the lining will reduce the weed growth and therefore the maintenance required to get adequate water to the end of the branch canals and private ditches. The lining should also reduce the seepage loss, leaving more water for the last users. If the reduced seepage lowers the water table, the resulting increased gradient may cancel some of the expected reduction in seepage.

2. Water measurement

Measuring structures of concrete, masonry, and steel have already been installed at the intake of Beni Magdoul and Kafret Nassar and at the end of spillways. A few have also been installed on selected farm sites. The larger structures contribute to a water budget study that should provide information for better management of the canal system. Various additional techniques for measuring the water delivered to each farm or field may have to be tried before an acceptable one is found.

3. Control of intakes to private ditches

A suitable method will be sought to control the intake to any private ditch to a reasonable amount. Anticipated problems include the cost of any possible modification of the control structures, the cost of water measurement if that becomes necessary, and the cost of enforcement or the alternative cost of obtaining voluntary cooperation.

4. Scheduling irrigation turns along the private ditches

Perhaps trials can be initiated that would encourage the farmers to take turns using the water from their private ditches, thus insuring that those near the end get a fair share. Ideally, each should agree that some of his turns will occur at night.

5. Land leveling and the use of water control devices

Land leveling will make night irrigation easier, thus eliminating part of the reluctance to irrigate at night. At the same time it should reduce the quantity of water needed for each irrigation, leaving more water for those farther downstream. The introduction of water control devices such as spiles, siphon tubes, or gated pipe, should further reduce labor and increase efficiency.

6. Irrigation scheduling on fields

The training of irrigation advisors who would be able to measure or calculate when it is time to irrigate and how much to apply should reduce the number of excessive irrigations.

At the same time these advisors could prevent moisture stress caused by waiting too long before irrigating. If an acceptable program for this kind of service can be found, it should decrease over-irrigation, leaving more water for areas now in short supply. Hopefully it would also increase yield.

7. Auxiliary water supplies

Farmers in the water-short areas have already discovered they can augment their water supplies by pumping from the drains or from wells. Some use these sources exclusively because they are more dependable than the canal water. The drain water has medium-high salinity, and has apparently contributed to an increase in soil salinity. With adequate leaching it could be used for tolerant crops. The well water is somewhat better. EWUP will likely not initiate trials with these water unless other efforts fail.

Summary and Conclusions

The irrigation canal system in Egypt may be unique in the world. It consists of relatively long canals and drains, each paralleling the Nile River down a narrow valley. The water level in the canals is designed to deliver water to the land about 30 to 50 cm below ground surface, thus requiring the farmer to lift it. An Archimedes screw and a well-designed water wheel are the most common lifting tools. Water control to the various branch canals is maintained by setting a specified water level at the canal intakes, rather than by measurement. Delivery is on a rotation basis. A typical private ditch serving several farms takes water from a canal through a pipe buried in the canal bank, the diameter of which is chosen according to the area served by the ditch. A constant head of water is supposed to be available over the pipe inlet. Ingenious farmers have added extra pipes to give them more insurance of receiving the amount of water they would like to have when they want it.

Measurements indicate that the system is not supplying equal amounts of water to all areas served. The most remote areas may receive only one-fourth as much water as those at the beginning of the canal system. Reasons for the differences include the illegal intakes, the rapid accumulation of weeds, silt and debris in the canals, and conveyance losses from the canals. In sandy soils, canal losses may reach nearly 4% per kilometer, plus any discharge over the spillway. A search for solutions to remedy these and other problems in the Mansouria district is now underway by the Egypt Water Use Project.

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ON-FARM IRRIGATION PRACTICES IN MANSOURIA DISTRICT, EGYPT

Mona El Kady, Wayne Clyma and Mahmoud Abu-Zeid

EWUP Technical Report No. 4

EGYPT WATER USE AND MANAGEMENT PROJECT

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October 1979

Prepared under support of the United States Agency for International Development Contract AID/NE-C-1351. All reported opinions, conclusions or recommendations are those of the project and not those of the funding agency of the United States Government.

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 conducted. 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. His decision on when to irrigate is influenced by the canal rotation to irrigate on a 4 day interval 25 percent of the time. When water is continuously available 9 to 12 days. The amount of water applied exceeds the water that can be stored by an estimated 100% with resultant fertilizer leaching and a fluctuating water table that both limits 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

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 one or more factors are limiting with the result that supplying traditional factors of production do not result in positive increases in yield. Level borders were recommended for improvement of the on-farm system. Evaluations of the new system are presently (1979) being conducted in Egypt.

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Preface

This report was prepared with the cooperation of the staff of the Egyptian Water Use and Management Project. The assistance of Wadie 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.

The project is in the Water Management and Irrigation Technologies Research Institute, Dr. M. Abu-Zeid, Director, Ministry of Irrigation but the Ministry of Agriculture has a collaborative role with the Soil and Water Research Institute, Dr. A. Serry, Director and Agricultural Economics Institute, Dr. G. Hindy, Undersecretary, providing personnel and services.

The Consortium for International Development with executive offices in Logan, Utah is the contractor with Colorado State University as the lead university for the project. American personnel on the project are from Colorado State University, Oregon State University and Montana State University.

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ON-FARM IRRIGATION PRACTICES IN MANSOURIA 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 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 Reservoir (5 billion m^3/year) and Bagal Aelia (2 billion m^3/year), the base flow of the Nile and some use from

[1/]Prepared under support of United States Agency for International Development, Contract AID/NE-C-1351. All reported opinions, conclusions or recommendations are those of the authors and not those of the funding agency of the United States Government.

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groundwater. This area averaged about 4 million Feddans* (1.7 million ha) under perennial irrigation and one million Feddans (0.42 million ha) under basin irrigation of which about 0.6 million Feddans (0.25 million ha) 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 6.1 million Feddans (2.6 million ha) of which about 1.0 million Feddans (0.4 million ha) 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 as Irrigation Districts. The districts range in area from 20 to 100 thousand Feddans (8 to 24 thousand ha). 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, and (4) the expected distribution and farm area losses. District supply canals (Wolfe, Shahin and Issa, 1979) serve branch and subbranch canals which provide water to private farm supply channels (Meskas).

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.

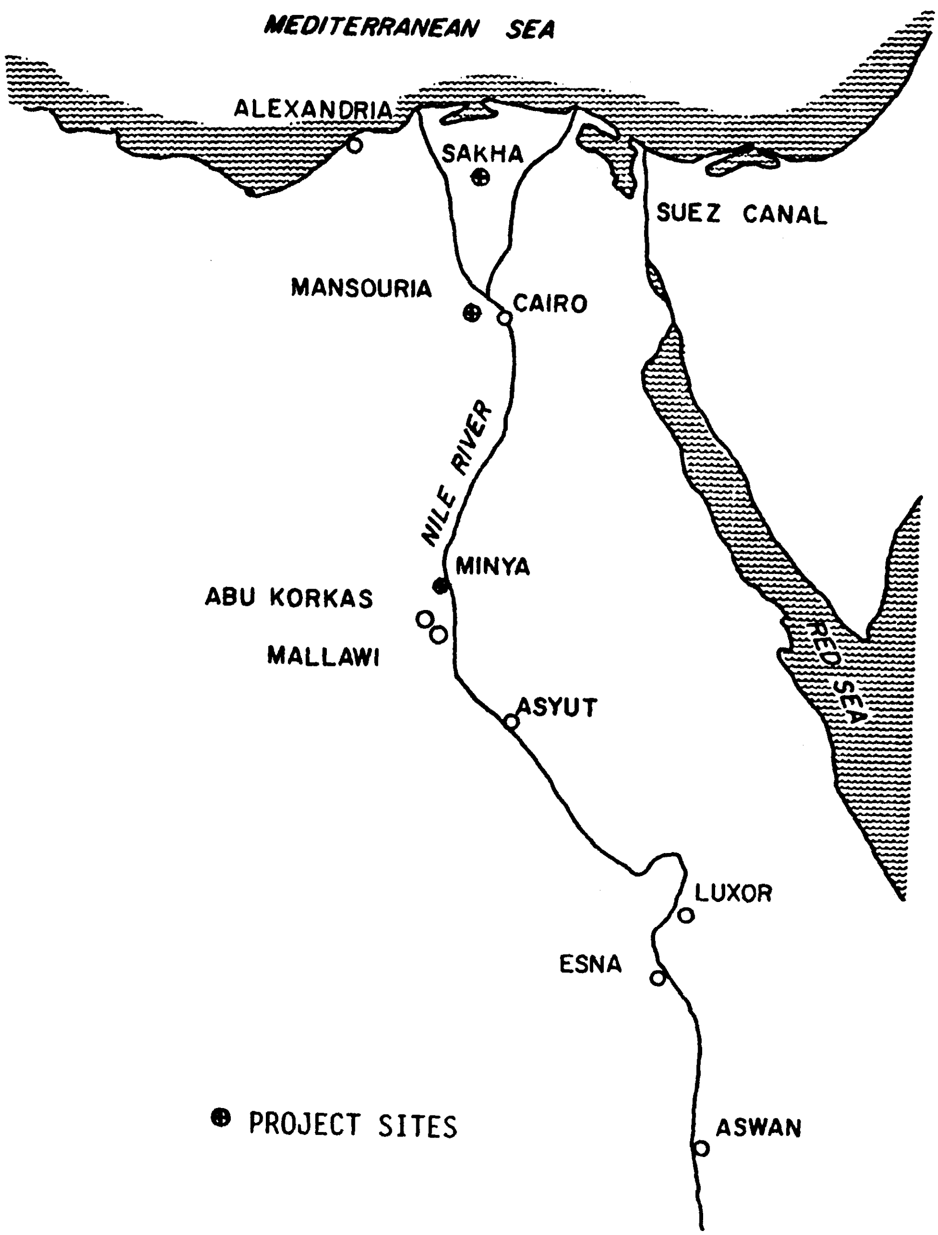


Figure 1. Location Map for Study Areas.

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 (Meska) that serves individual farms. An outlet may serve only one farm supply point or several 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 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 rate, use rate, local topography and the installation by farmers of additional unauthorized outlet, flow rates through each Meska 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

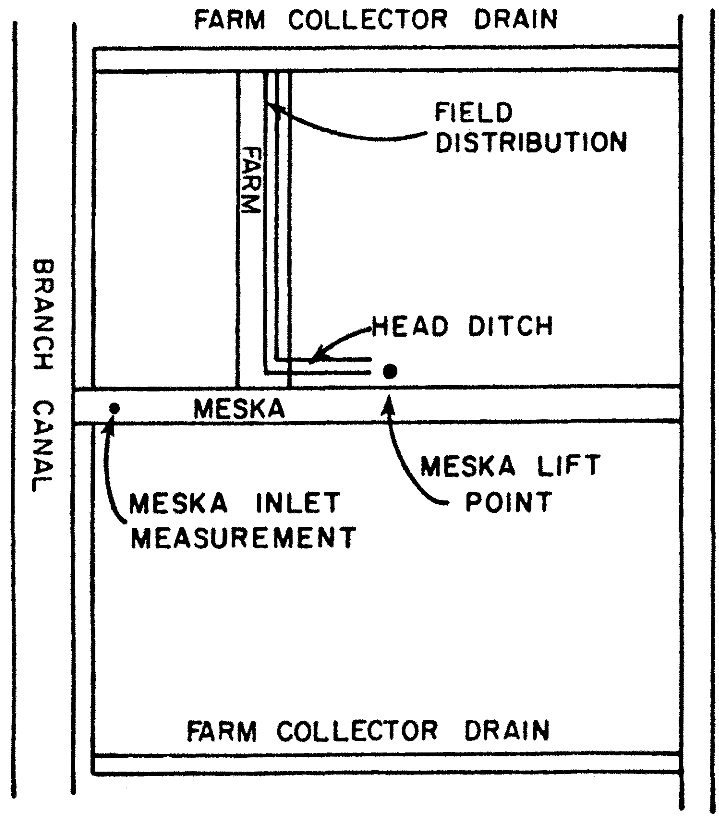


Figure 2. Arrangements of Branch Canal, Meska, Head Ditch, Field Ditch and Drains with Measuring Points for Farm Water Supply.

Shadouf*, Tambour**, or Sakia*** 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 the 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 - Archemedis screw powered by human labor.
***Sakia - water whele 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

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 use state variables for water application to describe and define farmer irrigation practices to identify priority problems in the Mansouria 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 desired 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, aeration, 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 of irrigation in Egypt of which the Mansouria District is the first such area (see location map in Figure 1).

Representative sites on two branch canals (Beni Magdoul 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

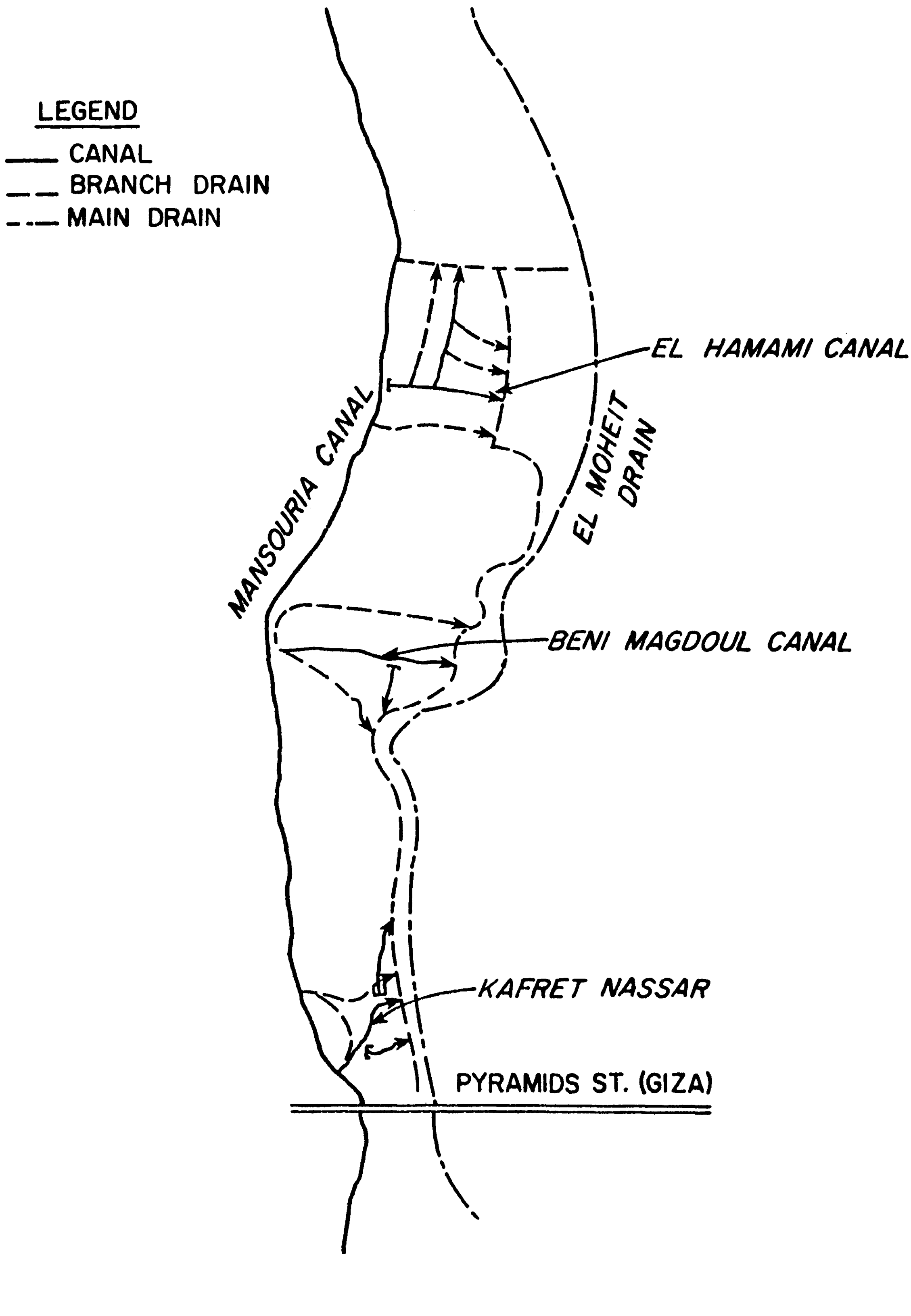


Figure 3. Location map for Kafret Nassar (K.N.), Beni Magdoul (B.M.C.) and El Hammami (E.H.C.) branch canals in Mansouria District.

collected on selected sites by other members of the interdisciplinary team (Clyma, Laudermilk 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 Meska
   - Flow rate near the site where water is lifted
   - Flow rate just out of the Sakia
   - 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 Mansouria 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, stay time between two successive crops).

   - Planting data: (data of planting, the farmer's practice in planting, 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 Mansouria 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 Mansouria 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 Magdoul. 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 Magdoul canal, farmers on one particular Meska appear to use a graded system of irrigation. The length of the field is from Meska 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 Mansouria 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. Critiera 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.

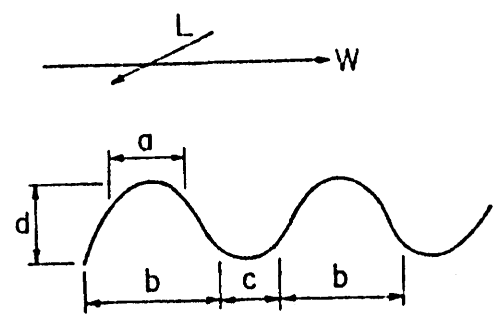
Field Geometry - The length and width of a unit enclosed by a ridge is the irrigation or bunded unit for a farm. When a farmer establishes this unit, he establishes many characteristics of his irrigation system. The relationship between flow rate and area irrigated is established by this unit. A farmer 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 Mansouria 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 0.002 to 0.03 Feddans (0.0008 to 0.014 ha). 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 Mansouria 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, Meska and sequence by which the units are irrigated are shown in Figure 5 (a) through 5 (f) from actual study 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 consumed in head ditches and field ditches and the distance water must travel in them.
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).

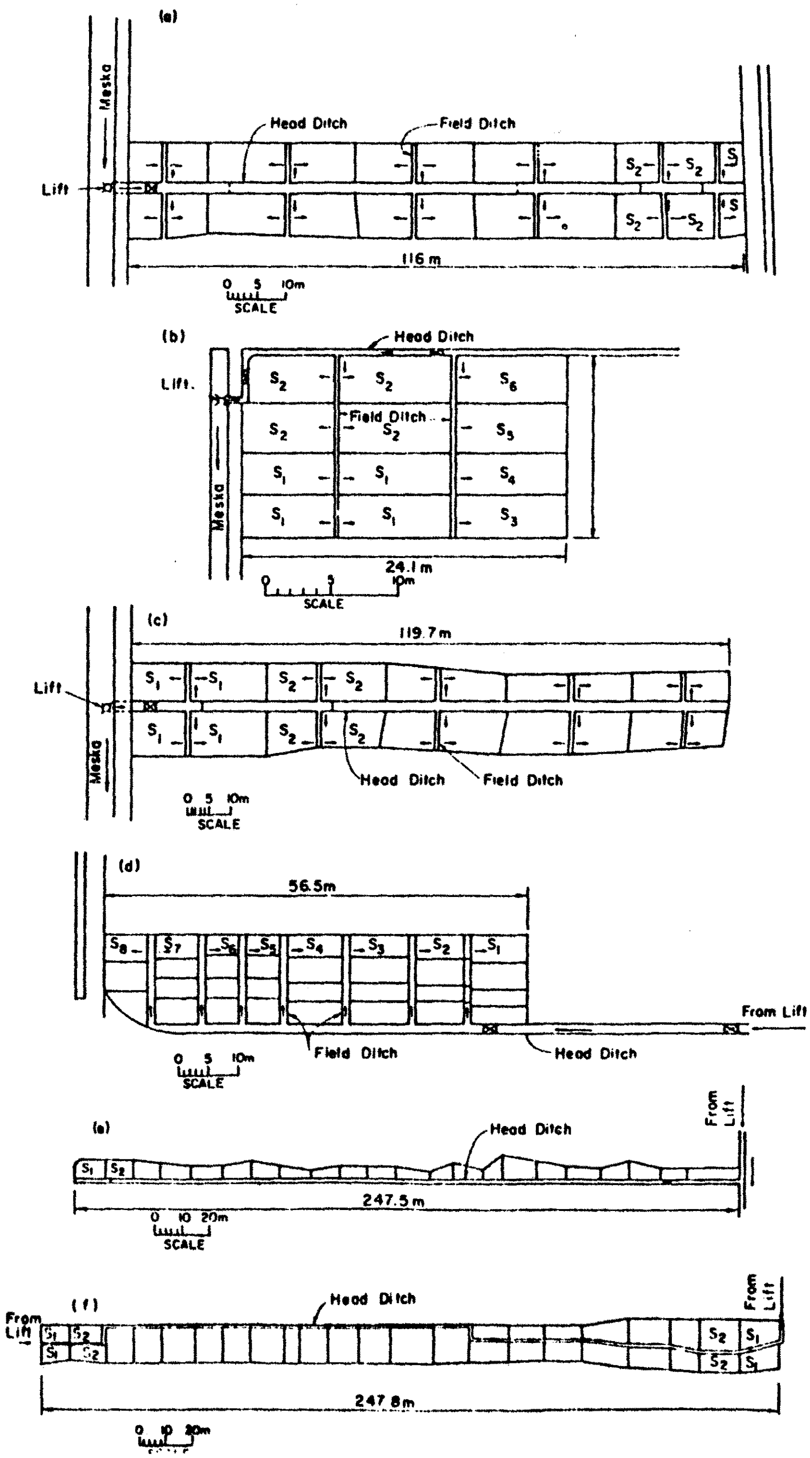


Figure 5. Field geometries of representative case study fields.

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 Meskas 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 Sakia 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 developed now.

Level (zero grade) irrigation systems require precision leveling. The deviations from design elevation within a bunded unit may not exceed ± 0.05 ft (± 0.015 m) as an acceptable standard (USDA, 1979). 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 Mansouria District will now be reviewed.

Table 1 gives the field length, the fall of the field from the end nearest the Meska 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 Meska and drain of near 10 cm is commonly provided in the Mansouria District. Farmers do not appear to use this slope to distribut 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 suggests 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. Only 10 percent were less than double the required range and 80 percent

Table 1. Slopes of Fields in the Mansouria 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

were more than double the required range. Furrow bunded units also exceeded the range in elevations criteria. In addition, 25 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 Mansouria 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 and Khan, 1979).

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 field requires additional water. Farmers must cover the high area or salinization of the area will eliminate the growing crop or severe

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 (2)	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	0.018
	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

Location	Mean Field Elevation (m): Ridge	Mean Field Elevation (m): Furrow	Range (cm): R	Range (cm): F	Max.: R	Max.: F	Min.: R	Min.: F	Standard Deviation: R	Standard Deviation: 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

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 - Infiltration data* which are available now (Figures 6 to 10) show that on Beni Magdoul 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 Magdoul 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 and 80 mm (Table 3) for most irrigations and the median for early irrigation must be attributed to initial intake rate.

Infiltraion rates affect the distribution of water in a field. The time difference between when water first covers an area and when it

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

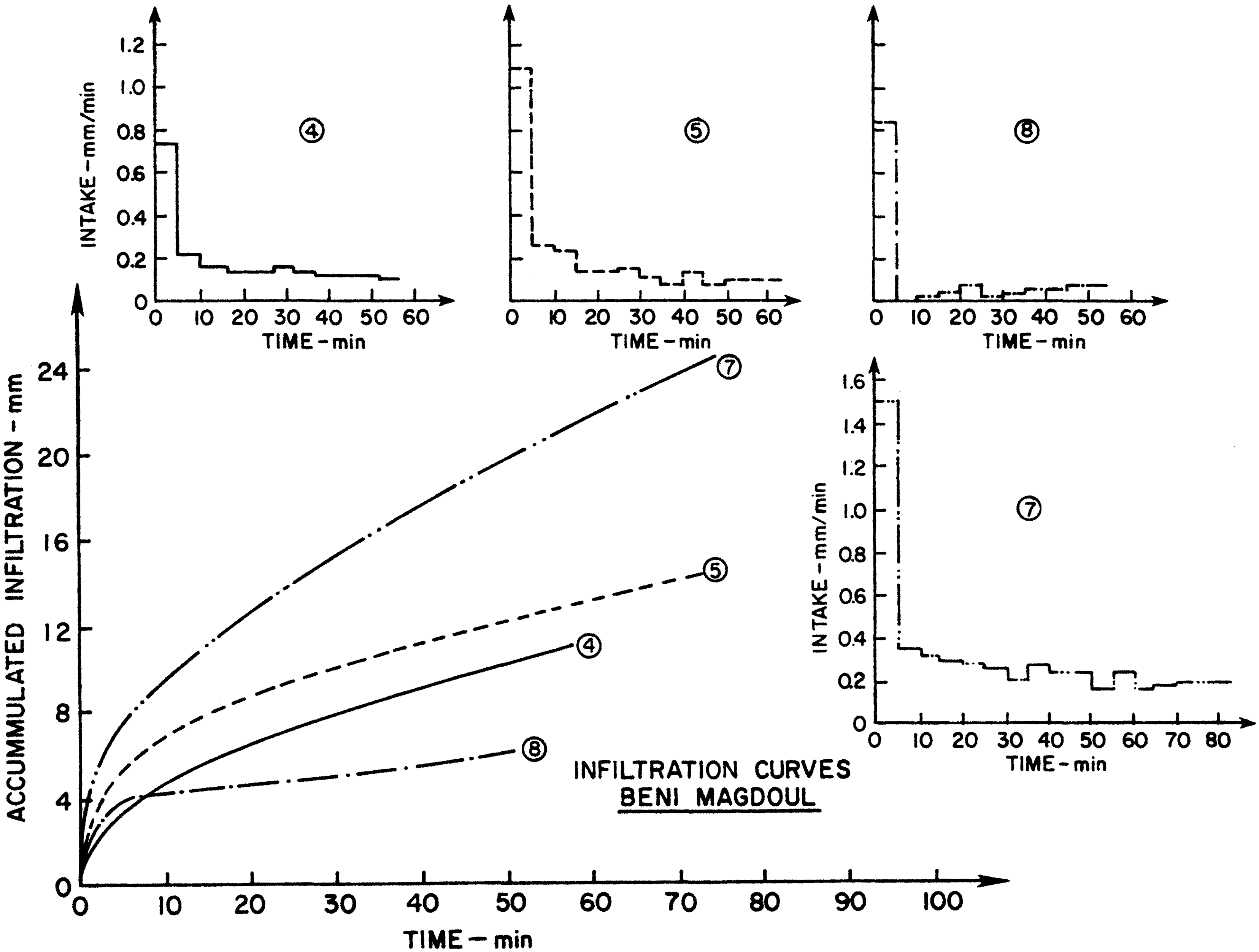
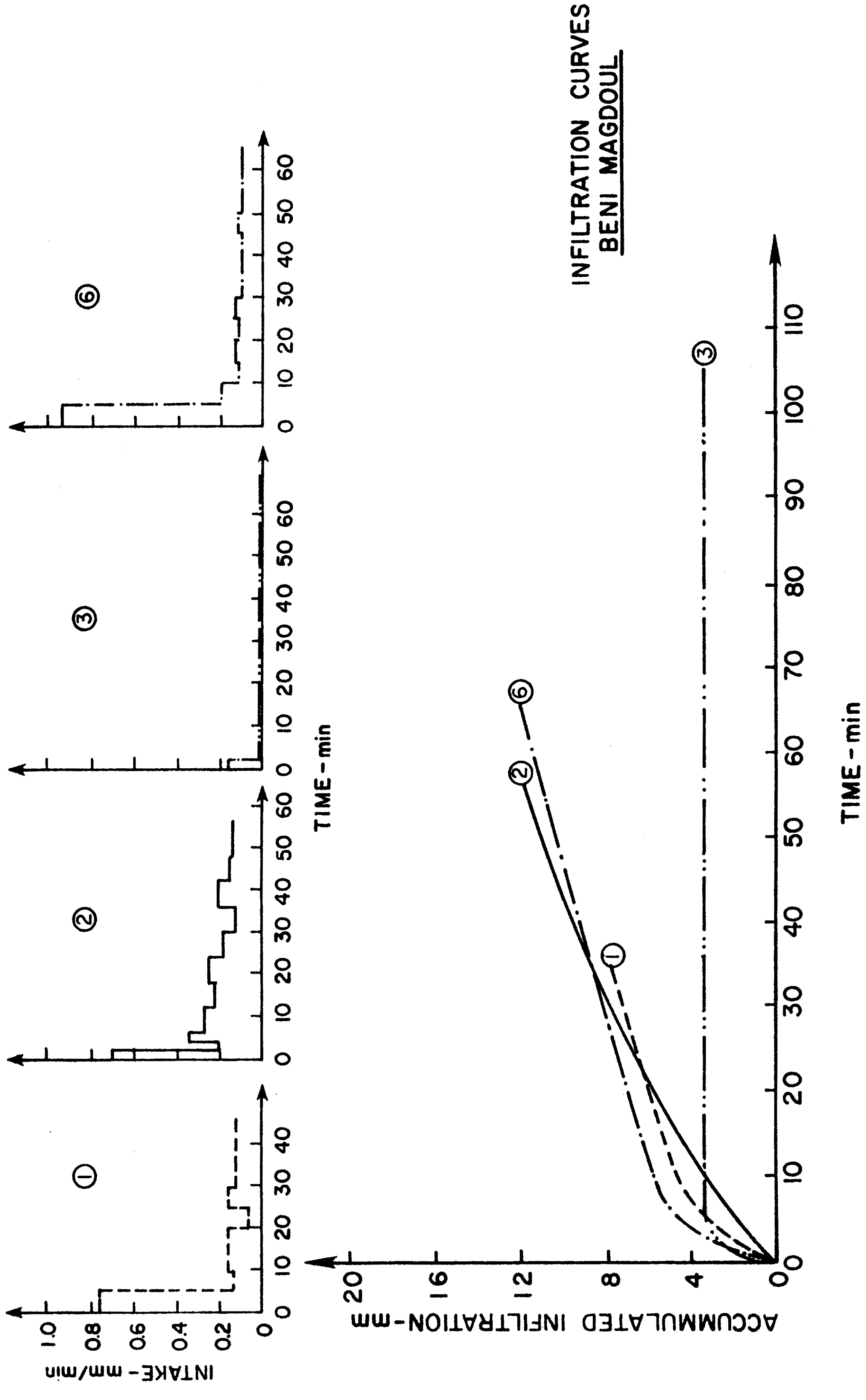
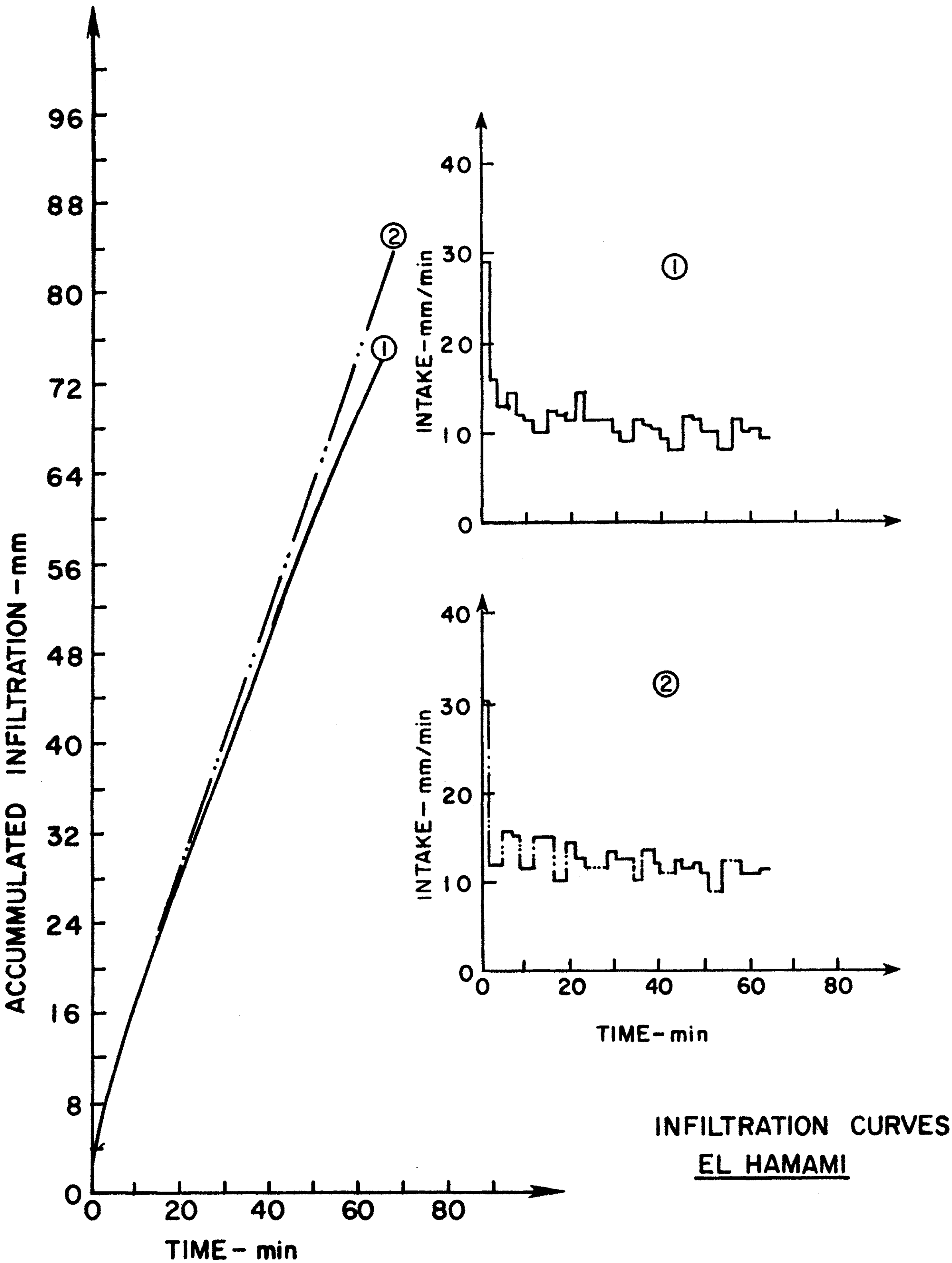

INTAKE - mm/min
TIME - min
④
⑤
⑧
⑦
ACCUMMULATED INFILTRATION - mm
INFILTRATION CURVES
BENI MAGDOUL

Figure 6


INFILTRATION CURVES
BENI MAGDOUL
INTAKE - mm/min
1.0
0.8
0.6
0.4
0.2
0
①
②
③
⑥
TIME - min
ACCUMMULATED INFILTRATION - mm
20
16
12
8
4
0
10
20
30
40
50
60
70
80
90
100
110
TIME - min



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 HAMAMI

Figure 8

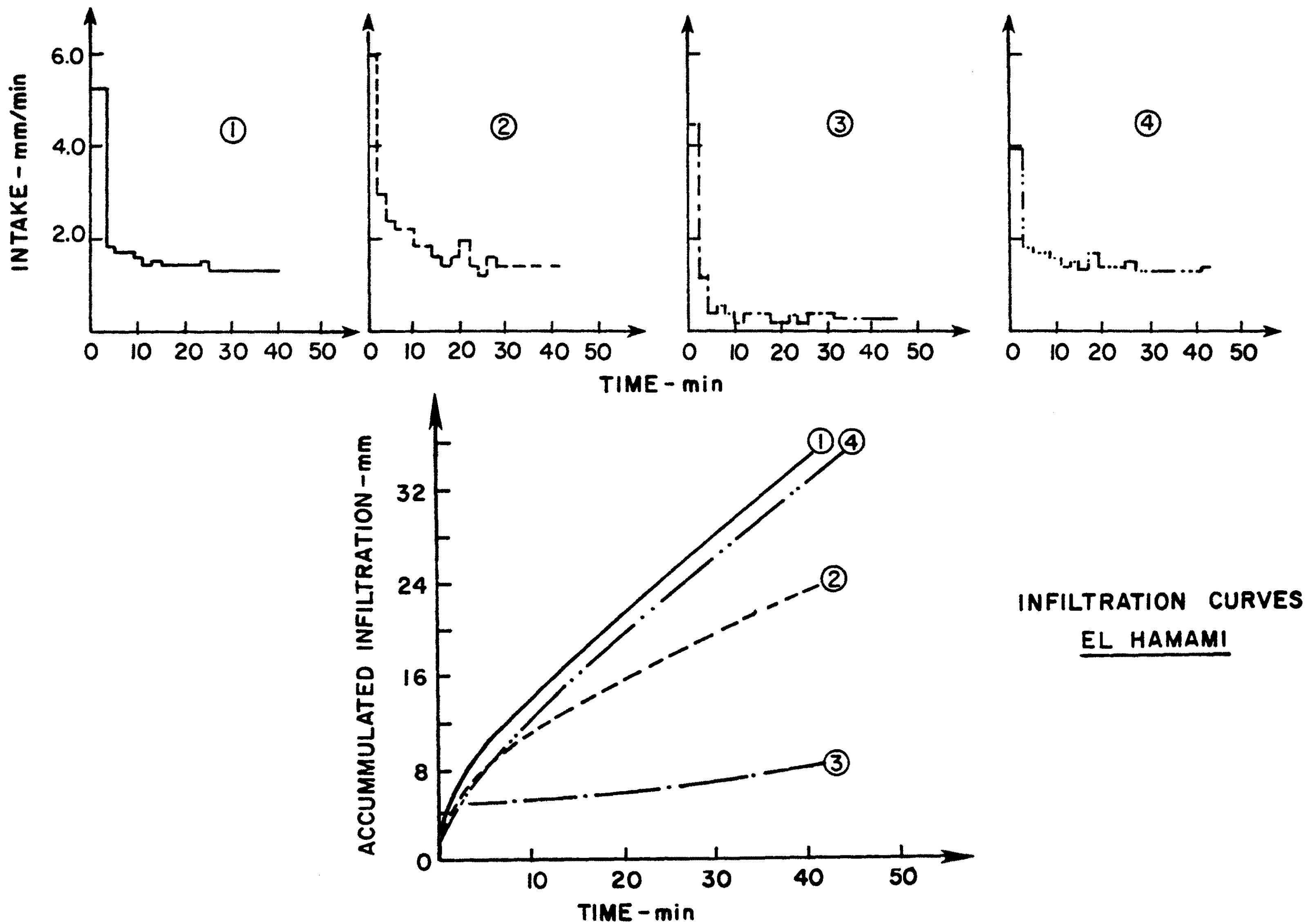

INTAKE - mm/min
6.0
4.0
2.0
①
②
③
④
0 10 20 30 40 50
TIME - min
ACCUMULATED INFILTRATION - mm
32
24
16
8
0
10 20 30 40 50
TIME - min
INFILTRATION CURVES
EL HAMAMI

Figure 9

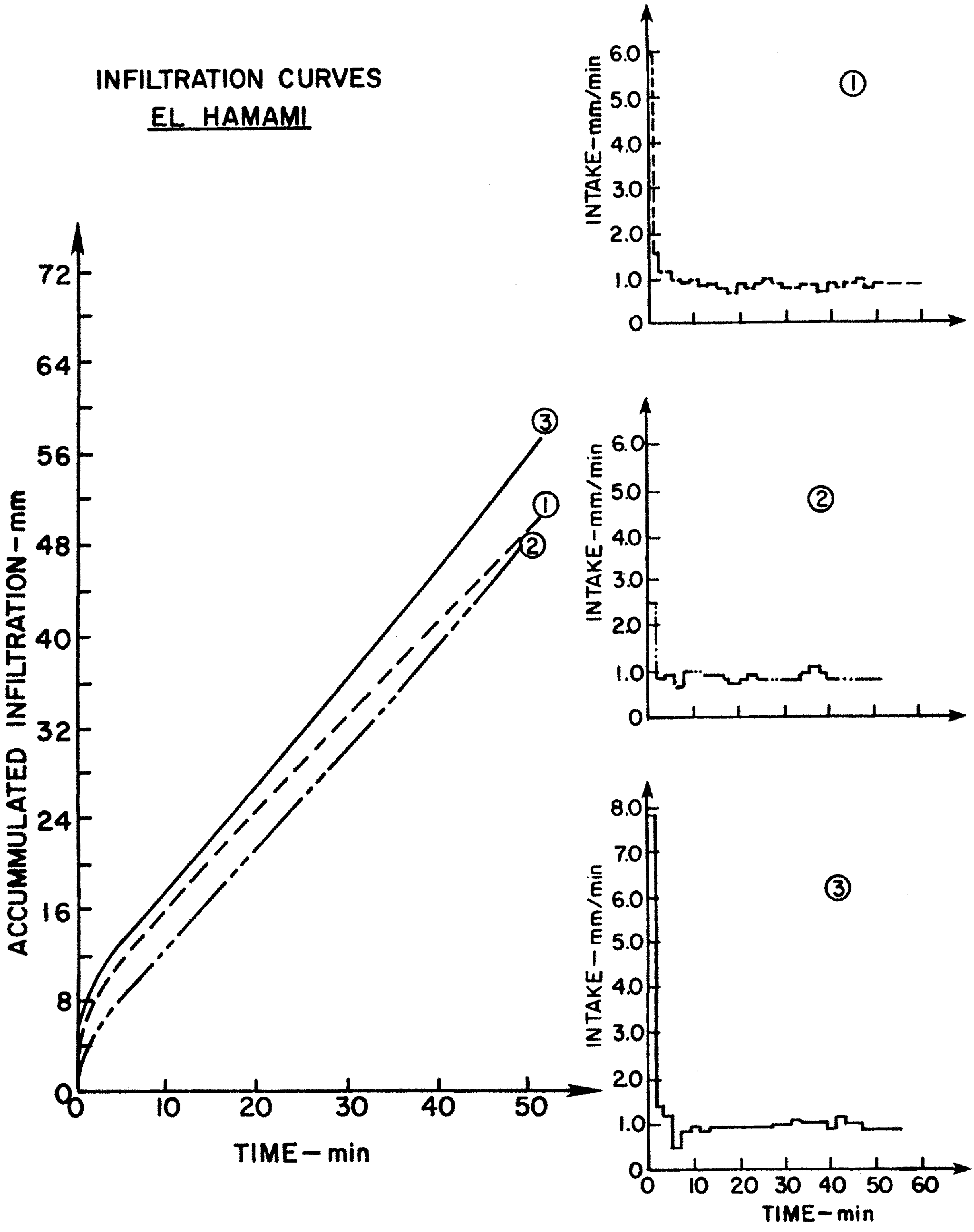

INFILTRATION CURVES
EL HAMAMI
ACCUMMULATED INFILTRATION—mm
72
64
56
48
40
32
24
16
8
0
0
10
20
30
40
50
TIME—min
①
②
③
INTAKE—mm/min
6.0
5.0
4.0
3.0
2.0
1.0
0
INTAKE—mm/min
6.0
5.0
4.0
3.0
2.0
1.0
0
INTAKE—mm/min
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
0
10
20
30
40
50
60
TIME—min

Figure 10

Table 3. Amount of Water Applied Per Irrigation for First Irrigation and All additional Irrigations for Beni Magdoul, El Hammami and Kafret Nasar 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 $\le$ 20				1	7		8	3
20 $\le$ 40		8		4	26		32	13
40 $\le$ 60	8	8		11	25	33	43	17
60 $\le$ 80		8	40	37	24	42	70	28
80 $\le$ 100	8	17		27	6	17	39	16
100 $\le$ 120	8			10	4		15	6
120 $\le$ 140	8		20	6	1		9	4
140 $\le$ 160	22.5	26		2	3		11	4
160 $\le$ 180	22.5	8	20	3	3	8	12	5
180 $\le$ 200	15	17			1		5	2
> 200	8	8	20	1			4	2
Total (Pct.)	100	100	100	102		100		100
Total (No.)	13	12	5	104	102	12	248	

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. If most of the water infiltrates in only one part of the field, major over-irrigation and under-irriguation occurs on the same field. 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

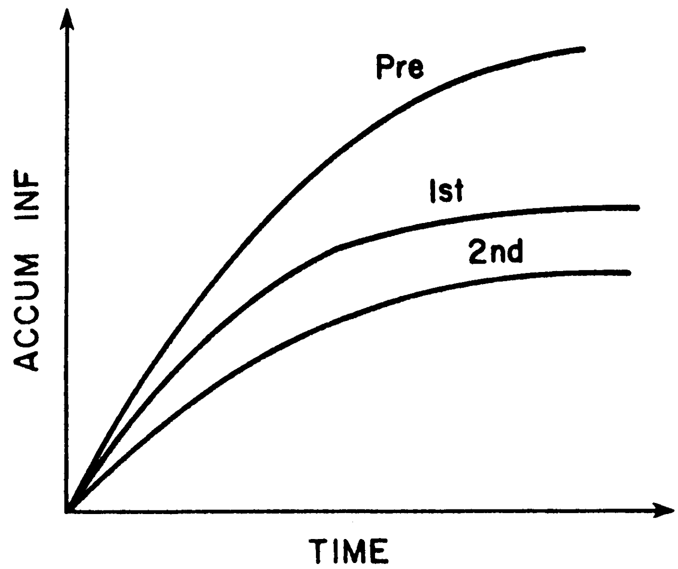


Figure 11. Effect of successive irrigations on infiltration.

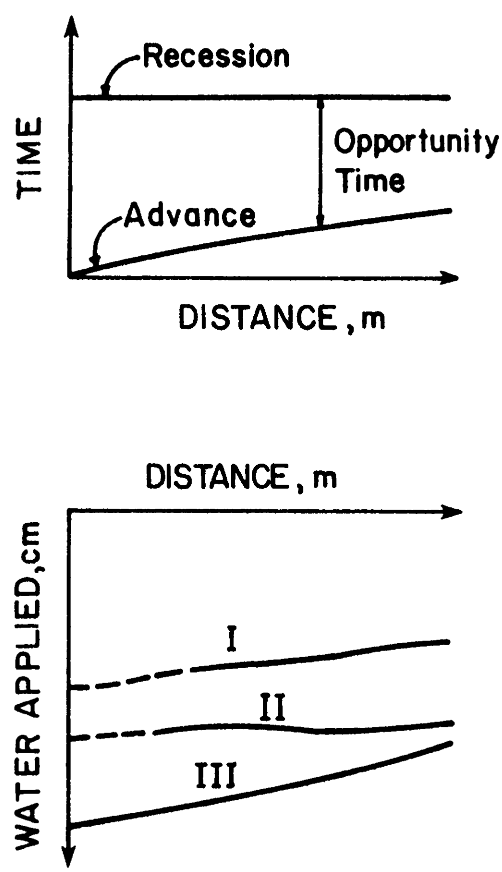


Figure 12. Advance and recession, and infiltration.

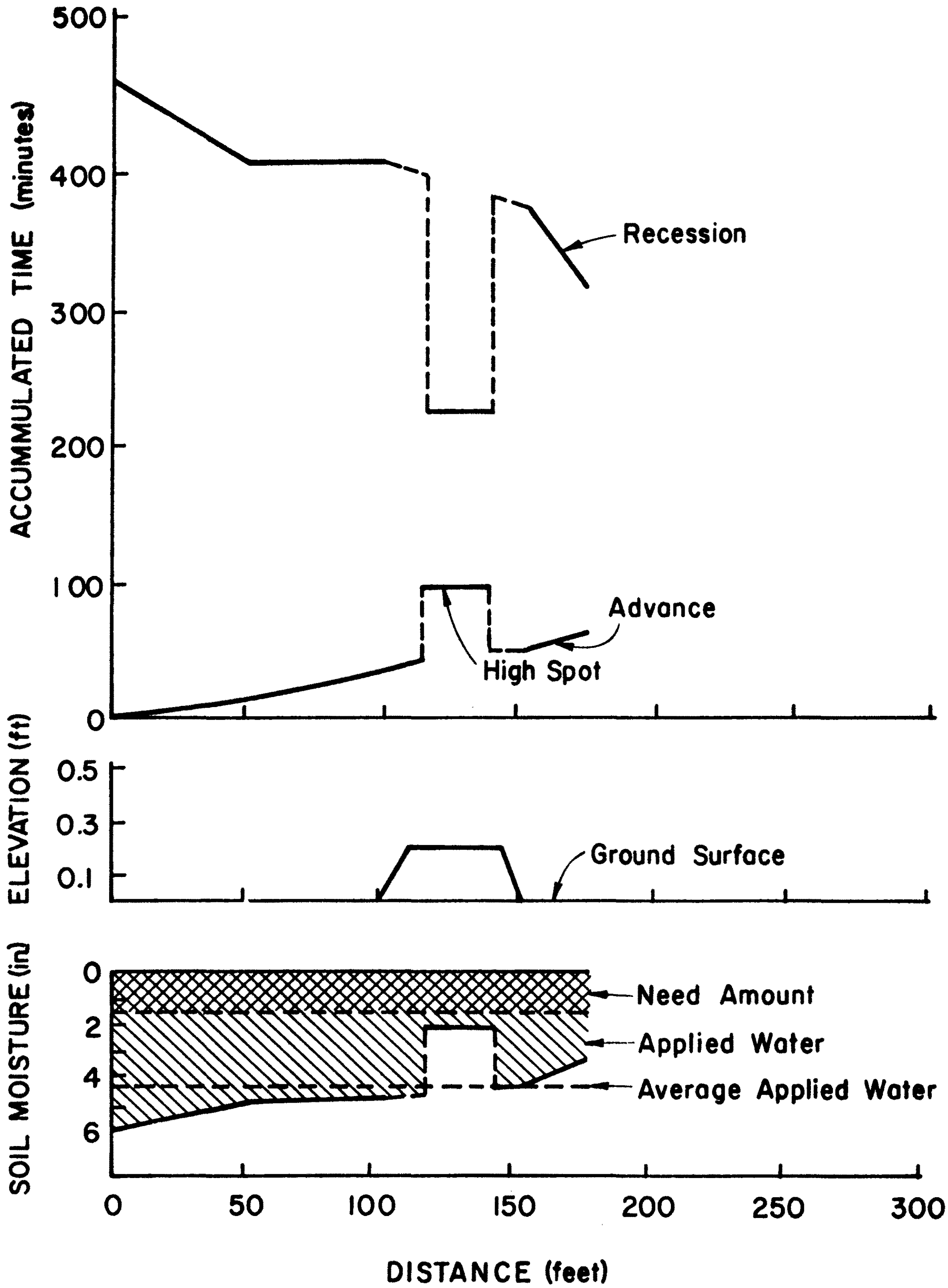

500
400
300
200
100
0
ACCUMMULATED TIME (minutes)
Recession
Advance
High Spot
ELEVATION (ft)
0.5
0.3
0.1
Ground Surface
SOIL MOISTURE (in)
0
2
4
6
Need Amount
Applied Water
Average Applied Water
0
50
100
150
200
250
300
DISTANCE (feet)

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 upper 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 Mansouria 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 Tanbour supplies water at between 5 and 18 l/s while the Sakia 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 who irrigates both a widely varying number of basins and a widely varying size of basins must know very precisely the flow rate or application of a given amount of water to each bunded unit is not likely. Since the farmer will use 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 Meska of the time of use (formally or informally). Meska outlets also have been enlarged without authorization. Therefore, simultaneous and heavy use of the water at the upper reaches of the Meskas 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 Max.	Min.	lit/sec. 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 Sakia, 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 very difficult for a farmer to regulate an application to a given amount without considering 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 Mansouria 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 are farmed 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

Table 5. Irrigation Frequency in El Mansouria District.

Irrigation Frequency in days	Distribution							
	El Hamami		Beni Magdol		Kafar 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

for regulating flow rate and amount of water applied results in much 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 were as follows:

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

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 for the irrigation after plowing. 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 internal for Beni Magdol and Kafar Nasar and 40 to 60 mm for El Hamami. The smaller median amount on El Hamami may not be significant for the limited data collected but could be explained by the predominance of vegetables at El Hamami. 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 Magdol and El Hamami is shown in Table 5. The results are different for each site since at least both the rotation and soils are different.

Beni Magdol 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 Hamami 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 Hamami 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 Kafar Nasar 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 Hamami 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
Kafar Nasar	518
El Hamami	650
Beni Magdol	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 Hamami 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 of decline of the water table during the season between irrigations is

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.	2	3	700	8	
B.M.	2	1	850	11.07	
B.M.	2	2	870	11.0	
B.M.	2	1	1170	6.0	
B.M.	7	2	500	12	
B.M. 1978	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. 1978	1	1	536.9	8	
K.N. 1977	1	1	500	8.5	
E.H. 1978	1	8	839.1	8	
E.H. 1978	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	

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, when 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 Mansouria 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 than field capacity only to the 15 cm depth. At 30 and 45 cm depths,

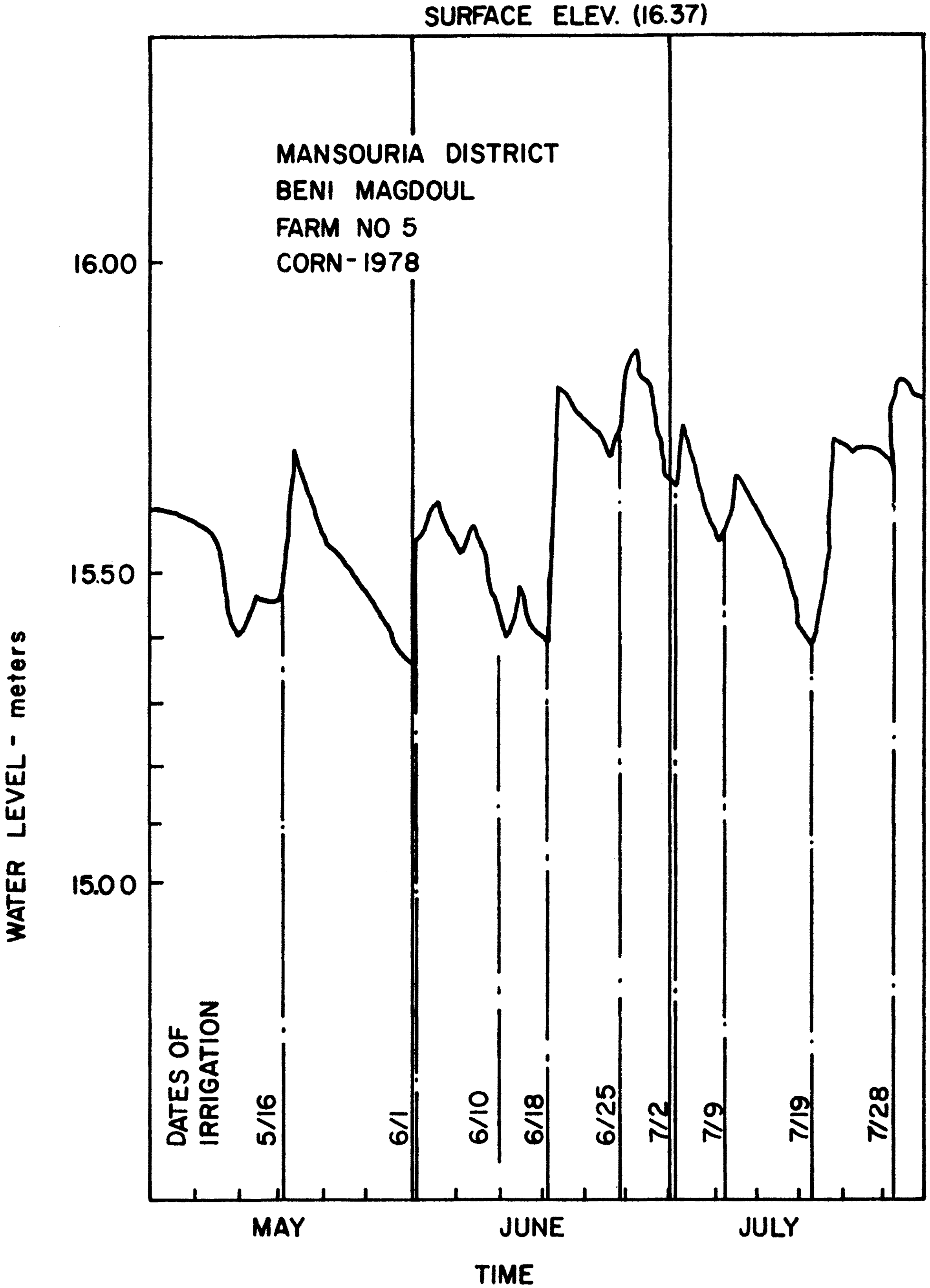


Figure 14. 1. Is water applied by the farmer?
2. Is water table contribution?
3. Is corn consumptive use?

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 replensished 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. Since 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

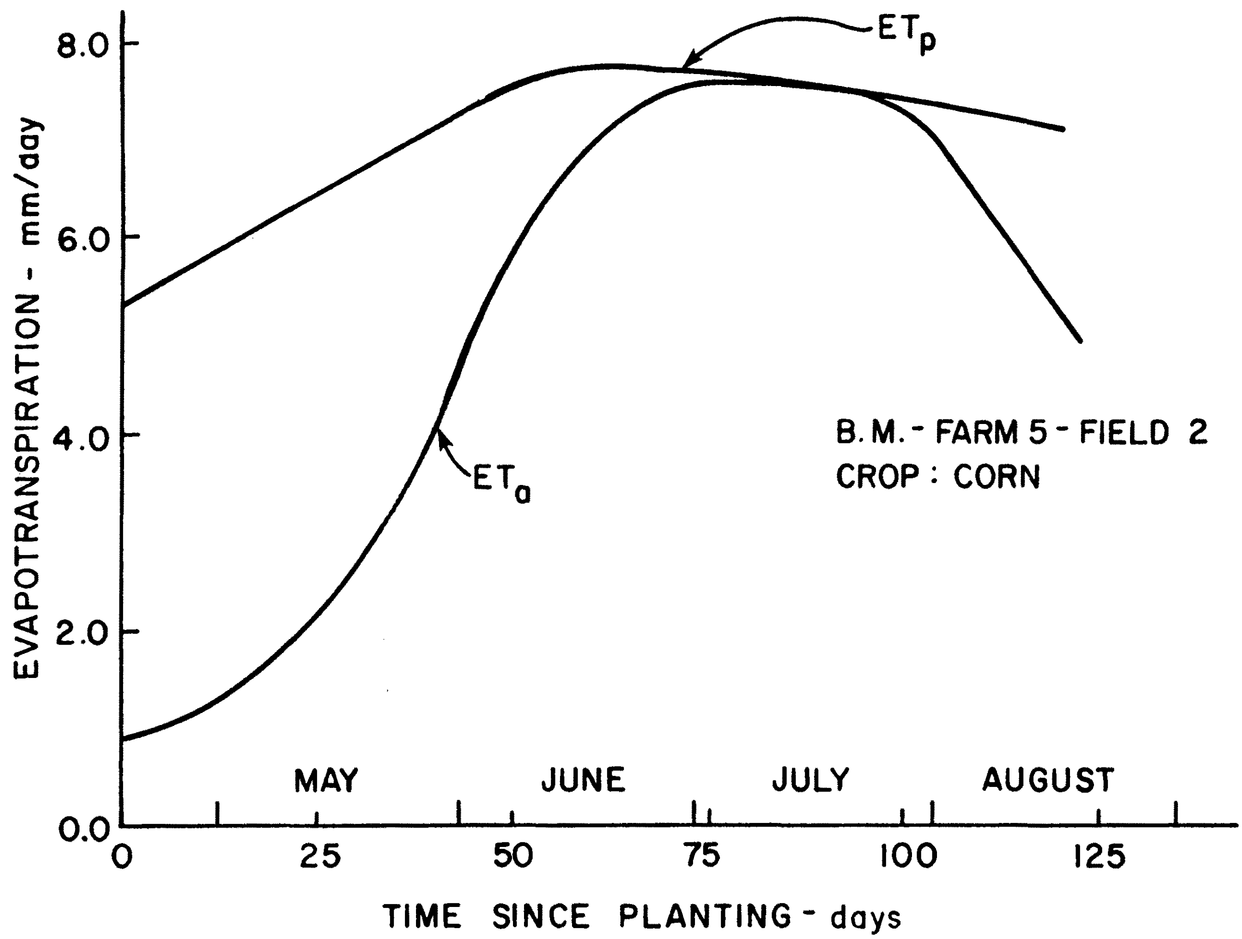


Figure 15. Seasonal Consumptive Use (ETa) and Potential Evapotranspiration (ETp) for a Corn Field at Beni Magdoul.

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 variales 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 Mansouria 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 Water	-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 sloam soil to 6-12 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 specified amount of water to a field. Tambour flow rates range from 5 go 18 l/s and Sakia 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 areo-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 decrease 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 are 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 Magdoul 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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EGYPTIAN WATER USE AND MANAGEMENT PROJECT

ECONOMIC COSTS OF WATER SHORTAGES ALONG BRANCH CANALS

by

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March, 1980

EWUP TECHNICAL REPORT NO. 5

Acknowledgement

Dr. Gene Quenemoen and Mr. Gamal Ayad contributed much to this study. These individuals identified the need for such a study and also provided coordination and support for collecting the data and conducting of the study. Dr. Mona El Kady, Project Leader at the Mansouria site made it possible for members of her research team to work on the study.

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INTRODUCTION

One of the problems identified by the Egyptian Water Use Project (EWUP) personnel is that of water shortages at the tail ends of certain branch canals. A report by EWUP engineers indicates a decrease in water delivery to branch canals at reaches successively more distant from the Mansouria intake. Decreases in water availability along branch canals were also observed; farmers at the tail of branch canals were not being delivered as much water as those at the beginning of branch canals. The authors make a concluding comment: "The most remote areas may receive only one-fourth as much water as those at the beginning of the canal system." (p. 21)[1] Specific observations have been made of severe water shortages during the summer season at the lower end of the El Shimi cannal located in the El Hammami Project site (Figure 1). Important economic costs are likely to be associated with these water shortages, both to farmers and to Egyptian agricultural economy. The purpose of this report is to present some observed differences in farms and farming practices resulting from varied amounts of water available and to make some economic evaluations of these differences.

The El Shimi branch serves an area of about 600 feddans. Estimates are that up to 200 feddans are affected by inadequate amounts of available water.[2] Thus, the amount of land affected represents a significant proportion of the

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[1]Wolfe, John, Farouk Shahin, and M. Saif Issa, "Preliminary Evaluation of Mansouria Canal System Gisa Governate, Egypt." Egypt Water Use Project Technical Report No. 3, Cairo, 1979.

[2]El Shinnawi Abdel Atty and M. E. Quenemoen, "The Problem of Water Delivery at the Tail of the El Shimi Branch Canal," EWUP Internal Report. December, 1978.

total area. The area studied includes the El Shimi branch and neighboring canals in the Mansouria area. Figure 1 locates the canals along which farmer enumerations were completed. Analysts of the Egyptian irrigation water delivery system do not see the problem represented by the El Shimi branch canal to be an isolated occurrence. Rather, water shortages at the ends of branch canals are widespread throughout the nation. A recently completed agricultural mechanization report holds that water shortages are a very important problem to farmers throughout Egypt. In a survey of farmers, 87 percent indicated that insufficient water was a problem.[3] This report does not evaluate the extent of the problem. It does consider the effects of water shortages along canals such as the El Shimi branch and proposes a more thorough investigation of the water shortage problem.

A detailed description of how water is delivered to farmers in the Mansouria District is reported by El Kady.[4] In the El Hammami region water is delivered on a four-days on, eight-days off rotation. According to El Kady, this system encourages more frequent irrigations than is necessary to meet the crops water requirements. The frequent irrigations lead to a tendency for over-irrigation, at least so far as water is available. Over-irrigation by farmers near the head of branch canals likely contribute to water shortages for farmers near the lower ends of branch canals. Farmers in the area affected by water shortages adjust to the water situation in a number of ways:

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[3]ERA 2000, Inc. "Further Mechanization of Egyptian Agriculture" Gaithersburg, MD, April, 1979.

[4]El Kady, Mona, Wayne Clyma, and Mahmoud Abu-Zeid, "On-Farm Irrigation Practices in Mansouria District, Egypt." Egypt Water Use and Management Project. EWUP Technical Report No. 4. 1980.

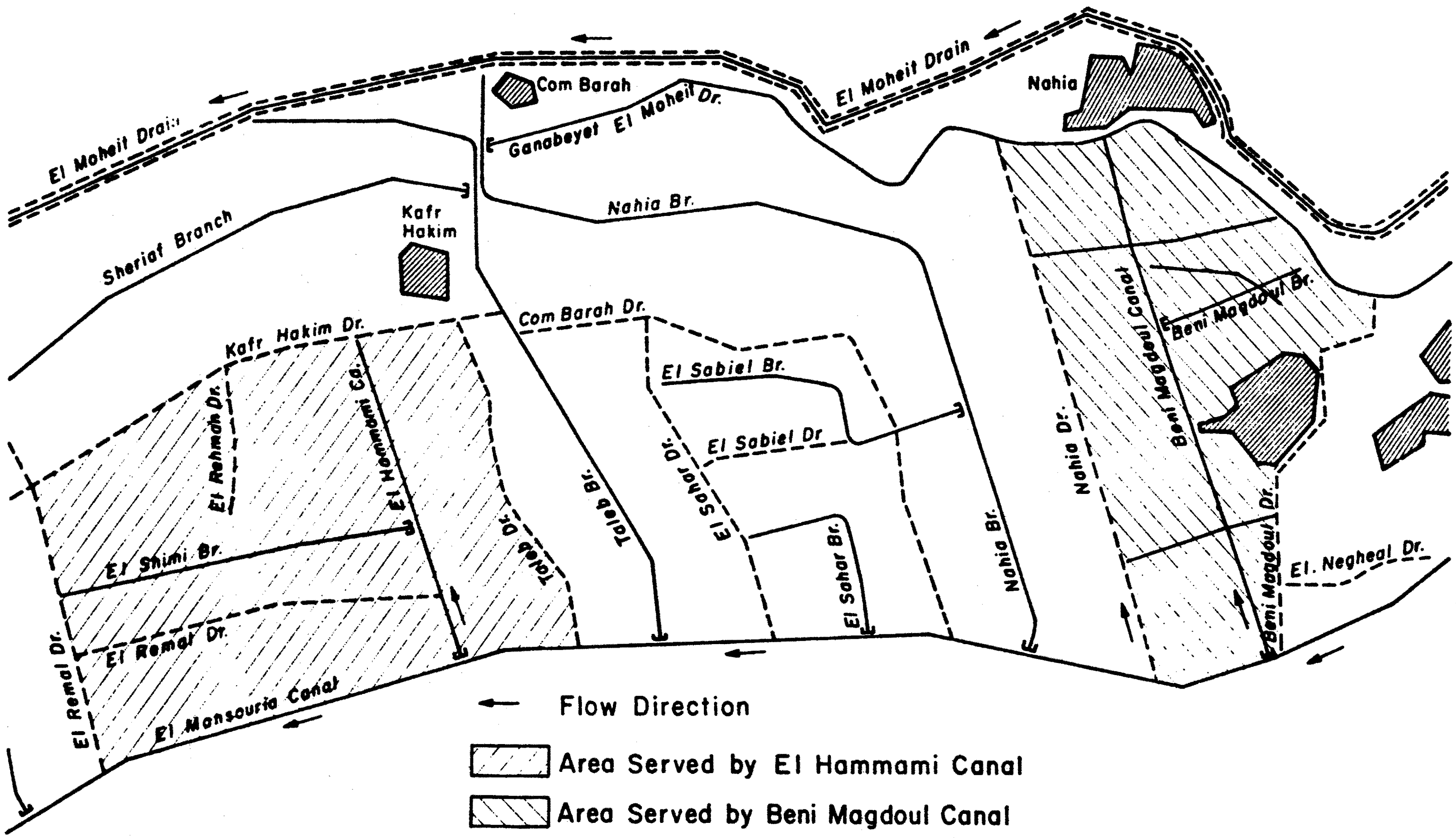

Figure 1. General layout and boundaries of the Beni Magdoul and El Hammami water courses.

(1) First, without action to reduce water shortages, land is left idle,

(2) or if planted to crops, poor yields result.

(3) Purchased inputs such as seed, fertilizer, and chemicals may be wasted (or not used) and the time and effort of farmers may be lost.

(4) Alternatively, crops may be planted which are less than optimal but are more tolerant of water shortages or require less water.

(5) Finally, farmers may have adjusted by finding other means to supply water to the land such as investments in wells and pumps or pumping from drains.

This report examines each of these adjustment hypotheses. It is expected that water shortages also affect land values. Inadequate water greatly lowers the potential productivity of the land and this is reflected in a lower land value.

RESEARCH PROCEDURE

To estimate which, if any, of the above adjustments are occurring along branch canals in the Mansouria canal system, data was obtained from farmer interviews during the 1979 summer season. Farmer interviews were conducted during the summer of 1979 by the Egyptian authors of this report. The interview questionnaire is included as Appendix A to this report. Farms were grouped along a given branch canal into upper one-third, middle one-third, and lower one-third depending on their location relative to the canal beginning and end. Only farmers in the upper and lower groups were interviewed. A total of 38 farmers were interviewed; 20 of these farmers have their land at the end of branch canals and data were obtained from 18 farmers at the upper reaches of branch canals.

The data are summarized by farmers located at the upper reaches of canals and those whose farms were located at the lower end of canals. Comparisons between the "upper-end" farmers and "lower-end" farmers will be the basis of our analysis. In this way we will be able to show the practices which are being followed by all farmers and those changes which are associated with water availability.

The data are summarized here to reflect the adjustments which these farmers have made or are making to perceived water-short situations. We first present the summaries of these data and in a final section some inferences about the economic costs associated with water shortages are presented.

RESULTS OF THE SURVEY

The questionnaire provided information about the way in which Egyptian farmers have adjusted or are adjusting to water shortages. The data collected provide information about most of the possible adjustments suggested in the introduction. These will be considered in turn. In addition, some other observations about farmer adjustments as revealed by the questionnaires will be offered.

Water Availability

First, we must answer the question as to whether there is a difference in canal water availability between upper-end farmers and lower-end farmers. Table 1 presents some information about the availability of canal water to farmers during the summer crop season. Farmers were asked about the proportion of time for which water availability is a problem. The question, as stated, may imply that the timing of water availability is the only problem. Because of the way which water is delivered, if water is not available according to schedule, the quantity of water delivered is also inadequate.[5] Responses from farmers, which indicate water is not available according to schedule, reveal that canal water is not available during the four-days on portion of the rotation. Appendix Tables A-1 and A-2 provide detailed information about how farmers at the lower end and upper end of branch canals, respectively, respond to this question.

In Table 1 it is seen that most farmers at the upper end of branch canals say water is available on schedule at least three-fourths of the time. Fifteen of eighteen respondents at the upper end indicate water is available three times out of four while only six of twenty respondents at the lower end of branch canals report water is available with such scheduled reliability. The largest number of farmers at the lower end of branch canals report water is available only one-fourth of the time. Thus, there is a marked difference between upper-end and lower-end farmers. Farmers at the lower reaches of branch canals experience inadequate water deliveries much more frequently than farmers in the upper reaches of these branch canals.

The report cited earlier indicated that night irrigation may be practiced by farmers for which daytime water deliveries are a problem.[6] Irrigation is sometimes possible at night because upper-end farmers may not be irrigating and water becomes available at the lower reaches of canals. Differences in night

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[5] El Kady, op. cit.

[6] op. cit., Wolfe, et al.

Table 1. Availability of Canal Water to Farmers Along Branch Canals During the Summer Season by Location.

Frequency of Canal Water Availability/ Night Irrigation	Location Along Branch Canal:	
	Upper One-Third	Lower One-Third
	(number of farmers)	
Usually on time	3	4
About 3/4 of time	12	2
About 1/2 of time	3	5
About 1/4 of time	--	8
Never on time	--	2
Practice night irrigation	13	14

irrigation between upper-end and lower-end groups are not evident here. Thirteen of eighteen upper-end farmers and fourteen of twenty lower-end farmers do at least some irrigating at night.

Table 2 reports on the frequency with which water availability is a problem during the winter season. Appendix Tables A-3 and A-4 provide a more detailed treatment. All of the upper-end farmers stated that water is always available on schedule during the winter season. Among the 20 lower-end farmers only 11 indicate winter canal water availability was no problem. Six lower-end farmers said canal water was available about three-fourths of the time and the remaining three farmers are distributed among the three more serious water shortage groups.

Water availability appears to be a problem primarily during the summer season but it is not confined entirely to that time of the year. Given that water availability is a problem and one which affects lower-end farmers more severely than upper-end farmers, it is useful to examine the differences in farming operations between these two groups.

Access to Pumps

Because canal water is not available as scheduled, many farmers have gained access to diesel-powered pumps to apply water to their crops. These pumps either have been purchased or the use of a pump is rented. Table 3 divides the upper-end and lower-end farmers into three groups: those who rent pumps, those who own pumps, and those with no pumps. (See corresponding Tables A-5 and A-6.)

Farmers obtaining access to pumps corresponds closely to the intensity of water availability problem. At the upper end of branch canals, where water availability is not so severe a problem, only 2 of 18 farmers use pumps. These two farmers rent pumps (and then only for a few days each summer).

Table 2. Availability of Canal Water to Farmers Along Branch Canals During the Winter Season by Location

Frequency of Canal Water Availability	Location Along Branch Canal: Upper One-Third	Location Along Branch Canal: Lower One-Third
	(number of farmers)	
Usually on time	18	11
About 3/4 on time	--	6
About 1/2 of time	--	1
About 1/4 of time	--	1
Never on time	--	1

Table 3. Access to Pumps by Farmers Along Branch Canals, by Location

Access to Pump	Location Along Branch Canal: Upper End	Lower End
	(number of farmers)	
Rents a pump	2	8
Owns a pump	--	6*
No pump	16	7

*One farmer both owns and rents.

Among lower-end farmers, 13 of 20 either rent or own pumps. One farmer both owns and rents. Seven have no access to pumps. Of those with access to pumps, 8 is by renting and 6 by ownership of the pumps.

Differences in water availability to farmers along branch canals have resulted in some farmers being forced to provide other means to obtain water for their crops. The use of pumps is much more common among lower-end farmers than among farmers near the upper end of branch canals. Thus, farmers at the lower end of branch canals are incurring a cost to secure water that is not required of farmers near the start of branch canals. More will be said of these costs later, but the costs include the cost of renting a pump or the ownership and use costs of owned pumps. In addition, farmers have often invested in a well to provide the water needed for the pumps.

Since farmers at the lower end of branch canals fall into two groups according to access to pumps, it is now important to recognize differences between these two groups. The following discussions of farmer adjustments to lack of water availability will continue to call attention to differences between upper-end and lower-end farmers and will also compare those at the lower end with access to pumps to those at the lower end with no pumps.

Farm Size Differences

A difference between upper-end and lower-end farmers which was not expected at the initiation of the study was a difference in farm size. However, tabulation of the data revealed some important differences in this score too. Table 4 shows how the farms interviewed vary in size according to location along a branch canal. At the upper end farms averaged 1.38 feddans in size. At the lower end average farm size is more than twice as great, 3.69 feddans. Important differences can also be observed between lower-end farmers who have access to pumps

Table 4. Average Farm Size by Location and by Access to Pumps

Farms Group	Average Number of Feddans of Land
All Upper End	1.38
All Lower End	3.69
All with pump access	4.91
Pump renters	2.72
Pump owners	7.42
No pumps	1.43

and those who do not. Farmers with no access to pumps tend to be rather small, averaging only 1.43 feddans. Lower-end farmers with access to pumps average 4.91 feddans. Among all those with access to pumps, farmers who own pumps average 7.42 feddans and those who rent pumps are less than one-half that size, 2.72 feddans.

Two different interpretations can be made of these differences. First, in that lower-end farms tend to be larger may indicate that because of water shortages at the lower ends of branch canals, farmers have been forced to expand the amount of land farmed to provide a satisfactory level of living for themselves and their families. Lack of sufficient water requires more extensive type of farming using fewer nonland inputs per unit of land. Net returns per unit of land are lower and more land is needed to provide adequate levels of income. Thus, if this interpretation is valid, a part of the adjustment to lack of a reliable supply of water is an expanded land base.

A second interpretation is that larger land holdings are the result of efforts to spread the fixed costs of alternative water sources (wells and pumps) over more land. Notice that lower-end farmers without pumps are of about the same average size (1.43 feddans) as upper-end farms (1.38 feddans). Farmers who rent pumps are about twice that size. But, farmers who have invested in pumps average 7.42 feddans. The larger land holding has enabled them to justify the investment in a pump.

While farmers who obtained an alternative source of water by renting or purchasing a pump bear an additional cost of water that most upper-end farmers do not incur, some lower-end farmers do not have pumps and must rely on the availability of water from canals. These farms are both small and lack a reliable source of water.

Cropping Intensity

It was mentioned above that lower-end farms, especially those without alternative water sources, may tend to be operated more extensively. That is, farmers use fewer non-water inputs per unit of land in response to the absence of a reliable source of water. Further, they may select crops with lower water requirements, delay planting, and use less water and associated inputs per unit of land. Changes in cropping intensity associated with water shortage can be manifest in several ways. First, the amount of idle land would be expected to be greater on canal-end farms than is present on farms at the upper reaches of canals. Also, the number of crops per feddan per year may be less on canal-end farms. Farmers with water shortages are likely to practice less intercropping and multiple cropping. Further, the selection of crops used may be different. Water shortages would lead to growing fewer high value crops and selecting crops which are capable of withstanding some water-stress may be more common. Finally, the crop yields obtained per feddan are expected to be smaller on the farms near the canal ends.

Table 5 shows the summer season cropping patterns of farmers. Maize tends to be the dominant crop for all farmers, occupying between 50 and 60 percent of the land. Upper-end farmers and lower-end farmers with pumps grow about the same proportions of maize in their cropping patterns. Lower-end farmers without pumps grow a much larger proportion of maize relative to vegetables and other crops, however.

Upper-end farmers have a slightly greater percentage of vegetables than lower-end farmers with pumps. Likely, since lower-end farmers with pumps are much larger than upper-end farmers, labor availability may limit the amounts of vegetables (which are relatively more labor intensive) grown on these lower-end

Table 5. Summer Season Cropping Patterns of Farmers by Location and Water Availability

Crop	Location Along Branch Canal: Upper* End	Lower End: All Farms	Lower End: With Pumps	Lower End: Without Pumps
	(feddans of crop ÷ feddans of land)x100			
Maize	53	60	55	86
Vegetables	42	31	33	21
Other	19	10	11	7

*Totals may add to greater than 100 because of the practice of intercropping.

Table 6. Winter Season Cropping Patterns of Farmers by Location and Water Availability

Crop	Location Along Branch Canal: Upper* End	Lower end: All Farms	Lower end: With Pumps	Lower end: Without Pumps
	(feddans of crop ÷ feddans of land)x100			
Berseem	70	38	38	77
Wheat	7	25	28	7
Tomatoes	6	14	16	--
Hot Pepper	1	15	14	16
Other	22	12	14	--

*Totals may add to greater than 100 because of the practice of intercropping.

farms. Lower-end farmers without pumps have only about one-half the amount of land commited to vegetables as the comparable sized farms near the upper end of branch canals. In Appendix Table A-7 it is seen that maize is the only summer crop for five of the seven lower-end farms with pumps. This cropping pattern is not unique to them (see Tables A-8 to A-10), but most farmers who have access to pumps grow some vegetables during the summer season.

During the winter season there is a closer correspondence in cropping patterns between farms of similar size, Table 6. That is, upper-end farmers and lower-end farmers without pumps are more alike in their cropping patterns. Berseem claims most of the land, 70 and 77 percent, respectively. These two groups of farms with about 1.4 feddans of land have about the same amount of wheat as well. The lower-end farms do grow more hot peppers in the winter than the upper-end farmers. Correspondingly, the upper-end farms have more other crops; flax, eggplant, leak, parsley, and garden rocket being some of the more common other crops.

The cropping patterns of the much larger lower-end farmers with pumps differ markedly from the smaller farms. A much smaller proportion of total land is commited to berseem. Likely, they do not need to devote such a high percentage of their land to forage production for livestock. They are able to grow more wheat and tomatoes as cash crops than the smaller farms.

In addition to the crop mix, another possible difference in farming operations associated with water availability is cropping intensity. Cropping intensity is defined as the total number of feddans of all crops divided by the total feddans of land farmed. Crops also vary as to their use of inputs per unit of land. Some crops, such as vegetables may require much more fertilizer, water, and labor per feddan than grain crops. Further, any given crop can be farmed with different levels of input intensity. Maize may be more sparsely seeded and receive less fertilizer in the anticipation of it having lower water requirements per feddan. From Table 7 the cropping intensities (crops/unit of land/year) of the various groups of farmers can be compared. (See Table A-11 and A-12 for more details.) The greatest intensity is found on upper-end farms. However, farms at the lower end with pumps also achieve cropping intensities greater than 2.0.

Thus, as more water is available during the summer, farms tend to (a) grow more vegetables and (b) have less of the total available land commited to maize. But, during the winter season when water is more uniformly available, cropping patterns appear to be more influenced by size of farm than by location along a branch canal. Small farms have larger proportions of their land devoted to berseem than the larger, canal-end farms with access to pumps. On the other hand, the larger farms grow more wheat, tomatoes and other cash crops.

Cropping intensity, as measured by the ratio total feddans of crops to the total feddans of land, does not appear to be greatly influenced by size or by position along a branch canal. But, if the crop mix is considered, cropping intensity differences are more pronounced. Since vegetables (an input intensive crop) is associated with superior water availability, whether provided by the canal or by pump, a part of the increased cropping intensity is hidden in the choice of crops. The small farms without pumps near the end of branch canals choose to concentrate their efforts to growing maize during the summer season.

Table 7. Cropping Intensities of Farms by Location and Water Availability

Season	Location Along Branch Canal:			
	Upper End	Lower End		
		All Farms	With Pumps	Without Pumps
Summer	1.14	1.01	1.01	1.0
Winter	1.06	1.14	1.14	1.0
Annual	2.20	2.13	2.15	2.0

Table 8. Expected Maize Yields on Farms by Location and Water Availability

Farmer Group	Expected Maize Yield/Feddan
	(ardabs)
Upper end	10.6
Lower end:	
with pumps	8.9
without pumps	6.7

A further dimension of cropping intensity is that of expected production per feddan. Farmers were asked about their expected yields from crops. Comparable data were obtained for only one crop and these results are presented in Table 8. Important differences are shown in the farmers' expected maize yield depending upon their circumstance for water availability. Upper-end farmers expect a maize yield of 10.6 ardabs* per feddan. Lower-end farmers with pumps have expected maize yields of 8.9 ardabs and lower-end farmers without pumps expect yields of only 6.7 ardabs. Thus, another measure of intensity, the amount of production per unit of land, is also associated with water availability. Crop yields are decreased as water becomes less available.

One might expect farmers at the lower end with pumps to have yield expectations as least as great as those farmers at the upper end. Three possible explanations for their lower expected yields can be advanced. (a) Even with pumps lower-end farmers incur an additional cost for water. For economic reasons they may choose to apply less water per feddan of maize than do upper-end farmers. The added costs they are incurring (pumping costs) do not justify as much water applied per feddan of maize as is the case when these pumping costs are less. (b) The soils near the lower reaches of branch canals are more saline than those at the upper reaches.[7] Perhaps because of inadequate deliveries of water to flush these salts from the soil, higher levels of salts have accumulated and these salts are deleterious to yields of most crops. (c) Further, water pumped

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*An ardab is a volume measure which varies in weight depending on the commodity measured; an ardab of maize is 140 kilograms or about 308 pounds.

[7]Dotzanko, A.D., M. Zanati, A.A. Abdel-Wahed, and A.M. Keleg, "Preliminary Soil Survey Report for the Beni Magdoul and El Hammami Areas." Egypt Water Use Project, EWUP Technical Report No. 2. 1979.

from the ground or from drains may be of lower quality than canal water.

Another measure of cropping intensity is the amount or extent of idle land. Farmers were asked how much or for how long they may leave land idle. Response to this question was rather limited, but 5 lower-end farmers indicated that they leave some land idle for a period of about one month. Two others indicated that they often delay planting of crops because of the lack of available water. Leaving land idle tends to be associated with farmers without access to pumps.

Anticipated Changes

The survey results presented thus far are measurements of how water availability is affecting farming operations. Differences in the organization and operation of upper-end and lower-end farms have been observed. We next turn to more "what if" kinds of issues. That is, if water were available according to schedule, how would cropping patterns, cropping intensities and expected yields change. Data on "what farmers would do if questions" are more qualitative than those data presented above, but they provide some additional information. The responses are detailed in Table A-13.

When asked how they would respond to water being available more on schedule during the summer, 12 lower-end farmers indicated that they would grow more vegetables, 5 would keep the same crops (two of these volunteered they would expect a higher yield) 2 would grow more maize and 2 would grow more of other crops.

The better delivery of water relative to the water rotation schedule and crop water requirements during the winter season is also reinforced in these data. During the winter season most farmers would maintain the same crops.

The differences observed between upper-end and lower-end farmers and between those with and without alternative water sources are supported by these indicated changes in improved water delivery. The amounts of summer vegetables are being limited by available water; more maize is grown than would be if the water situation were changed. Lower-end farmers without alternative water sources also expect lower maize yields because of the problems associated with water availability; several farmers indicated they would expect a higher yield if more water were available.

Given the adjustments farmers have made or are making to their circumstances of water delivery, it is appropriate to consider the potential benefits from actions to improve the distribution of water along branch canals. The following section discusses some of the potential benefits. The necessary data to demonstrate the benefits from alternative water distributions are not readily available. The data on which the following discussions are based do serve to illustrate the costs and benefits to improved water distribution. The material presented also illustrates the potential importance on the problem to the agricultural economy of Egypt.

Implications of Water Delivery Problems

The information presented above illustrate that differences are present between upper-end and lower-end farmers along branch canals. These differences are associated with the delivery of irrigation water. The availability of irrigation water according to schedule is important to (a) the income potentials of individual farmers and (b) to the area or district, measured as the extent to which agricultural output potentials are being reached. (c) Further, the problem has national significance to the government of Egypt and the agricultural sectors ability to contribute to national economic development goals.

Farmer Income

Farmers at the lower end of branch canals may be adversely affected by one or more ways. First, they may incur additional costs to supply water to their farms. Investments in pumps and wells and/or expenditures for pump rentals are being incurred by some farmers. Second, their cropping patterns are affected. Farmers are forced to choose crops which are relatively less sensitive to moisture stress and must forego the opportunity to produce vegetables (in the Mansouria district) with greater income earning potentials. Finally, even for the same crop mix, lower-end farmers cannot achieve the same yields per unit of land as their peers at the upper end.

Table 9 shows the amount of investment in pumps and wells reported by the farmers who responded. Total investments vary from L.E. 400 to L.E. 2,300; investment per feddan ranges from about L.E. 89 to L.E. 250.

Three of the farmers who own pumps also have wells; one of these farmers has two wells. Two others pump from a drain. The source of water for the remaining farmer is not known. One farmer indicated that he jointly owns the pump with two other farmers.

Farmer Number 2 rents his pump so that it serves about 25 feddans in addition to the 3 feddans he owns. His rental income on the pump is about L.E. 0.75 per hour; total annual income from pump rental is about L.E. 675.

Farmer Number 6, who jointly owns his pump with two others, also rents the pump to others. The pump serves 13.5 feddans for the three owners and is rented to provide water to another 4 feddans. The rental income is L.E. 0.60 per hour or about L.E. 60 per year. Thus, farmers who own pumps may be spreading the fixed costs of these pumps by providing either water or a pump for rent to his neighbors.

Table 9. Investments in Alternative Water Sources Reported by Lower-End Farmers Who Own Pumps

Farmer[a] Number	Investment	Land Farmed	Investment per Feddan
	(L.E.)	(feddans)	(L.E.)
1	2,000	17	117.65
2	700	3	233.33
3	400	2.5	160
5	1,500	6	250
6	400	4.5	88.89
15	2,300	11.5	200
Average	1,217	7.4	164.45

[a]Farmer numbers here correspond to those identified in Tables A-1 through A-13.

In addition to these investments, which must be amortized over several years, farmers must pay the operating costs for using these pumps. Upper-end farmers also have water lifting costs; the data obtained for this study are not sufficient to compare the costs of lifting water between upper-end and lower-end farmers, however. Reports are in preparation by other EWUP economists which examine the costs of lifting water by alternative means.[8] Appendix B-1 and B-2 provide some investment and operating cost data as reported by two farmers included in this study. This study was not designed to provide sufficient information about differences in water lifting costs between upper-end and lower-end farmers to make comparisons.

Other farmers rent pumps to offset canal water delivery shortfalls. Table 10 summarizes the average rental cost obtained from those who reported. Pump rental rates vary a great amount, from L.E. 0.50 per hour to L.E. 1.00 per hour. The average rental rate is L.E. 0.67. Likely, these variations are associated with size and flow rate but the data obtained do not include such measurements.

Farmers who neither own or rent pumps, and perhaps some who rent pumps only for certain crops or irrigations, have different kinds of costs. Their cost are opportunity costs of income foregone. It was shown earlier that the cropping patterns favor maize at the expense of vegetables. Further, expected maize yields are much lower than those expected by upper-end farmers and by lower-end farmers with pumps.

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[3] Quenemoen, M. E. and Shinnawi Abdel Atty El Shinnawi, "An Economic Analysis of Water Lifting With a Diesel Pump for a Farm at El Hammami." A paper presented at the UNESCO Training Conference on Irrigation Development. Egypt Water Use Project. 1979.

Table 10. Pump Rental Costs Paid by Lower-End Farmers Reporting

Farmer Number	Rental Cost per Hour
	(L.E.)
3	0.60
7	0.80
8	0.80
9	0.50
12	0.50
19	1.00
20	.50

First, consider the differences in income per feddan from vegetables versus maize. The EWUP Enterprise Cost Studies estimate the net return above all costs for cabbage in the El Hammami area are L.E. 351.36 per feddan.[9] In the same area, the net return above all costs for eggplant is L.E. 227.62 per feddan.[10] And for tomatoes in the Bemi Magdoul area, per feddan net returns above all costs are estimated at L.E. 52.54.[11] Currently available data do not permit direct comparisons to maize in the Mansouria district. However, enterprise costs and returns have been made for maize in the Abu-Raia area of the Kafr El Sheikh Governate. The yields reported in this estimate is 13 ardabs, slightly greater than the 10.6 ardab yield expected by Mansouria district farmers. Net return per feddan of maize above all costs is reported as L.E. 7.19.[12] It appears that net returns above all costs are considerably higher for vegetables than for maize. Income sacrifices per feddan may range from L.E. 46, comparing maize to tomatoes, to L.E. 344 when comparing maize to cabbage.*

Even if maize is produced, the opportunity cost of foregone income is great. Gross returns per feddan from maize yielding 10.6 ardab and priced at L.E. 8 per ardab is L.E. 84.8. The gross returns per feddan associated with the 6.7 ardab maize expected by lower-end farmers without pumps is L.E. 53.6. A difference of L.E. 31.2 in expected gross returns per feddan of maize exists

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[9] El Shimmawi and Farouk Abdel Al, "Crop Enterprise Cost Study, Cabbage at El Hammami Area". Egypt Water Use Project, 1979.

[10] El Shammai and Farouk Abdel A, "Crop Enterprise Cost Study, Eggplant at El Hammami Area". Egypt Water Use Project, 1979.

[11] Lotfi, Nasr and Farouk Abdel Al, "Crop Enterprise Cost Study, Tomatoes at Bami Magdoul Area". Egypt Water Use Project, 1978.

[12] Quenemoen, M. E., Yusef Yusef and Gamal Ayad, "Crop Enterprise Cost Study Maize at Abu-Raia." Egypt Water Use Project, 1978.

*These analyses hold true for individual farmers only; if all farmers increased vegetable production, additional supplies would cause prices to decrease and the net income differences to narrow.

between these two groups.

Production losses along branch canals. Differences in water costs and net income per feddan between farmers with adequate irrigation water and those with water shortages can be sizable. Here, it will be shown that for a given amount of water delivered to the head of a branch canal, total production can be increased by improving the distribution of water along the branch. That is, a greater total output can be reached by providing more water to lower-end farmers, even if this requires reducing water use of upper-end farmers.* Thus, if water use efficiency is measured as the amount of (or value of) agricultural output per unit of water, an improvement in water use efficiency would occur by providing a more uniform distribution of water along all branch canals. The potential benefits from a more uniform distribution are different depending on whether or not adequate amounts of water are being available at the head of branch canals to meet the crop water requirements for all land served by the canal. Here we assume adequate water is available at the head of the branch canal. The potential gains from improved water distribution then depend on the case if (a) upper-end farmers are using excessive amounts of water and thereby prevent the water from being delivered to lower-end users, or (b) upper-end farmers are not using water excessively but the water is being lost by seepages, weed growth, etc., from the branch canals. Water use efficiency cannot be considered in isolation from other input use. Suppose in either case that adequate amounts of all other inputs are available and are varied in correct proportions to the amount of water applied. Figures 2 and 3 illustrate these two cases.

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*If lower-end water shortages are caused by losses in the branch canal from seepage, weed growth, etc., reallocations may not be necessary. Upper-end irrigations would not affected by measures to reduce in-canal losses which would provide more water to lower-end users.

Figure 2 is based on a production response function for corn (maize) at Davis, California.[13] As for Egypt, little or no growing season precipitation occurred in the experiments on which the function is based. The functional relationship between water (W) in acre-inches, pounds of nitrogen (N) fertilizer, and pounds of maize production (M) per acre is:

$$(1) \quad M = 3294.4 + 367.2W + .52N - 7.06W^2 + .0038N^2 - .0458WN$$

Since it is assumed the levels of all other inputs but water are given, setting N=100 the production response equation reduces to:

$$(2) \quad M = 3852.4 + 366.7W - 7.06W^2$$

The maximum per acre yield occurs when 25.97 acre-inches of water are applied resulting in a yield of 8,614 pounds of maize per acre. Converting these measurements to cubic meters (m^3) per feddan and ardabs of maize, the maximum yield occurs when 2,770.8m^3 of water is applied and a yield of 29.03 ardabs of maize is reached. This yield is more than double the greatest of yields observed among the farmers sampled in this survey. The response function is fit to data from a controlled experiment and the cultural practices applied in California are different from those used in Egypt. The functional relationship given in equation 2 is adjusted for both the experimental and cultural practice effects and the following equation results:*

$$(3) \quad Y = 1926.2 + 183.4W - 3.53W^2$$

With equation 3, yields still reach a maximum at 2770.8m^3 of water; the maximum yield is 14.5 ardabs per feddan. Such is consistent with the survey data and other reports of maize yields in Egypt.[14]

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*Equation 3 is derived as Y = 1/2 (equation 2)

[13] Heady, E.O. and R.W. Hexem. Water Production Functions for Irrigated Agriculture. Iowa State University Press. Ames, Iowa. 1978. p. 92.

[14] Fitch, J.B., A.A. Goueli, and M. El Gabely, "The Cropping System for Maize in Egypt, Survey Findings and Implications for Policy in Egypt," Workshop on Improved Farming Systems for the Nile Valley. Ministry of Agriculture and UNDP/FAO. Cairo. 1979.

In Figure 2 we assume that upper-end farmers are not using excessive amounts of water. Shown along the water response curves for maize, are points corresponding to the possible water application rates for upper-end and lower-end farmers. First, Point A on the curve locates where lower-end farmers without pumps may be operating; they may be receiving only one-fourth the amount of water as upper-end farmers.[15] Point C locates where upper-end farmers may be operating; they are applying water at the level which maximizes their yields.

At A about 700 cubic meters of water are applied and at C, about four times as much or 2,800 cubic meters are applied. In equation 3 the maximum yield of 14.5 ardabs is reached with about 2,600m^3 of water per feddan. From equation 3 the estimated yield reduction resulting from reducing water application by, say, 500m^3 can be estimated. If $W=2{,}100m^3$, maize yields would be reduced by 0.30 ardab. If that 500m^3 were made available to lower-end farmers, water applications could be increased from 650m^3 per feddan (Point A) to 1,250m^3 per feddan and an additional yield of about 2.37 ardab would be forthcoming. A gain of 2.37 - .30 = 2.07 ardab of maize would be obtained on each feddan following this reallocation. Such redistributions could continue until the marginal increment in yield per unit of water is equated for the upper-end and lower-end farmers such as would occur at Point B. At B, the output of two feddans would be about 26.8 ardabs (13.4 x 2 feddans). But, prior to the redistribution with lower-end farmers operating at A and upper-end farmers at B, the output from two feddans would be only 24.5 ardabs (10.0 + 14.5). This distribution of the same amount of water, a total of 3,250 cubic meters for two feddans, would yield about 9 percent more maize.

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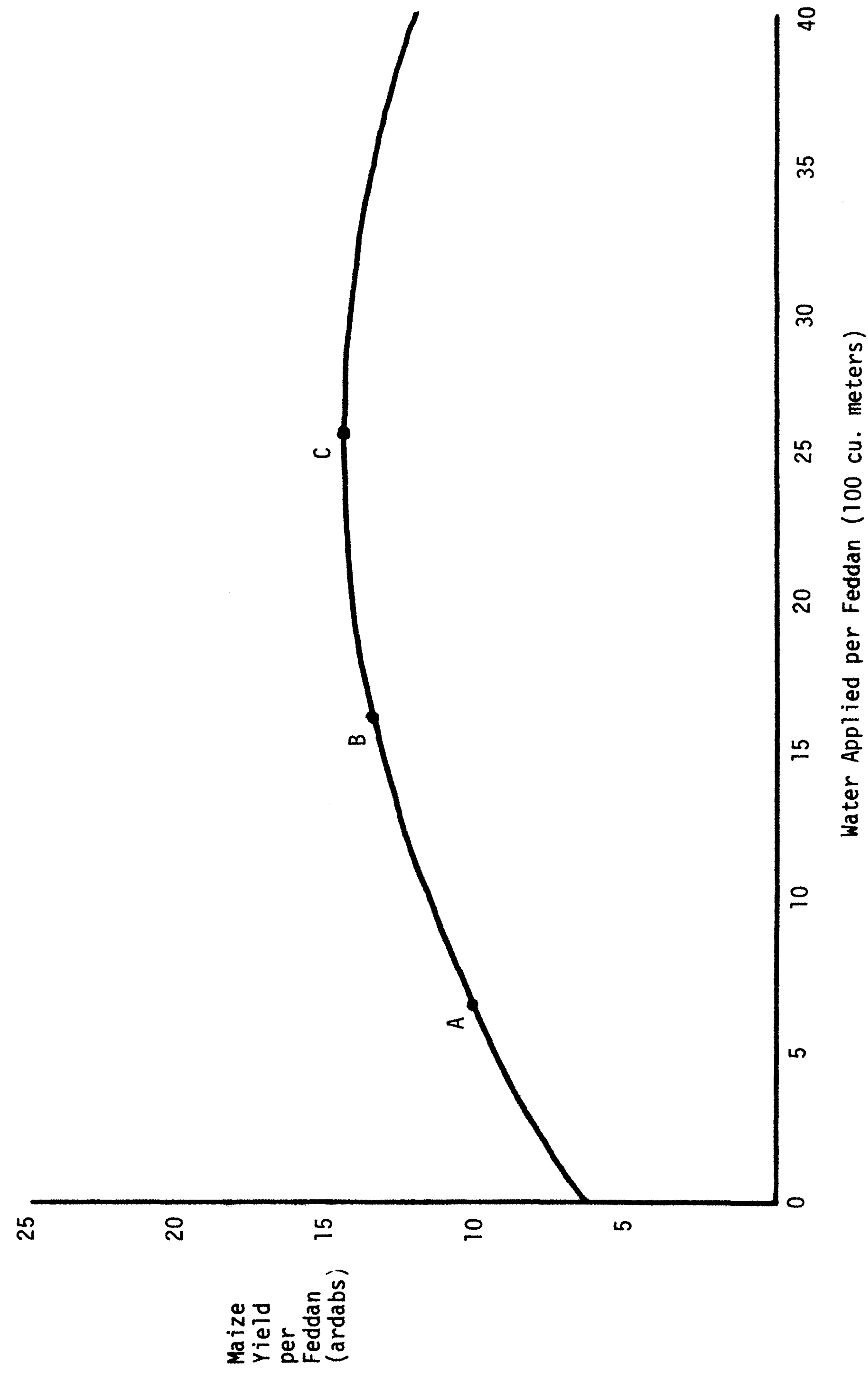
[15] op. cit., Wolfe, _et al_.

Figure 2. Water Response Curve for Maize; Upper-End Farmers Not Using Water Excessively



If, however, the situation is as depicted in Figure 3, the potential gains from redistribution are even more significant. Here it is assumed that (a) adequate amounts of water are being delivered to the head of branch canals and that (b) upper-end farmers are using water destined for lower-end users. The upper-end farmers are, in fact, using so much water that it is deliterious to their yields.* That some farmers may be using water excessively was cited as a possibility in an earlier study.[16] This report found some indication that as water applications increase, total yields decrease. Such is the case at Point C. In Figure 3, a total of about 2,500m^3 is provided for each feddan of maize, an amount which approximates its consumptive use requirements. The distribution is not uniform, however, upper-end farmers claim 4,000m^3 of water leaving only 1,000m^3 for lower-end farmers. Points A and C depict the lower-end and upper-end farmers operations, respectively.

Lower-end farmers are using 1,000 cubic meters of water (1/4 the amount of upper-end users) and are obtaining a yield of about 11.5 ardabs per feddan. Upper-end farmers are using 4,000 cubic meters and get a yield of 12.0 ardabs. Now, redistribution of water from the upper-end to lower-end will benefit both groups. If 1,500 cubic meters are taken from each upper-end feddan, reducing the amount applied from 4,000m^3 to 2,500m^3, yield would increase from 12.0 ardabs to 14.5 ardabs. A corresponding increase in the amount of water delivered to maize on lower-end farms would increase the water used per feddan from 1,000 to 2,500m^3 and increase their yields from 11.5 to 14.5 ardabs. Dividing the water

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*Such water use practices appear irrational. They are rational, however, in that such input use practices often occur because of lack of knowledge, risk aversion, or are necessary to insure one's continued use of a resource.

16 El Kady, op. cit., p. 54.

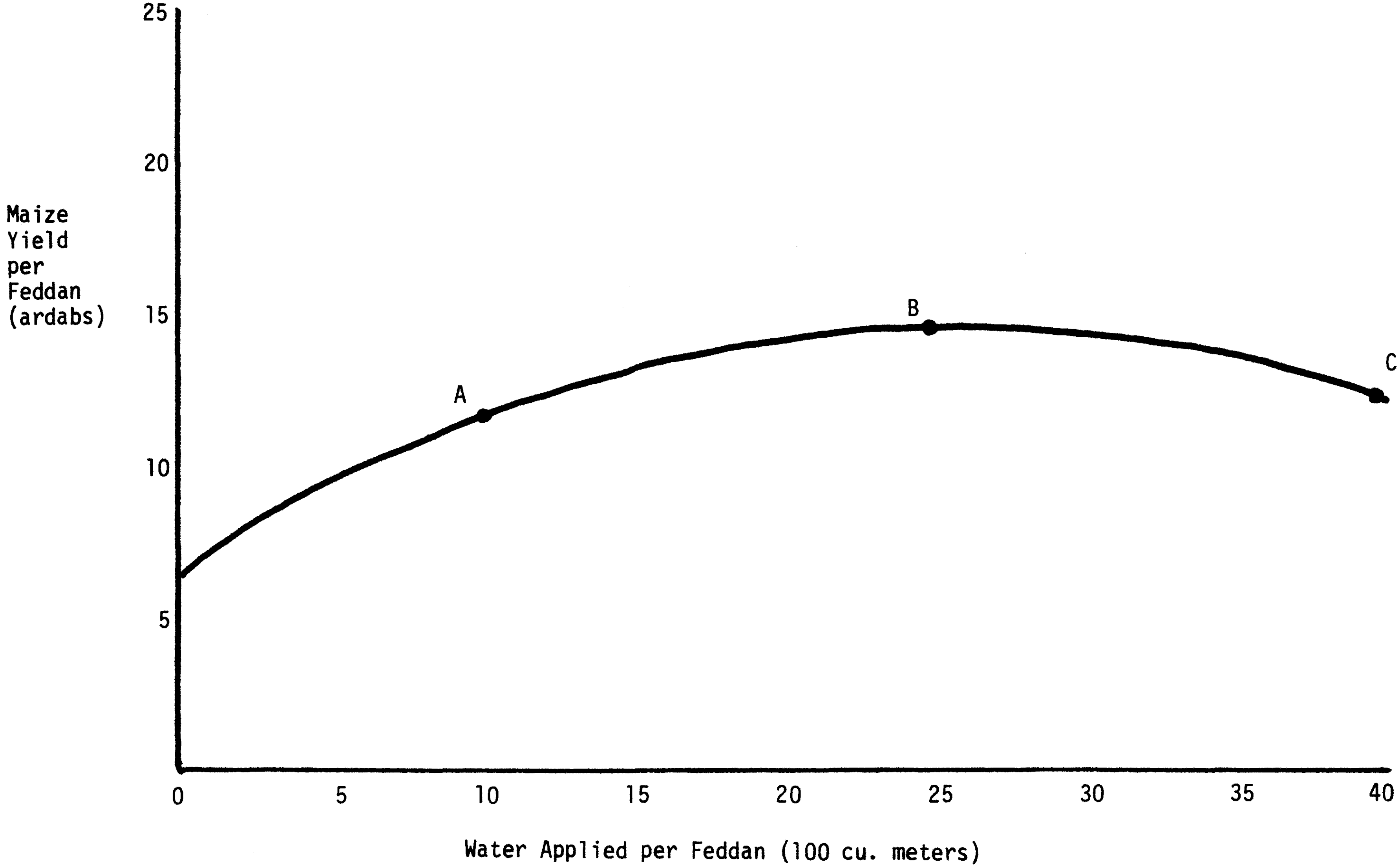

Figure 3. Water Response Curve for Maize; Upper-End Farmers Using Water Excessively

equally among upper-end and lower-end land, allowing 2,500m^3 for each feddan equates the yield increment per marginal unit of water. At this point (Point B in Figure 3) the yield would be 14.5 ardabs for both upper-end and lower-end lands. Thus, total output from two feddans, one located at the upper end and the other at the lower end, would increase from 11.5 + 12.0 = 23.5 ardabs to 29 ardabs. This is a 23 percent increase.

Depending on whether situation in Figure 2 or Figure 3 prevails, potentials to increase water use efficiency and agricultural output along branch canals are present. Output of maize alone could increase from 9 to 23 percent. Likely, changes would also occur in the cropping patterns as lower-end farmers would grow more vegetables. Thus, the benefits demonstrated by Figures 2 and 3 are on the conservative side. The potentials to achieve improvements in water use efficiency are even greater than the illustrations reveal.

Aggregate Effects

Just as the efficiency of water use along a branch canal can be increased by improved distribution of water and these efficiency gains are realized as a greater level of agricultural output, approximations can be made of the potential benefits to the agricultural output of the nation. Egypt has about 5.5 million feddans of land. In the Mansouria area, lower-end farmers without access to alternative sources of water have about 86 percent of the land in maize during the summer season. Their peers with water have only about 54 percent of their land in maize. Conversely, vegetables make up only 21 percent of lower-end without water farmers summer crops while those with water have between 33 and 42 percent (say 37 percent) of their land in vegetables. One-third of the land is being operated below its potential. The Mansouria district includes 27,745 feddans.[17] The lower-end farms produce only (27,745 ÷ 3 X .21) 1,942 feddans of vegetables while upper-end farms produce (27,745 ÷ 3 X .37) 3,422 feddans of vegetables. The difference in net farm income per feddan of vegetables and that of maize ranged from L.E. 46 to 344. Assuming a difference of L.E. 200, the income foregone from not producing vegetables in the Mansouria district alone could amount to L.E. 296,000 per year. It is very possible, however, that the amount of vegetables grown is constrained by labor availability. Thus, extrapolation like those presented here should be interpreted with some reservations.

In addition, the net income per feddan of maize grown by lower-end farmers is below potential. Increases in gross income per feddan of maize could range from 9 to 23 percent. Gross income per feddan of maize is about 13 ardabs at L.E.8 = L.E.104. Assume maize would occupy only 54 percent of the summer land, as with farmers with adequate water, and 4,994 feddans of maize are "below potential (27,745 feddans x 1/3 x .54). A 10 percent increase in gross income per feddan amounts to L.E. 51,938 (4,994 x .72); a 23 percent increase would increase gross farm income by L.E. 119,456.

Not all areas of Egypt possess the income potentials from vegetables as does the Mansouria district. Nevertheless, these analyses illustrate the potential gains which can be achieved by improving the efficiency of water distribution and use. Further, such estimates of the benefits from improvements in water use efficiency can serve as a guide as to how much can be spent to improve the efficiency of water delivery and use. Such is the goal of the Egypt Water Use and Management Project.

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[17] op. cit. Wolfe, et. al.

EGYPT WATER USE AND MANAGEMENT PROJECT
(ECONOMICS TEAM)
INTENSIVE (FARMER) SURVEY
EVALUATION OF WATER SHORTAGES
ON BRANCH CANALS
SITE AND GOVERNORATE: ____________________

1. **Name** ______________________ Age ______________

2. **Family Members:** Wife ______________________________

   Children: Age Sex

   ______ ________

   ______ ________

3. **Location:** Name of canal ______________________________

   Canal start ____________

   Canal end ______________

4. **Amount of land farmed:*** Number of feddans ______________

   Number of feddans owned __________

   Number of feddans rented _________

5. Livestock and Equipment Inventories:

   a. Livestock

Livestock	No.	Age	Uses
Buffalo	____	____	____________________
Cattle	____	____	____________________
Donkeys	____	____	____________________
Goats	____	____	____________________
Sheep	____	____	____________________
Chickens	____	____	____________________
Other (specify)			
____________	____	____	____________________

Data prepared by: ____________________

Date: ____________________

* تكتب المساحة بالارقام العشرية وليست بالقراريط (انظر الصفحة الاخيرة)

b. Equipment

	No.	Size
Sakia	______	______
Tambour	______	______
Shadoof	______	______
Plow	______	______
Tractor	______	______
Planter	______	______
Diesel pump	______	______
Electric pump	______	______

6. Source of water; number of feddans served by:*

Canal only	______
Canal & drain	______
Canal & well	______
Well only	______
Other (specify)	______

7. Crops Grown:

a. Summer Crops	No. of feddans*	(expected) Average Yield
______	______	______
______	______	______
______	______	______

b. Winter Crops	No. of feddans	(expected) Average Yield
______	______	______
______	______	______
______	______	______

______

* تكتب المساحة بالأرقام العشرية وليست بالقراريط (أنظر الصفحة الأخيرة)

8. **Water Rotation:**

Summer; Days on ______ Days off ______

Winter; Days on ______ Days off ______

9. **Canal Water Availability:**

a. Summer season

(1) Usually available on schedule ____________

(2) Available as scheduled about 3 times out of 4 ____________

(3) Available as scheduled about one-half the time ____________

(4) Available as scheduled about one-fourth the time ____________

(5) Never available as scheduled ____________

(6) Is water available at night? ____________

Explain: ____________

____

(7) Will you or do you irrigate at night: ____________

Explain ____________

____

b. Winter season

(1) Usually available onshedule ____________

(2) Available as scheduled about 3 times out of 4 ____________

(3) Available as scheduled about one half the time ____________

(4) Available as scheduled about one-fourth the time ____________

(5) Never available as scheduled ____________

(6) Is water available at night? ____________

Explain ____________

____

(7) Will you or do you irrigate at night? ____________

Explain ____________

____

10. Changes in farming practices because of problems with water availability:

a. Leave land idle ______ if so, number of feddans _____, for how many months/year _______

b. Change crops grown from ____________ to _________________

c. Develop an alternative water source from ________________ (date) to ________________ (date)

11. If water was always available according to rotation, what crops would be grown?

Summer crops	No. of feddans	(expected) average yield
____________	________	________
____________	________	________
____________	________	________

Winter crops	No. of feddans	(expected) average yield
____________	________	________
____________	________	________
____________	________	________

12. Do you rent a pump? Yes ☐ No ☐

13. Do you own a pump? Yes ☐ No ☐

a. If yes on 12 or 13, source of power:

☐ Diesel

☐ Electric

☐ Other (specify) ____________

b. Pump characteristics:

Motor size ________________

Investment cost (if owned) ________________

Year purchased (if owned) ________________

Rental cost (if rented)

c. Number of months per year in which the pump is used ________________

14. Reasons for using pump:

a. Labor shortage ____________________

b. Problem of feed for livestock used to turn sakia ____________________

c. Can apply available canal water on a more timely basis ______________

d. Lower cost method of pumping water ______________________________

e. Used as an alternative to taking water from canal ___________________

f. Other (specify): ____

____

15. Do you have a well to supply part of the water used on your farm?

Yes ☐ No ☐

a. If yes, year installed ____________________

Investment cost ____________________

Depth ________________________

b. Number of months per year the well is used to supplement canal water ________________________________

c. Number of years in 10 the well will be needed to supplement canal water ____________________________

16. Reason for investing in well:

a. Better water ________________

b. Water is always available when needed ___________

c. Needed because of water shortages from canal during some months _______

d. Other (specify) ____

17. Do you obtain some water used on your farm from sources other than the canal or well? Please explain ____

____

____

18. **Is quality of water a problem at any of the sources available to you ?**

Farm Location Map

Conversion from Kerates to feddans

K.	F.	K.	F	K.	F
1	0.04	9	0.38	17	0.71
2	0.08	10	0.42	18	0.75
3	0.13	11	0.46	19	0.79
4	0.17	12	0.50	20	0.83
5	0.21	13	0.54	21	0.88
6	0.25	14	0.58	22	0.92
7	0.29	15	0.63	23	0.96
8	0.33	16	0.67	24	1.00

Table A-1. Availability of Canal Water to Farmers at the Lower End of Branch Canals During Summer Season and Practice of Night Irrigation

Farm Number	Canal Water is Available: Usually on Time	About 3/4 of the Time	About 1/2 of the Time	About 1/4 of the Time	Never on Time	Night Irrigation Yes	No
1					X	X	
2					X		
3				X			
4		X					
5				X		X	
6			X			X	
7				X		X	
8				X		X	
9				X		X	
10		X				X	
11			X			X	
12			X			X	
13			X				X
14	X					X	
15				X			X
16			X			X	
17	X					X	
18	X						X
19				X		X	
20				X		X	
Number	3	2	5	8	2	14	3

Table A-2. Availability of Canal Water to Farmers at the Upper End of Branch Canals During the Summer Season and Practice of Night Irrigation

Farm Number	Canal Water is Available: Usually on Time	About 3/4 of the Time	About 1/2 of the Time	About 1/4 of the Time	Never on Time	Night Irrigation Yes	No
1	X					X(sometimes)	
2	X					X	
3			X				X
4		X				X	
5		X				X	
6		X				X	
7		X				X	
8		X					X
9		X				X	
10			X			X	
11			X			X	
12		X				X	
13		X				X	
14		X					X
15		X					X
16		X				X	
17	X						X
18		X				X	
Number	3	12	3			13	5

Table A-3. Availability of Canal Water to Farmers at the Lower End of Branch Canals During the Winter Season

Farmer Number	Canal Water is Available: Usually on Time	About 3/4 of the Time	About 1/2 of the Time	About 1/4 of the Time	Never on Time
1					X
2				X	
3	X				
4	X				
5		X			
6	X				
7		X			
8	X				
9			X		
10		X			
11		X			
12		X			
13		X			
14	X				
15	X				
16	X				
17	X				
18	X				
19	X				
20	X				
Number	11	6	1	1	1

Table A-4. Availability of Canal Water at the Upper End of Branch Canals During the Winter Season

Farmer Number	Canal Water is Available: Usually on Time	About 3/4 of the Time	About 1/2 of the Time	About 1/4 of the Time	Never on Time
1	X				
2	X				
3	X				
4	X				
5	X				
6	X				
7	X				
8	X				
9	X				
10	X				
11	X				
12	X				
13	X				
14	X				
15	X				
16	X				
17	X				
18	X				
Number	18				

Table A-5. Access to Irrigation Pumps by Farmers at the Lower End of Branch Canals

Farm Number	Rent a Pump	Own a Pump	Months Pump Used
1		X	12
2		X	10
3	X	X	3
4			
5		X	12
6		X	12
7	X		3
8	X		3-5
9	X		<1
10			
11	X		<1
12	X		<1
13			
14			
15		X	7-8
16			
17			
18			
19	X		<1
20	X		<1
Number	8	6	---

Table A-6. Access to Irrigation Pumps by Farmers at the Upper End of Branch Canals

Farm Number	Rent a Pump	Own a Pump	Months Pump Used
1			
2			
3			
4			
5			
6	Yes		1
7			
8			
9			
10			
11			
12			
13	Yes		<1
14			
15			
16			
17			
18			

Table A-7. Cropping Patterns of Farmers at Lower End of Branch Canals During Summer Season

Farmer Number	Total Land	Maize (grain)	Maize (forage)	Vegetables	Other
	---- no. of feddan ----				
1	17	8	3	6	
2	3	1		2	
3	2.5	1.25	.6	.6	
4	4.25	3.5	.75	1.5	
5	6	2			2.5
6	4.5	2	1	1.5	
7	3.5	1	1	1.5	
8	1.33	1	.33		
9	1	1			
10	1	1			
11	1.5	1		.5	
12	4.5		1.5	1.75	1.75
13	.4	.4			
14	1.4	.8	.6		
15	11.5	4		5	2.5
16	.63	.63			
17	1	1			
18	1.38			.63	.75
19	5	4	.67	.33	
20	2.5	.83		1.67	
Total	73.89	34.41	9.45	22.98	7.50
Average	3.69	1.72	.47	1.15	.38
Percent	----	47	13	31	10

Table A-8. Cropping Patterns of Farmers at Upper End of Branch Canals During Summer Season

Farmer Number	Total Land	Maize (grain)	Maize (forage)	Vegetables	Other Crops
	---- no. of feddan ----				
1	1.5	1.25		.38	
2	1.5	1.5			
3	.3			.3	
4	1.5	.5	.5	.5	.5
5	1.25	1.0		.5	
6	.67				.67
7	.83			.83	
8	.17			.17	
9	2	1.0	.25	.5	.5
10	2	.75		1.25	
11	2	2			
12	2.75	1		1.0	1.25
13	.63	.29		.34	
14	3	1.5		2.08	
15	.33			.33	
16	3	1.5			1.5
17	.5	.25		.75	
18	.92			1.5	.42
Total	24.85	12.54	.75	10.43	4.84
Average	1.38	.70	.04	.58	.27
Percent	-----	50	3	42	19

Table A-9. Cropping Patterns of Farmers at Lower End of Branch Canals During Winter Season

Farmer Number	Total Land	Berseem	Wheat	Tomatoes	Hot Peppers	Other
	----- no. of feddan -----					
1	17	5	10	8	2	
2	3	1	1			1
3	2.5	1.25	1.25			
4	4.25	3.5	.75			
5	6	1	.5	.5	2	2
6	4.5	1	2		1.5	
7	3.5	1	1	1	1	.5
8	1.33	.33		.5	.5	
9	1	.5	.5			
10	1	1				
11	2	1				1
12	4.5	3	1.5			
13	.4	.4				
14	1.4	.6			.8	
15	11.5	2.5		.5	2	
16	.63	.63				
17	1	1				
18	1.38	.58			.79	
19	5	2				3
20	2.5	.83			.20	1.33
Total	74.39	28.12	18.5	10.5	10.79	8.83
Average	3.72	1.41	.93	.52	.54	.44
Percent	-----	38	25	14	15	12

Table A-10. Cropping Patterns of Farmers at the Upper End of Branch Canals During the Winter Season

Farmer Number	Total Land	Berseem	Wheat	Tomatoes	Hot Peppers	Other
	----- no. of feddan -----					
1	1.5	1.25				.25
2	1.5	1.5				
3	.3	.3				
4	1.5	1.25			.25	
5	1.25	1.25				
6	.67	.67				
7	.83	.83				
8	.17	.17				
9	2	1.5		1.0		
10	2	1.5				.5
11	2	1				1
12	2.75	1.58	.33			.92
13	.63	.17				1.38
14	3	1.5		.5		1.0
15	.33					.33
16	3	1.5	1.5			
17	.5	.5				
18	.92	.92				
Total	24.85	17.39	1.83	1.5	.25	5.38
Average	1.38	.97	.1	.08	.01	.30
Percent	----	70	7	6	1	22

Table A-11. Cropping Intensity on Farms at Lower End of Branch Canals

Farmer Number	Total Land	Total Summer Crops	Total Winter Crops	Crop Intensity Summer	Crop Intensity Winter	Total Crop Intensity
	--- no. of feddan ---			--- ratio ---		
1	17	17	25	1	1.47	2.47
2	3	3	3	1	1	2
3	2.5	2.5	2.5	1	1	2
4	4.25	4.25	4.25	1	1	2
5	6	6	6	1	1	2
6	4.5	4.5	4.5	1	1	2
7	3.5	3.5	4.5	1	1.29	2.28
8	1.33	1.33	1.33	1	1	2
9	1	1	1	1	1	2
10	1	1	1	1	1	2
11[a]	1.5	1.5	2	1	1	2
12	4.5	5	4.5	1.11	1	2.11
13	.4	.4	.4	1	1	2
14	1.4	1.4	1.4	1	1	2
15	11.5	11.5	11.5	1	1	2
16	.63	.63	.63	1	1	2
17	1	1	1	1	1	2
18	1.38	1.38	1.38	1	1	2
19	5	5	5	1	1	1.23
20	2.5	2.5	2.36	1	.94	1.94
Total	73.89	74.39	83.25	1.01	1.13	2.13

[a]Farmer farms .5 feddan more in winter than in summer

Table A-12. Cropping Intensity on Farms at the Upper End of Branch Canals

Farmer Number	Total Land	Total Summer Crops	Total Winter Crops	Crop Intensity Summer	Crop Intensity Winter	Total Crop Intensity
	--- no. of feddan ---			--- ratio ---		
1	1.5	1.63	1.5	1.09	1	2.09
2	1.5	1.5	1.5	1	1	2
3	.3	.3	.3	1	1	2
4	1.5	2.0	1.5	1.33	1	2.33
5	1.25	1.5	1.25	1.2	1	2.2
6	.67	.67	.67	1	1	2
7	.83	.83	.83	1	1	2
8	.17	.17	.17	1	1	2
9	2	2.25	2.5	1.13	1.25	2.4
10	2	2	2	1	1	2
11	2	2	2	1	1	2
12	2.75	3.25	2.83	1.18	1.03	2.2
13	.63	.63	1.55	1	2.46	3.5
14	3	3.33	3	1.11	1	2.11
15	.33	.33	.33	1	1	2
16	3	3	3	1	1	2
17	.5	1.0	.5	2	1	3
18	.92	1.92	.92	2.08	1	3.09
Total	24.85	28.31	26.35	1.14	1.06	2.20

Table A-13. Expected Changes in Summer and Winter Crops if Canal Water Delivery was Improved

Farmer Number	Summer Crops Would Grow More				Winter Crops Would Grow More			
	Same Crops	Maize	Vegetable	Other	Same Crops	Wheat	Vegetable	Other
1	X				X			
2			X					
3			X				X	
4			X		X			
5				X	X			X
6			X		X			
7		X		X	X			X
8			X		X			
9			X		X			
10			X					
11	X							
12		X	X					
13			X					
14	X				X			
15	X				X			
16			X				X	
17			X			X		
18	X				X			
19			X		X			
20	X				X			
Total	6	2	12	2	12	1	2	2

APPENDIX B-1

The Cost of Lifting Water with a Stationary Horizontal Diesel Pump

Farmer Number 5

Basic information and assumptions:

1. The pump is Ruston - made in England.
2. Size 6/6" pump (9/10) horse power motor.
3. Average time to irrigate one feddan - 3 hours each irrigation.
4. Number of irrigations per year - 24 times.
5. Average lift is 1.5 meters from a major drain.
6. Area served is 11 feddans
7. Initial investment:

a. pump and motor (including installation)	LE 1,200
b. building and two intake types	LE 330
	LE 1,530

8. Expected useful life of investment - 20 years.
9. Interest rate is 10 percent.
10. Operating Expenses:
    Diesel fuel, 2.5 liters per hour @ LE 0.025 per liter.
    Oil, 0.37 Kg. per hour @ LE 0.450 per kg. (1
    Grease, annual cost LE 8.0
    Gaskats for pump, annual cost LE 5.0.
    Labor to operate the pump LE 0.05 per hour (this is the value of the farmer's time while operating the pump).
    Maintenance and repairs LE 50.0 per year.

Annual fixed costs:

Depreciation LE 1,530÷20 years	LE 76.5
Interest on investment $\frac{1,530}{2}$ x .10	LE 76.5
Total for 11 feddans	LE 153.0
Average per feddan LE 153÷11	LE 13.91

Variable cost per feddan:

Diesel fuel, 2.5 liters X 24 irrigations x 3 hours x LE 0.025	LE 4.50
Oil, 0.375 kg. X 24 irrigations x 3 hours x LE 0.45	LE 12.15
Grease, LE 8÷11	LE 0.73
Fibers, LE 5÷11	LE 0.45
Labor, 24 irrigations x 3 hours x LE 0.05	LE 3.60
Maintenance and repairs LE 50.0÷11	LE 4.54
Total variable cost per feddan	LE 25.97
Total annual fixed and variable cost per feddan	LE 39.88

(1 The oil consumption is high because this is a low speed pump oiled by a drop system.

This total cost is somewhat higher than the ordinary estimated water lifting cost (LE 25 - 30), because the farmer was obliged to construct this pump to serve only 11 feddans. But, in fact the farmer rents his pump to lift the drainage water to his neighbors to irrigate about 6 more feddans.

<u>Added return</u>:	6 feddans x 10 irrigations x 3 hours X LE 0.70 per hour	LE 126.00
<u>Added cost</u>:	Diesel fuel, 2.5 liters x 10 irrigations x 3 hours x LE 0.025	LE 1.875
	Oil, 0.375 kg x 10 irrigations x 3 hours x LE 0.45	LE 5.062
	Labor for operating	LE 1.500
	Maintenance and repairs	LE 1.891
	Grease and Gaskets	LE 0.491
	Total Added cost	LE 10.819

The net return is LE 126 - 10.819 = LE 115.181
The average return per feddan for his owned land is:

$$\frac{115}{11} = 10.45 \text{ per feddan}$$

Then the total annual fixed and variable cost per feddan becomes less (LE 39.88 - 10.45 = 29.43) which is approximately the usual cost of water lifting by a diesel pump.

APPENDIX B-2

Farmer Number 15

Basic information and assumptions:

1. The pump is a diesel Shobra - made at Helwan factory.

2. Size 6/6" pump - 11 horse power engine.

3. Average time to irrigate one feddan is 3 hours.

4. Number of irrigations per year is about 24.

5. Average area served by the pump is only 5 feddans.

6. Average lift is 2.5 meter from a well.

7. Initial investment:

Pump and motor	LE 980
Drilling the well 37 m. x LE 6.0	222
Type is 37 m. x LE 8.5	315
Casing is 18 m. x LE 10	180
Intake type 2 m. x LE 8.5	17
Discharge type is 1 m. x LE 11	11
Construction cost LE 45 (installation)	45
Small pump for bringing water at the beginning, LE 11	11
Building an installation is LE 400	400
It occupies 16 m^2, LE 19 (LE 5000/Fed)	19
The total fixed cost	2200

8. Except useful life of investment is about 20 years.

9. Interest rate is about 10 percent.

10. Operating expenses:

Diesel fuel, 1.7 liters per hour @ LE 0.025/liter
Oil, .05 kg. per hour @ LE 0.350 per kg.
Grease annual cost LE 2.0
The farmer operates the pump by himself
Maintenance and repairs, LE 20 per year

Annual fixed costs:

Depreciation LE 2200 ÷ 20 years	LE 110
Interest on investment $\frac{2200}{2}$ x .10	110
Total annual fixed cost for 5 feddans	220
Average fixed cost per feddan LE 220 ÷ 5	44

<u>Variable cost per feddan</u>:

Diesel fuel 1.7 liters x 24 irrigation x 3 hour x LE 0.025	LE 3.06
Oil .05 kg x 24 irrigations x 3 hours x LE 35	1.26
Grease LE 2 ÷ 5 feddans	.40
Maintenance and repairs LE 20 ÷ 5	4.00
Total variable cost per feddan	8.72
Total annual fixed and variable cost per feddan	LE 52.72

The dual figure shows us that the cost of pumping is about twice the ordinary cost. This means that the farmer will lose LE 23 - LE 29 per year when he obtains water from a well and pump.

PROBLEM IDENTIFICATION REPORT

FOR KAFR EL SHEIKH STUDY AREA

July, 1980

EWUP Technical Report No. 6

Prepared under support of
United States Agency for International Development
Contract AID/NE-C-1351
All reported opinions, conclusions or
recommendations are those of the
author and not those of the funding
agency of the United States Government.

By

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July 1980

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PREFACE

This report was prepared by the staff of the Egyptian Water Use and Management Project. The project is funded by the U. S. Agency for International Development, under a grant agreement between the United States of America and the Arab Republic of Egypt. Dr. D. S. Brown is the Mission Director USAID and Mr. Niel Dimick is Project Manager USAID.

The project is in the Water Management and Irrigation Technologies Research Institute, Dr. H. Wahby, Director, Ministry of Irrigation but the Ministry of Agriculture has a collaborative role with the Soil and Water Research Institute, Dr. A. Serry, Director and the Agricultural Economics Institute, Dr. G. Hindy, Undersecretary, providing personnel and services.

The Consortium for International Development with executive offices in Tuscon, Arizona is the contractor with Colorado State University as the lead university for the project. American personnel on the project are from Colorado State University, Oregon State University and Montana State University.

CONVERSION FACTORS[1/]

Area		Sq. meter		Acre		Feddan		Hectare
1 feddan (fed)	=	4,200.8335	=	1.03805	=	1	=	0.42008
1 acre	=	4,046,856	=	1	=	0.96335	=	0.40469
1 hectare (ha)	=	10,000	=	2.47105	=	2.38048	=	1
1 sq kilometer	=	100×10^4	=	247.105	=	238.048	=	100
1 sq mile	=	259×10^6	=	640	=	616.4	=	259

Water Use:

1 billion m^3 = 810,710 acre-feet
1,000 m^3 = 0.81071 acre-foot = 9.72852 acre-inch
1,000 m^3/feddan = 0.781 acre-foot/acre = 9.372 acre-inch/acre
= 238 mm of rainfall

Commodity Measurements

	Egyptian Unit	Weight in kg	Weight in lbs
Cotton (unginned)	Metric kantar	157.5	346.92
Cotton (lint or ginned)	Metric kantar	50.0	110.13
Sugar, onion, flax straw	Kantar	45.0	99.12
Rice (rough or unmilled)	Dariba	945.0	2081.50
Lentils	Ardeb	160.0	352.42
Clover	Ardeb	157.0	345.81
Broadbeans, fenugreek	Ardeb	155.0	341.41
Wheat, chickpeas, lupine	Ardeb	150.0	330.40
Maize, Sorghum	Ardeb	140.0	308.37
Linseed	Ardeb	122.0	268.72
Barley, cottonseed, sesame	Ardeb	120.0	264.32
Groundnuts (in shells)	Ardeb	75.0	165.20

Other

1 ardeb = 198 liters = 5.62 bushels (U.S.)
1 ardeb/feddan = 5.41 bushels/acre
1 kg/feddan = 2.12 lb/acre

[1/] From Contemporary Egyptian Agriculture, by H. A. Tobgy.

ABSTRACT

PROBLEM IDENTIFICATION REPORT FOR

KAFR EL SHEIKH STUDY AREA

INTRODUCTION

The Egypt Water Use and Management Project (EWUP) was designed to assist in improving existing management practices of irrigated agriculture in Egypt. Although water use and management is emphasized in the project title, it was realized in the formulization of the project that management of all resources used in modern irrigated agriculture systems must be considered and accomplished for a permanent agriculture in Egypt. The project is structured to function in an interdisciplinary mode to formulate and demonstrate viable on-farm management alternatives for the typical Egyptian farmer. Thus, the Egypt Water Use and Management Project constitutes a new strategy for irrigation development both in approach to project objectives and in staffing. The EWUP team includes agronomists, engineers, economists and sociologists from the United States and Egypt. The team works with the Egyptian farmer at the field level to find out what is being done and what viable alternatives exist for improving our farm management practices.

The basic project procedure is to: first, identify problems quantitatively, second, search for appropriate solutions and finally demonstrate by use of large pilot areas the viable solutions that may be diffused throughout the country on a large scale. These procedures are carried out in three areas in Egypt that represent a range of Egyptian agriculture. These areas are located in Upper Egypt (El Minya), Upper Delta (El Mansouria, near Cairo) and the lower delta (Kafr El Sheikh). A problem identification report has already been prepared for the El Mansouria area near Cairo.

The reader is referred to the Mansouria report for additional details on the objectives and structure of the Project.

.../...

The purpose of this report is to present the problems identified in the lower delta in the Kafr El Sheikh Governorate. The objective of problem identification is to identify and characterize major physical, hydrological, chemical, biological, economic and organizational factors that constitute significant potentials for increasing crop production and keep agriculture viable in Egypt.

This report will summarize the most significant factors and will give the reader a broad overview of the characteristics of the area and its problems. The basic soil and land classification survey for the area selected to represent Kafr El Sheikh will appear as a separate report.

GENERAL DESCRIPTION OF KAFR EL SHEIKH AREA

The Kafr El Sheikh Governorate, consisting of 815,335 feddan, lies in the lower Nile Delta nearly midway between the two branches of the Nile, Rossitta and Damietta. The agricultural conditions and situations found in Kafr El Sheikh are similar to those found in the other lower Nile governorates, Behera, Sharkia and Dakahlia. Most of this area is composed of newly reclaimed land still under partial reclamation. Irrigated rice has been the main summer crop in these areas for the past 80 years.

Historical Background

In 1883, the Behera company* started to reclaim the southern portion of Kafr El Sheikh district. The land was leveled, a system of canals and drains were constructed, and small basins were filled with water at frequent intervals for reclamation. The intervals depended upon evaporation and rainfall.

.../...

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* This was an English stock company nationalized after the 1952 revolution.

The first reclamation period was completed without cultivation. When the soils were leached to a level that could be tolerated by a submerged crop, Echinochloa cursgalic was planted during the summers of subsequent years.

Later, when the soils had been further improved, a high-tolerance rice seed variety was broadcast directly onto the granulated soil. Continuous flooding during the summer had the effect of producing high rice yields as well as continuing the salt leaching of saline soils. A subsequent period allowed Egyptian clover to be planted during the winter months of low water supply. Finally in 1906, farmers imigrated from the southern governorates to Kafr El Sheikh to purchase the newly reclaimed land from the Behera company for a low price.

Further reclamation was attempted from 1954 to 1967 by the Ministry of Reclamation. However, after the construction of the High Aswan Dam, the schedule established by the Behera Company and followed by the Ministry of Reclamation was abandoned. The demand for irrigation water during the summer increased with the increase in cultivated land and which resulted in the low availability of water for reclamation. Since the construction of the High Aswan Dam, both rice production and reclamation of new land have been hindered by water problems.

Irrigation practices have changed because of the requirements for lifting water using the new perennial irrigation system. Whenever the supply of water is greater than the irrigation requirements, over-irrigation results. This results in an overall system inefficiency which reduces the amount of water for rice production and/or reclamation.

Soils of the Kafr El Sheikh District

General

The Kafr El Sheikh governorate consists of seven districts, one of which is called Kafr El Sheikh. A complete soil survey was carried out for the district by the Soil Survey Department, Ministry of Agriculture in 1957 and 1958. Table 1 shows the distribution of cultivated (class A soils) and uncultivated (class B soils) in the district. The classes are subdivided into soils of decreasing productivity because of saline and/or sodic conditions.

In table 2, the increase in the sub classes of cultivated and uncultivated soils is shown since 1958.

Several efforts have been made since 1960 to improve the soils of the Kafr El Sheikh district as well as those of the same type in other North Delta regions. The progress in this regard can be observed from the data presented in Table 2. None of the soils have been changed to class I. Individual farmer effort cannot produce class I soils because of the sub soil sodicity.

Continuous irrigation during a multi-cropping rotation, including paddy rice, leached an appreciable amount of salt from sodic-saline soils, (class III and IV); this is the source of the increase in class II. The percentage of increase by 1978 in the area of class II soils was 151% compared with 1958. However, only slight success was achieved in reclaiming the uncultivated areas during the past 20 years. The increase in cultivated areas in 1978 is only 5% over the cultivated area of 1958.

The Soils of the Southern Portion of Kafr El Sheikh District

This portion of the district consists of the areas which were cultivated at the time of the Gieth et al (1959) survey and includes Marin alluvial soils classes II and III and IV, respectively. They are formed by the continuous deposition of the suspended matter carried by the River Nile during the flooding season (Ball, 1952). These materials represent the disintegration and weathering porducts of the metamorphic ingenous rocks in Southern Sudan and basalts of the Ethiopian plateau. They are compacted to 150 cm depth below the surface. Only the surface soil is granulated, due to soil tillage. The profiles show no hard pans or rocks to hinder root penetration, Gieth et al (1959). The grain size distribution of Kafr El Sheikh soil sediments was

.../...

Table (1): Soil classification of Kafr El Sheikh District according to land productivity Gieth et al (1959)

Area of Cultivated Soils (Fed)					Area of Cultivated Soils (Fed)		
	Sub Classes				Sub Classes		Total
I	II	III	IV	Total of classes I-IV	V	VI	
0	31.503	70,738	8,267	110,508	48,729	9,628	168,865
0	19	42	5	65	29	6	100

Table (2): Percent increase or decrease in areas of different soil categories of Kafr El Sheikh district from 1958 to 1978.

Soil Category	Year 1958	1978	% decrease or increase in areas
A. Cultivated Areas in Fed.			
Class I	---	---	---
Class II	31,503	79,176	+ 151
Class III	70,738	32,525	- 54
Class IV	8,267	4,369	- 47
Total	110,508	116,070	- 5
B. Uncultivated Areas in Fed.			
Class V	48,729	31,986	- 34
Class VI	9,628	25,756	+ 158
	58,357	57,745	- 1
Total surface area of the district in feddans	168,865	137,812	

.../...

investigated by Khalil et al (1976). They found that this soils is generally compacted, and its structure is blocky. The clay content of soils is slightly greater towards the north than in the southern part of the district. They also stated that the general increase of clay with depth may be related to the migration of the finest clay particles from the upper to the lower horizons.

During the time of the survey of Gieth et al (1959), the groundwater table was not observed within the top 150 cm. of the soil profile, except in some areas which were at lower elevations or were adjacent to canals or drains. The groundwater tables in these areas were measured 80-150 cm. below the soil surface.

Most of the soils in the southern portion of the district were considered, according to the 1959 survey, to be slowly permeable to irrigation water, and to have a high capacity for water retention. The maximum water holding capacity ranged between 55 and 70%. The cation exchange capacity ranged between 30 and 40 meq/100 g soil.

Chemical analysis of most of these soils revealed that they were moderately saline, Gieth et al (1959). The electrical conductivity of the saturation extract of most of the samples ranged between 4 and 8 mmhos/cm. Sodium was found to be the dominant cation. The sodium absorption ration (SAR) of most of these soils ranged between 10 and 15%. Some sodic soils showed higher SAR values. In general, it can be stated that a considerable area of the northern Nile Delta suffers from salinity or alkalinity or both as a result of saline groundwater near the soil surface, (Kovda 1958).

General Irrigation Distribution System in the Kafr El Sheikh District

Figure 1 shows the geographical location of Kafr El Sheikh and the main travel path for water delivered to the Kafr El Sheikh area. As shown in Figure 1a, water reaches Kafr El Sheikh by a series of main distributory canals. Water is diverted at the Zefta Barrage of the Damietta Branch of the Nile into the El Abasy Branch where a subsequent take-out discharges into the Bahr Shebin Canal. A portion of this flow is discharged into the

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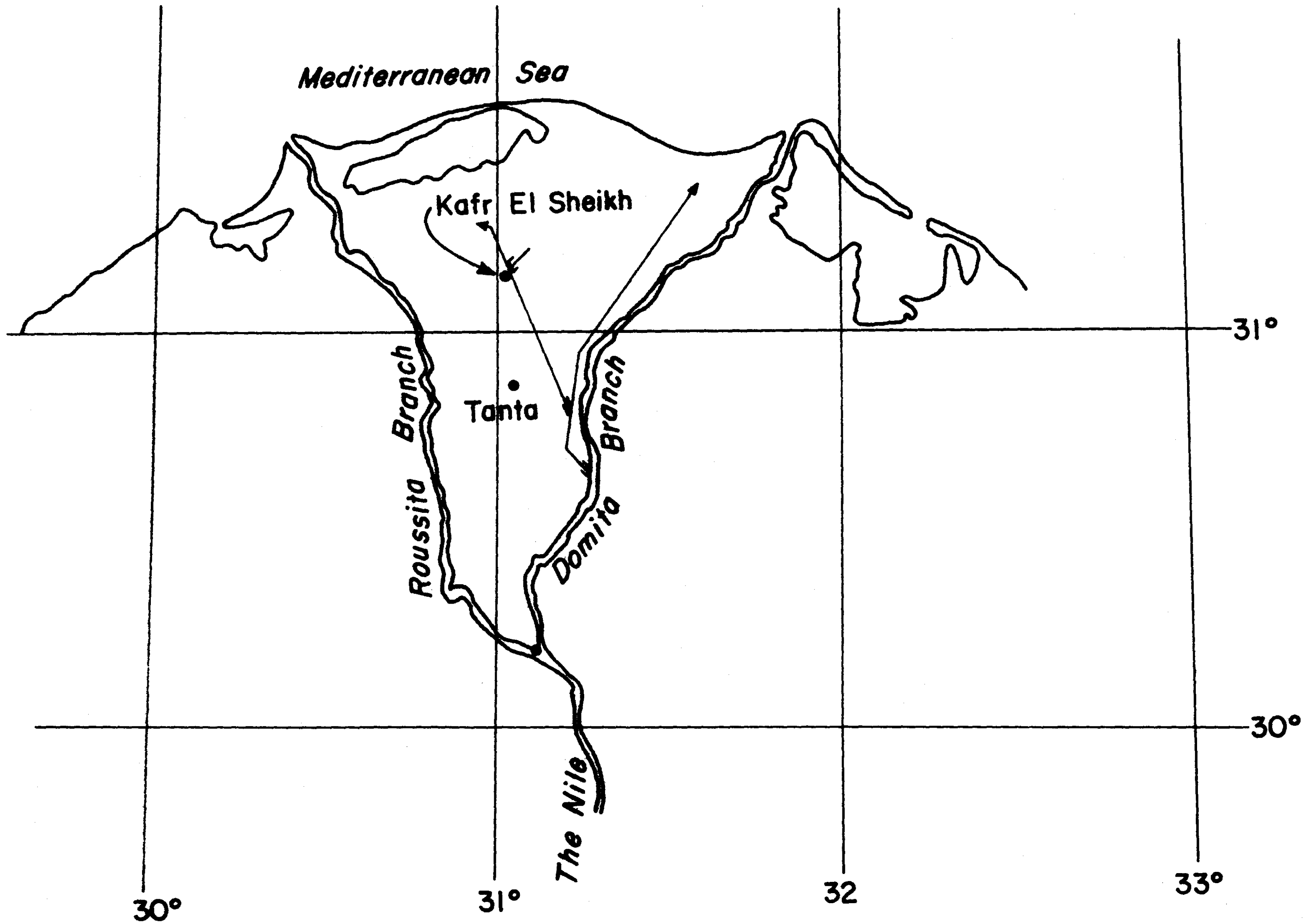

Figure 1. Geographic Location of Main Distributary Canals for Delivery of Water to Kafr El Sheikh

Layout Shows Main Carriers Take From Damietta Br. to Dacalt Canal

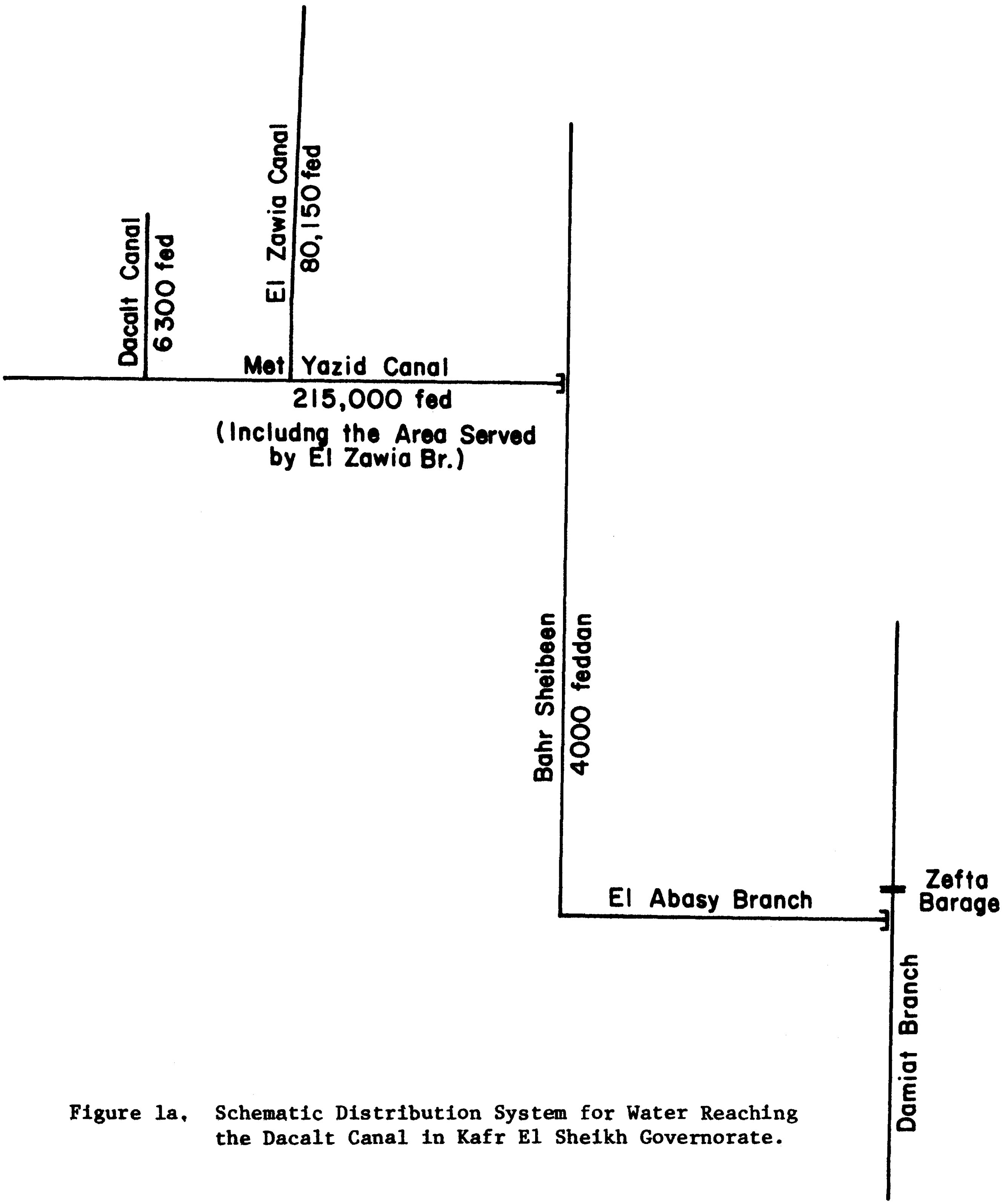

Figure 1a, Schematic Distribution System for Water Reaching the Dacalt Canal in Kafr El Sheikh Governorate.

Meet Yazid Canal. This canal in turn serves the Dacalt canal that is one of the major distributors for the Kafr El Sheikh area. The discharge from the Meet Yazid Canal into the Dacalt Canal averages 7.0 cubic meters per sec. There are two regulators on the canal for controlling and rotating the water in the canal. The basic rotation is 4 days on and 4 days off during the summer months and 7 days on and 7 days off during the winter months.

DESCRIPTION OF PROJECT AREA, ABU-RAYA

Physiographic Features

Location

The hydrographic irrigation unit chosen for the project work was the downstream end of the Dacalt Canal below the Helal regulator. This reach of the canal serves approximately 3200 feddans. This major hydrologic unit is bounded on the east by drain number 7 and on the west by the El Raghama Drain. The north boundary is the Hamoul Reyadh Road and the south boundary is small branch drain near the Helal regulaor. The Dacalt Canal crosses the area from north to south dividing it into two equal parts.

Topography

The land surface is flat and very gently sloping towards the north, and the area in general lies at contour 2 m above sea level.

Geomorphology

The soils of Abu Raya area were formed from the Holocene alluvial deposits. These deposits consist essentially of dark greyish brown material formerly carried by the Nile in suspention due to the presence of micaceous-minerals and biotite. These deposits extend to a considerable thickness in depth as a consequence of the river having for thousands of years annually overflowed its banks and deposited its suspension load. The thickness of the deposits varies according to localities as well as to the irregular surface of the sand and gravels on which they were originally laid down and due to the fact that the river changed its path from time to time.

However, the mean thickness of the Nile suspended matter varies from about 6-7 meters in Aswan-Qena to about 11.2 meters in the northern Delta; the average thickness in the Delta being about 9.8 meters.

The composition of the Nile sediments throughout its entire thickness coincides substantially with that of the materials carried in suspension by the river at the present time. However, some differences and a certain degree of alteration must undoubtedly have taken place under the action of plant life and percolation water since the time of deposition, yet these differences in composition are relatively small. The principal differences being higher proportions of ferric oxide, alumina and carbonate of lime, and smaller proportions of magnesia and organic matter, in the deeper layers of the Nile sediments as compared with the suspended matter of the river today (Ball, 1952).

Soils

During the problem identification work, the Soil Survey Department of the Ministry of Agriculture completed a soils survey of the Abu Raya area.

The area was surveyed in detail using the cadastral maps of scale 1:2500 as a base map. The field data were later transferred from those maps to a 1:10,000 scale map to prepare the soil map of the area. Soil profiles (pits) were examined and sampled at an average density of 12 pits per square kilometers. The soils of the area were classified according to the U.S. Soil Taxonomy system. Due to its heavy texture and the montmorillonit nature of their clays, the major part of the area was classified as Virtisols and the remaining part as Entisols Torrifluvents. Results from this classification work will be published as a separate project paper. However the salinity and sodicity status of the soils which in effect relate to the water management problems are given below.

.../...

Soil samples from one hundred sites uniformily distributed over the area were tested for salinity and sodicity. The distribution of salts as well as the values of SAR varied greatly at the different depths of the profiles studied. Therefore, the values of electric conductivity of the saturation extract and those of SAR are presented individally for the root zone, (0-80 cm depth) and for the deeper soil layer (80-150 cm depth).

Soil Salinity

The electrical conductivity of the saturation extract of 100 samples are grouped into 3 categories in Table (3).

Of the 100 samples, only 8% had EC values that were sufficiently high to have a hazardous effect in the root zone of the system. In contrast, 34% of the 96 samples from the deeper zone were strongly saline. High migration of salts by capillary action to the root zone can be expected if irrigation water is applied to upland crops at infrequent intervals and insufficient amounts during the summer.

For soils exhibited as moderately saline, leaching requirements should be calculated in determining the optimum amounts of water to be applied to upland crops in addition to consumptive use. These soil samples represent 48 percent of 100 samples taken from the root zone.

The distribution of surface and subsurface soil salinity for Abu Raya is shown in figures 2 and 3.

Soil Sodicity

The sodium absorption ratios (SAR) of 100 soils samples taken from the root zone and from the deeper soil layer are summarized into three categories in table 4.

Table (3): Salinity status of Abu Raya soils

Salinity Scale	No. of soils	% in category	Average EC per category
A. Root Zone (0-80 cm):			
Non saline, 4 mmhos/cm	44	44	2.75
Moderately saline, 4-8 mmhos/cm	48	48	5.36
Strongly saline, 8 mmhos/cm	8	8	15.24
B. Sub-soil (80-150 cm):			
Non saline, 4 mmhos/cm	24	28	2.64
Moderately saline, 4-8 mmhos/cm	33	38	5.82
Strongly saline, 8 mmhos/cm	29	34	12.94

Table (4): Soil sodicity at Abu Raya

SAR	No. of soils	% in category	Average SAR per category
A. Root Zone (0-80 cm):			
Low, 10	58	58	6.70
Medium, 10-15	30	30	12.22
High, 15	12	12	18.33
B. Deep sub-soil (80-150 cm):			
Low, 10	20	23	7.47
Medium, 10-15	22	26	12.14
High, 15	44	51	20.84

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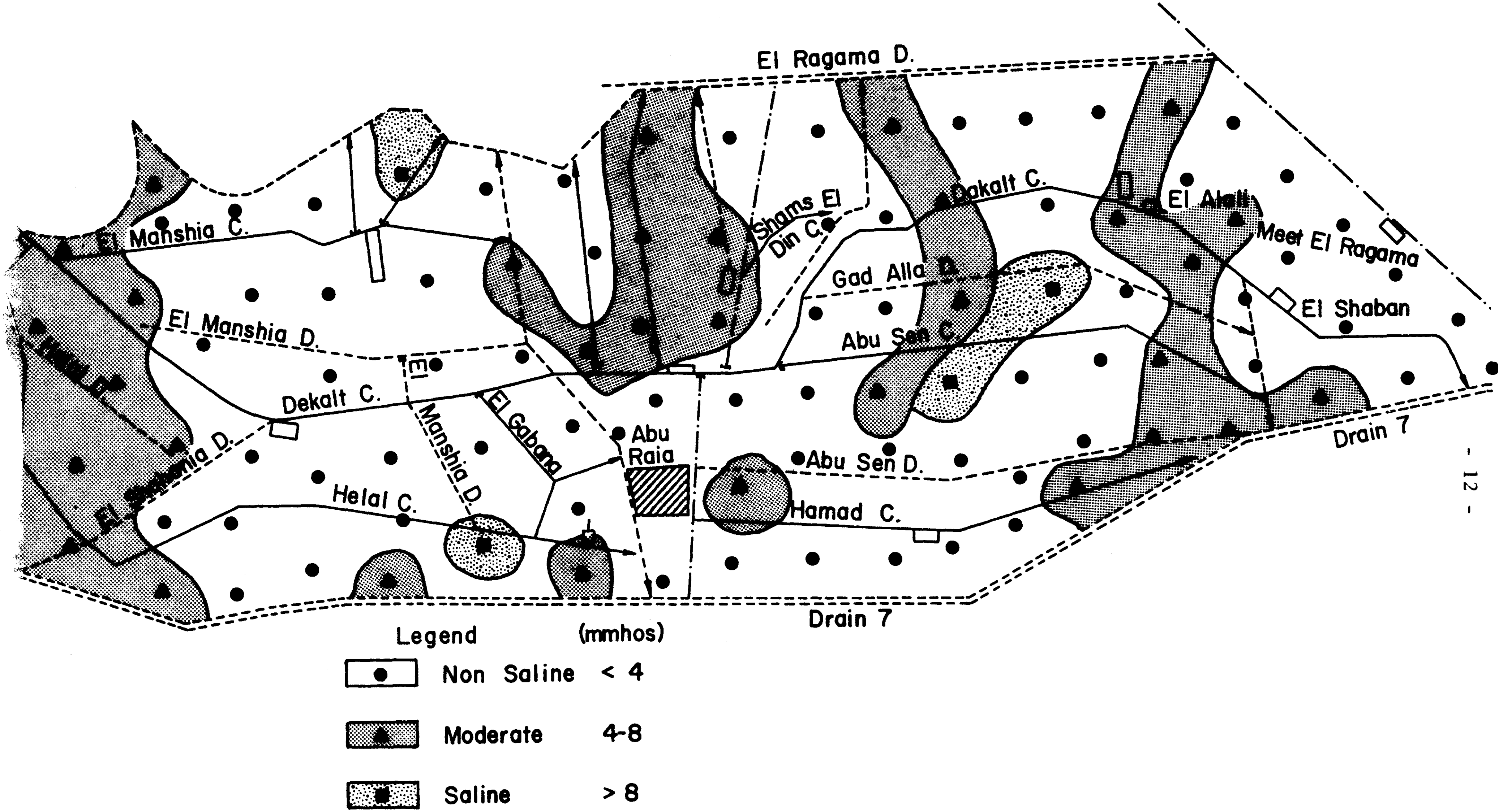

Figure 2. Distribution of Soil Salinity in the Surface Soils (0-25 cms) of the Abou Rayah Area

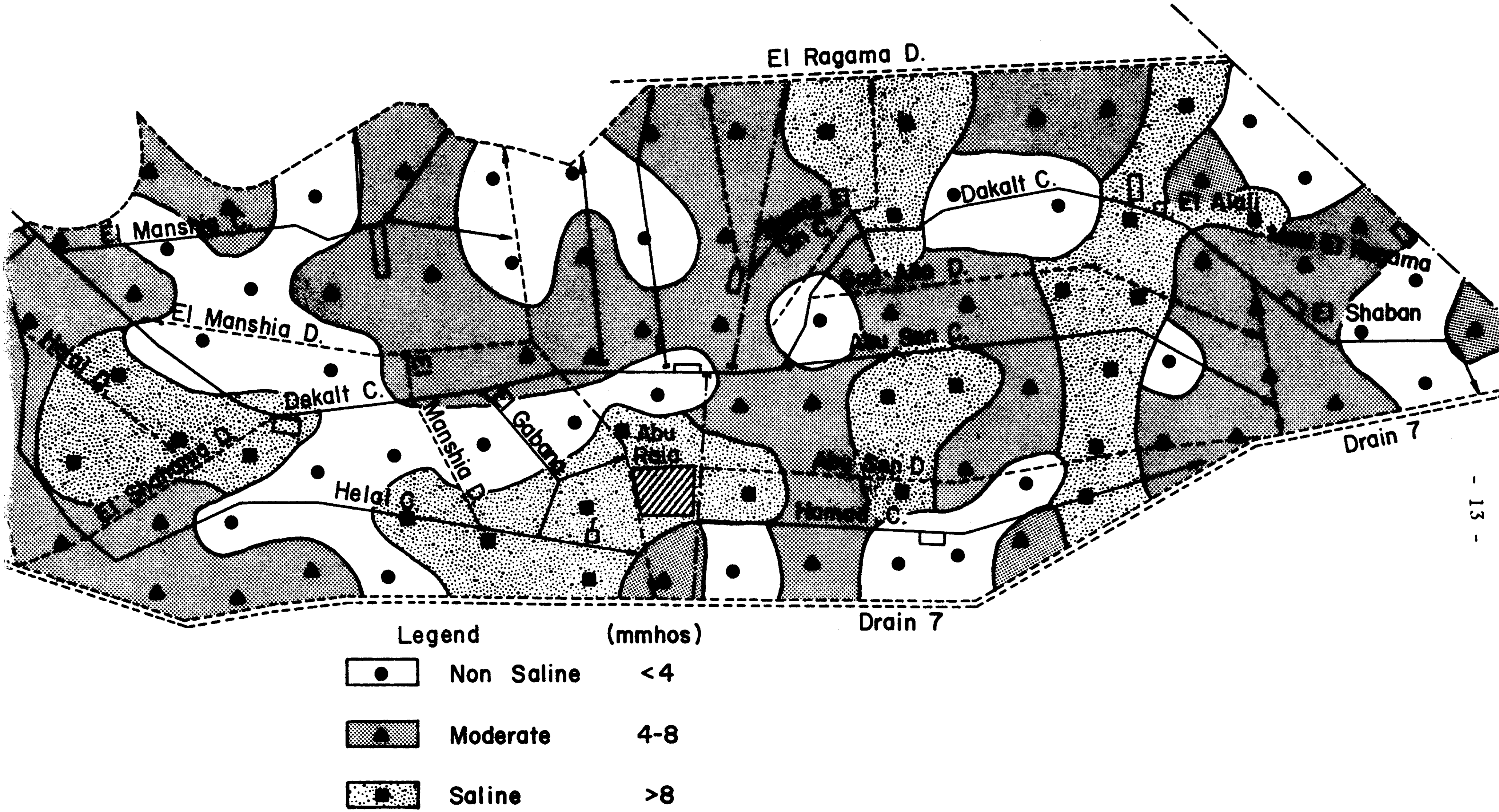

Figure 3. Distribution of Soil Salinity in the Subsurface Soils of the Abou Rayah Area

Potentially serious problems can be expected in 30 percent of the soils where SAR values from the root zone ranged from 10-15. Particularly, if present farm management practices continue. Sodic problems have already developed in the root zone in 12 percent of the area where SAR values are now above 15. While, severe sodic problems have already developed in 51 percent of the deeper soil of the cultivated area where SAR values are now above 20.

The distribution of values of SAR in the surface and subsurface soils of Abu Raya are shown in figures 4 and 5.

The exchangeable sodium percentage (ESP) of 26 soil samples taken from the root zone and from the deep soil layer are summarized in three categories in Table 5.

Unlike salinity, most of the soils show alkalinity. Of the 26 samples, 58% had ESP values that are moderately alkaline in the root zone and 38% were highly alkaline.

Abu Raya Village

The principal village for the downstream reach of the Dacalt canal is the village of Abu Raha which is located in the northern part of the southern portion of the Kafr El Sheikh district. It is a relatively small Egyptian village (approximately 3500 population) situated near the geographical mid point of the Delta region and lies nearly in the center of the eastern half of the hydrographic study area. Although on "old lands", the village became a viable community as recently as the early 1930s (typical of many villages in the central and northern Delta region). Government services based in the village include an agricultural coop service center, a human health unit, and a school. The village at this time does not have electrical service, a potable water system, resident village bank and vetinary medicine service, or reliable all-weather roads to area service centers. Commercial and repair

.../...

Table (5): Alkalinity status of Abu Raya soils

ESP	No. of soils	% in category	Average ESP per category
A. Root Zone (0-80 cm):			
Low, 10	1	4	9.25
Medium, 10-15	15	58	12.73
High 15	20	38	18.62
B. Deep sub-soil (80-150 cm):			
Low, 10	0	--	---
Medium, 10-15	1	5	13.2
High, 15	20	95	24.57

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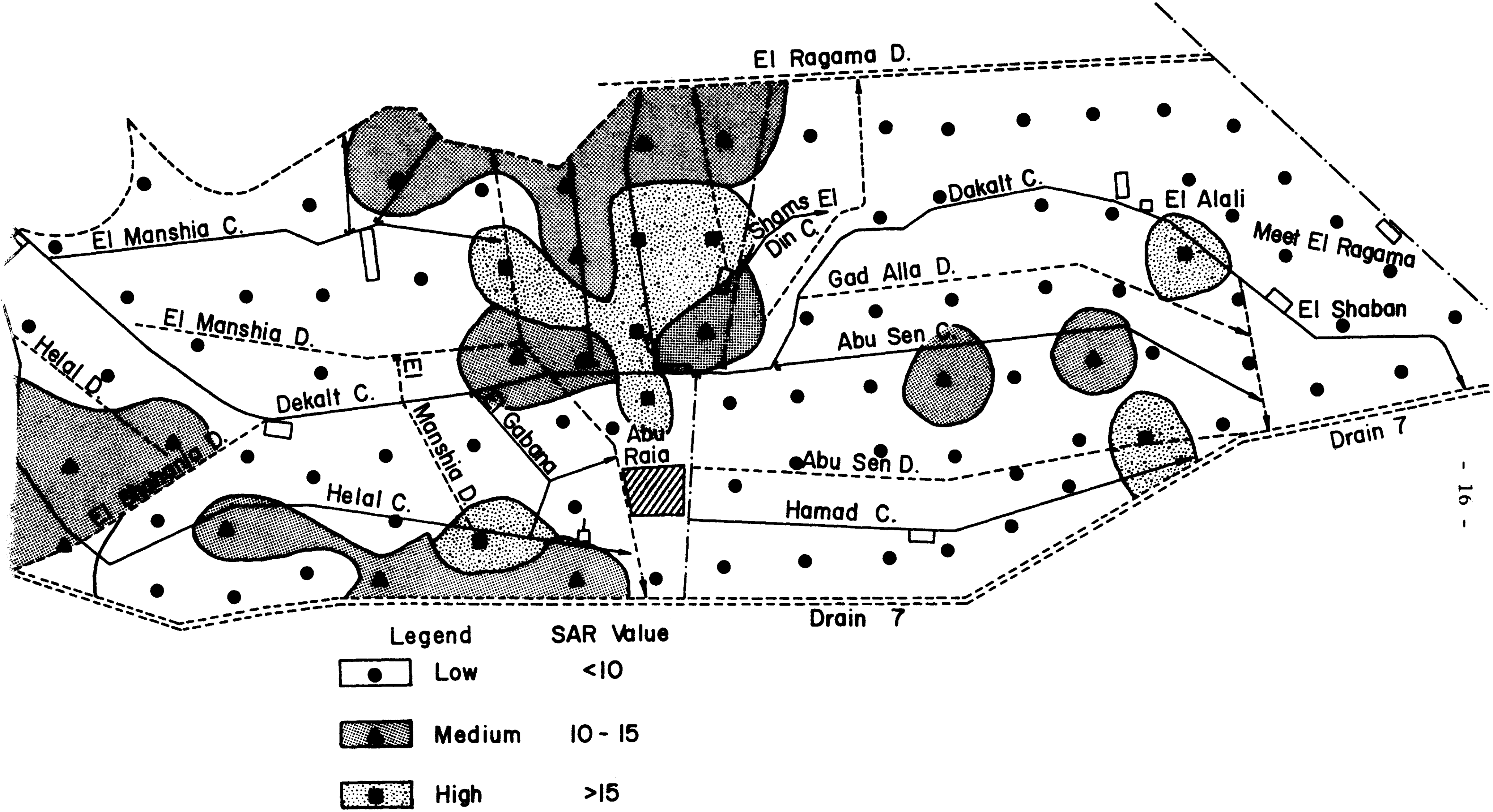

Figure 4. Distribution of Values of SAR in the Surface Soils (0-25 cms) of Abou Rayah

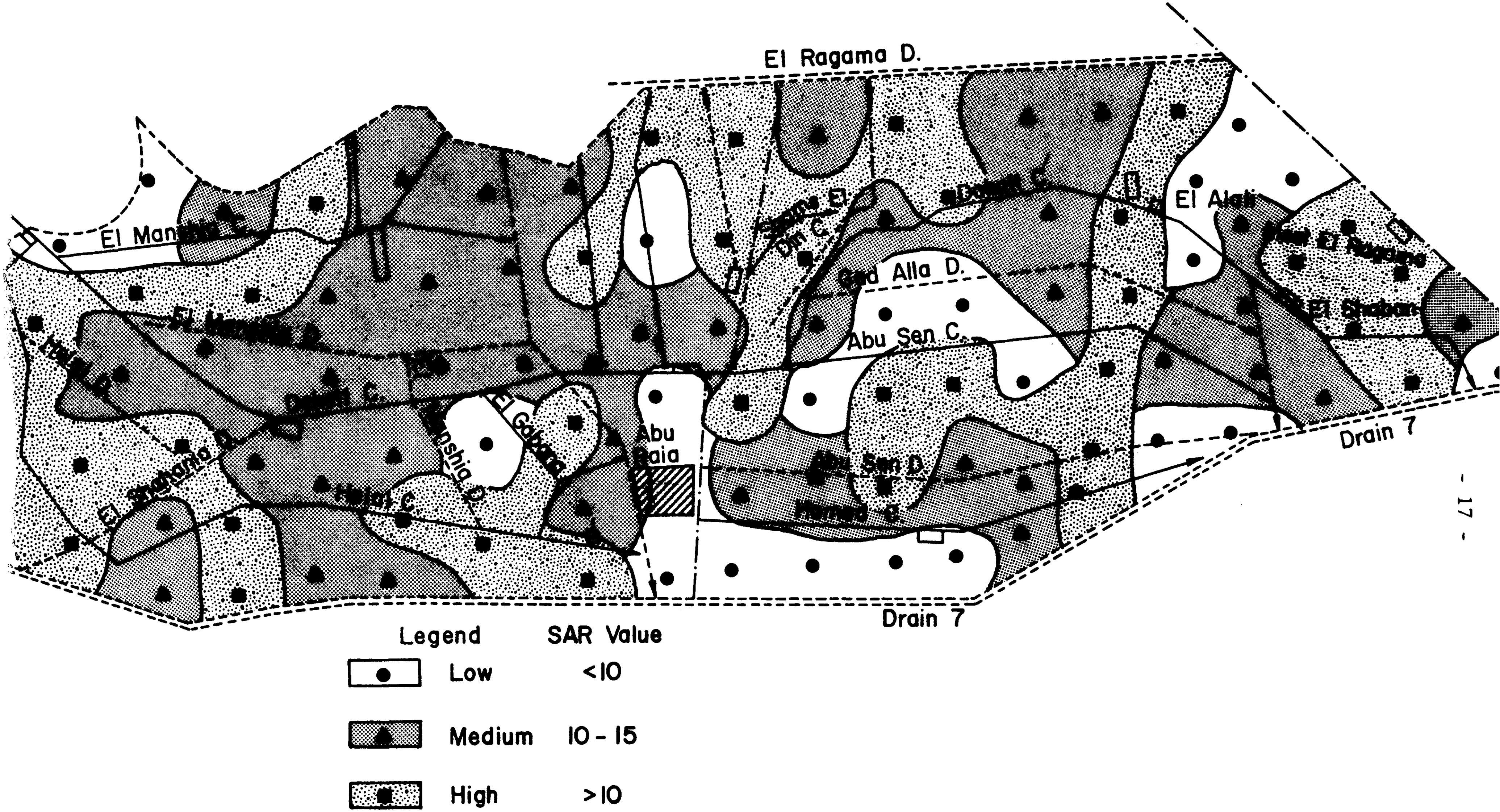

Figure 5. Distribution of Values of SAR in the Subsurface (>25 cms) of Abou Rayah

services are very limited in the village.

Abu Raya is overwhelmingly Moslem. It has an age-sex population distribution typical of those portions of rural Egypt not in close proximity to very large urban centers (eg. a very young population, close male/female ratio, etc.). The village is politically stable and lacks factional stress (although there is considerable rivalry between it and several politically appended sub-villages and neighboring villages). Indigeneous leadership in the village appears capable and strong. Local decision-making process operate smoothly, and seem characterized by pragmatic expediency, informal consensus and a broadly-based desire to avoid confrontation among community participants. In consequence, the general social atmosphere of the village is pleasant, peaceful and friendly.

The characteristics do not imply individual passivity, however, Abu Raya adults (as in common in more remote Egyptian villages) are markedly independent in attitude and action, reasonable self reliant, and evidence considerable initiative and dedication in their favorite persuits. Accordingly, they tend to be quite open and candid as individuals, and are not easily intimidated by outside authority or policy, which they often take issue with. Although, formal education levels tend to be quite low (illiteracy predominates among adults), practical insights and personal creativity appear quite high. Research data show an average level of receptivity to innovation and change considerably higher than we had expected. Generally, the Abu Raya population demonstrates good trust and respect for fellow-citizens and outsiders until they sense evidence that it is undeserved.

General Agriculture and Cropping Patterns

Farm holdings by Abu Raya farmers vary in size from less than one feddan to more than 20. These farms produce a variety of winter and summer crops. The major winter crops are wheat, flax, berseem, beans, and vegetables while the summer crops are cotton, rice, corn and vegetables.

.../...

The distribution of farm size for the Abu Raya cooperation is given in table 6. These data indicate that more than one half of the farmers have less than three feddans. As a matter of fact, forty seven percent are in the 1-3 feddan class and thirty percent are in the 3-5 feddan class. Only seventeen percent have more than 5 fed. Given the need for achieving economies of scale for modern agricultural technology, one is tempted to define one of the constraints to agriculture as the small farm. However, looking at the political realities of Egyptian agriculture and Egyptian society in general it is not likely that anything will be done to change this situation in the near future. It is perhaps realistic, therefore to accept small farm size as a "given" rather than defining it as a problem.

Data obtained from 12 farmers along two water courses in the Abu Raya area given in table 7 shows that the major winter crops are berseem and wheat. In fact, fifty eight percent of the area is in berseem while twenty three percent is in wheat during the winter assuming these farmers typically represent the area. For summer crops, on the other hand, rice represents forty seven percent of the area and cotton thirty six percent. According to governmental policy only 50% of the land should be in rice production on a given water course. One should not assume from the data shown in table 7 that farmers follow the governmental policy. This will be brought out later in the report as a problem in water management.

Water Distribution and Irrigation Methods

As typical throughout Egypt, water is distributed from the main canals into branch canals or meskas for distribution on the fields or farms. The Helal regulator serves as the control for water distribution downstream on the Dacalt canal to its end. This downstream reach of the canal serves 6 branch canals which supply water for on-farm irrigation. The Dacalt canal not only serves as a carrier but also has legal outlets for on-farm irrigation.

.../...

Table (6): Distribution of farm size Abu Raya Cooperative Kafr El Sheikh

Size Class	Number of farmers	Percent of total farmers	Number of fed.	Percent of total fed.
Less than 1 fed.	59	6	36	1
1 to 3 fed.	430	47	820	26
3 to 5 fed.	284	30	937	30
5 to 10 fed.	124	13	809	26
10 to 20 fed.	30	3	380	12
20 to 50 fed.	6	1	139	5
Total	933	100	3121	100

Table (7): Winter and summer cropping patterns among 12 farms along two water courses in the Abu Raya area

Winter crops	Area Feddans	% of Total	Summer Crops	Area Feddans	% of Total
Wheat	16.25	23.3	Cotton	25.50	36.4
Flax	7.54	10.8	Rice	33.20	47.4
Berseem	40.33	58.0	Maize	7.20	10.3
Beans	2.2	3.3	Vegetables	4.08	5.9
Vegetables	3.25	4.9			
Total	69.57	100		69.98	100

Water is primarily lifted by sakias for irrigation on the farm. The method of on-farm water distribution is similar to that described in the Mansouria problem identification report. Water is lifted into a Marwa and then distributed into small flat basins with or without furrows. As described in the above mentioned report; the basins are filled with water until the surface is completely covered. Preplanting irrigations are generally the rule before seeds are sown for most crops.

Water Course Sites

Two water courses, Om'Sen and Hammad Canals, were selected in the Abu Raya area for intensive problem identification work. Both of these water courses serve land at the extreme downstream end of Dacalt canal. The area is shown in figure 6. The Hammad canal runs mostly parallel and adjacent to deep drain No. 7, while Om'Sen lies nearly midway between deep drains No. 7 and El Raghama drain. Both canals are served by smaller drains parallel to the canals.

Four common sites were selected by an interdisciplinary team. There are two sites on each of the Hammad and Om'Sen canals. One site is at the head of each canal and the other at the tail. Two sites were in cotton allocations, one at the tail of the Hammad canal and one at the head of the Om'Sen canal. Alternately the head of the Hammad canal and the tail of the Om'Sen canal will be areas allocated to rice production.

Om'Sen Canal

The inlet to Om'Sen Canal is on the right hand side (east side) of Dacalt canal approximately 8.4 km from the beginning of Dacalt canal at Meet Yazid canal. The meska serves 34 sakias over its approximate 1700 m length. The area served in 205 feddans. The downstream boundary condition is blocked. At one time there was free outlow to Gadalla Drain. The area served by Om'Sen canal is bounded by Gadalla and Om'Sen drains on the west and east sides, respectively. The north end of this area is also bounded by Gadalla Drain

.../...

with the south end being bounded by Hammad Canal and Dacalt canal. The canal is served by a 5 day on/10 day off rotation in winter season and by a 4 day on/4 day off rotation in summer season. Sakias are unevenly spaced along the canal; the first one is located after only 30 m. The first nine sakias are within the first 400 m. Then there is about 60 m with no sakias. Seven more sakias are evenly spaced in the next 270 m; then there are 70 m of no sakias. Then there are 11 sakias within a 350 m reach, after which there is a 130 m reach with no sakias. The final seven sakias are spaced in the final 400 m reach. 80% of the sakias are within the first two-thirds of the canal. This is a major factor contributing to the perceived water shortage at the end of the canal. During critical periods the end of the canal will not receive the necessary amount of water without some fixed scheme of rotation of sakia operation along the canal.

Hammad Canal

The inlet to Hammad Canal is on the right hand side (east side) of Dacalt Canal approximately 8.1 km from the beginning of Dacalt Canal at Meet Yazid Canal. The canal serves 26 sakias over its approximate 2230 m length. The area served is 210 feddans. The downstream boundary of the canal is blocked (as apposed to free outflow condition). Hammad Canal follows Abu Raya Road for the first 550 m, after which is takes a 90° turn north and continues the final 1680 m approximately mid way between Om'Sen Drain and Drain No. 7 (see figure 6). During the winter cropping season the canal is served by a 5 day on/10 day off rotation. The main winter crops are wheat, berseem, flax and broadbeans. During the summer season the canal is served by a 4 day on/ 4 day off rotation. The main summer crops are rice, cotton and some corn. There are only 2 sakias in the 1st 500 m of the canal. The remainder are spaced fairly evenly down the rest of the length. The Omda of Abu Raya owns the land around the portion of the canal adjacent to Abu Raya Road and has control of the first 3 or 4 sakias on the canal.

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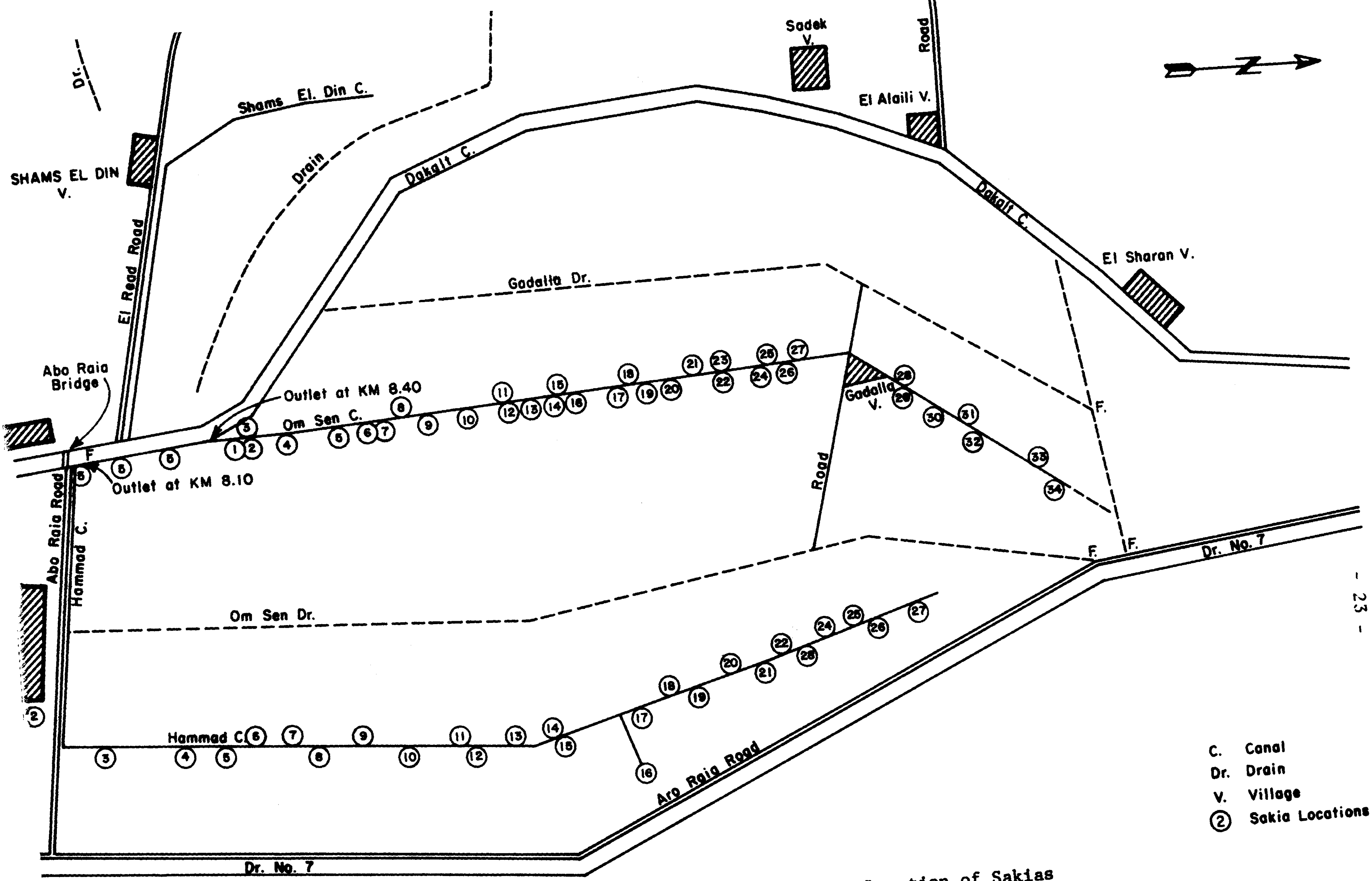

Figure 6. Geographic Location of Om Sen and Hammad Canals Showing Location of Sakias and Other Important Geographic Features

PROBLEM IDENTIFICATION PROCEDURES

The hydrological units mentioned and described in the previous section were selected to represent a typical set of soils, cropping and irrigation patterns of "lower delta" Egypt. Within these units, individual farms were selected to represent those same sets of conditions and situation that may be typical of lower delta farmers.

Before selection of individual farms, a pre-project activity team visited the area of Abu Raya to orient the village officials and representative farmers about the goals and objectives of the project and to solicit their support. After receiving full support, farms were then selected at the upper and lower reaches of each hydrologic unit for intensive data collection pertaining to agronomic and on-farm water management practices.

The main office staff in cooperation with representative team members develop criteria for selecting farms along the water courses.

Some of these criteria included type of crop, method of irrigation, position along the meska and size of the farm.

With inputs from all disciplines, questionnaire and interview forms were developed to obtain socio-economic data by selecting additional farmers and farms to obtain a larger representative sample of the village and hydrologic unit. A number of farms were selected along each water course by the economists to obtain farm records for the development of a farm planning field trial. Records of present farming activity among farmers were essential to show how farm record keeping can become a valuable tool for farm planning to increase incomes of farmers.

Detailed procedures were developed by the engineers and agronomists and socio-economic groups for obtaining on-farm water management problem identi-

.../...

fication data for the intensive study site mentioned above. Every effort was made to observe and quantify present practices so as to determine the technical problems encountered on the farm. An outline of the measurements and information collected from these farms is given below. The details are a matter of team record in the Kafr El Sheikh files.

Measurement and information to be collected by various discipline groups of the field team include:

Engineering

During the initial period of problem identification data should be gathered that will help formulate hypotheses for water management for the Abu Raya area. The following are some of the measurements and information that should be collected by the engineers:

1. Obtain the best available map of the Abu Raya area. Change the scale if necessary. Fill in any field boundaries approximately, which are not already shown on the map. Establish some kind of temporary code system to identify each field.

2. Observe and record each irrigation on some fields by date and time. Include the time period during the irrigation. Observe whether or not runoff occurs, and measure the amount, in relation to the amount applied. Estimate the precision of the land leveling by observing the uniformity of water coverage as the last portion is absorbed. Note the time required for the ponded water to disappear from 50% of the surface area of a basin.

3. Observe and record on the map the location of all meskas, the direction of flow, the area served by each meska, the method of control of water entering the meska, and runoff from the end if any.

4. Note the use of water lifting devices if any.

.../...

5. Observe the operation of the canal serving the area, its basis of delivery, including the rotation schedule if any, its normal water levels and their fluctuations within a 24 hour period, within a rotation, and with increasing crop demand.

6. Measure the quantity of water applied in the daytime vs night.

7. Observe the need for drainage if any.

8. Observe the apparent adequacy of the water supply in general.

9. Assist with team interviews of farmers at the Abueha site. (rotate with other disciplines)

Economic

1. Assist with team interviews of farmers at the Abu Raya site.

2. Obtain data from the Cooperative regarding:
   a. Number of farms
   b. Classification of ownership and tenure status
   c. Farm size
   d. Inventory of pumps, tractors and farm machinery
   e. Water delivery methods to the farms, e.g. tambour, gravity, pumps, etc.
   f. Cropping pattern for Abu Raya area.

3. Collect all secondary data about Abu Raya area and request translation to English if appropriate.

Sociology

The main office sociologists in cooperation with other discipline leaders have prepared an interview questionnaire that will be employed by the sociologists of the Kafr El Sheikh field team to obtain an idea of what the farmers

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think regarding how to increase their production and how to create a better life for village people. Other team members from other disciplines will assist in the interview. Discipline team members will rotate as members of the interview teams so that all team members may participate. The following are specific information to be gathered:

1. Make general observations of local field conditions and in general will support team building activities and other disciplines technical observations.

2. Short interview will be undertaken with a cross-section of typical farm operators in the Abueha area in collaboration with toher disciplines, until sufficient numbers are completed to affort confidence that we know sufficiently what farmers feel and think about their problems of production.

Agronomy

The agronomic team will visit as many farms as practical and make observations on agronomic and management practices. Agronomic team members should make the following observations and obtain as much quantitative information as possible regarding farming practices and conditions on individual farms.

1. Type of crops cultivated and growth characteristics
    a. Condition of crop (general)
    b. Plant density
    c. Pest infestations
    d. Weed infestations
    e. Drought or wet feet growth characteristics
    f. Foliar diagnosis for nutrient deficiency

2. Soil Characteristics
    a. Crusting, cracking, etc. impermeable layers

.../...

b. Evidence of salinity or sodicity

c. Seed bed type

d. Brief classification of surface and 30 cm using "spit" method

3. Management Practices

   a. Cropping patterns, intercropping patterns

   b. Fertilizer practices

      1. animal residue

      2. plant residue

   c. Method of varietal selection

   d. Cultivation methods

   e. Insect disease control methods

   f. Seedbed preparation methods

Before making the observations, agronomists in cooperation with engineers should establish a temporary coding system for each field for indentification.

A general surface and sub-surface soil texture survey was taken by the soil survey department in the Ministry of Agriculture. Standard soil survey practices were followed to obtain representative data for the hydrologic area to determine soil structure, consistency, color, mottling depth, and water table location. Soil profiles from representative sites were analyzed for exchange capacity, exchangeable sodium and water soluble salts, Ph, gypsum requirement, soil organic matter, soil fertility analysis, lime and moisture retention curve.

In addition to the above, an extensive soil testing survey was made to identify problems in the village so that sampling procedures can be designed for fertility recommendations.

The results of the fertility and soil surveys will be presented in separate reports and are not included herein, except for the salinity and sodicity status of the soils.

.../...

It is well to note here that problem identification procedures can be generally defined here, but specific details on the procedures followed to identify a specific problem will be reserved for reports dealing with quantitative description of the problems. The results of this problem identification report are mostly qualitative and will serve as a guide for more intensive investigations needed for problem solution.

RESULTS OF PROBLEM IDENTIFICATION STUDY

Social and Economic Problems

Introduction

Some of the major procedures, findings and conclusions of problem identification research conducted by the EWUP sociology group in the area around Abu Raya village from July, 1978 to April, 1979 are given below. The purpose of this work was to characterize social psychological, organizational and cultural factors of relevance to project effectiveness in the area as applied activities are undertaken.

Included are: (1) identification of "felt needs" and problems from sample farmer's perspectives; and (2) identification of constraints and opportunities for irrigated agriculture development from our professional perspective.

The conclusions are based largely in three sets of detailed interviews with each of twenty farmers operating case study sites being investigated by the other EWUP disciplines. Precautions were taken to insure that these farmers were generally representative of the farmers operating in the area. As well, conclusions are based in secondary data obtained from local government sources (eg. coop records, district reports, etc.) and from national sources (eg. census records and published government reports). Direct observation of the field team and special topical studies undertaken to follow up general leads also have contributed data and interpretive insights reported here.

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The economists worked closely with the sciologists in the development of a questionnaire which was subsequently administered by the sociologists. The economists took as much information from the questionnaire as was available and used it in the development of the farm plans. This avoided the problem, from the farmers' point of view, of making repeated inquiries about the same information.

The economics team developed a farm plan with three farmers at each site. The initial farm plan was for the agricultural crop year 1978. The primary purpose in developing these farm plans, which were actually developed in an ex-post sense, was to provide training for the Economics team in farm planning and farm management data analysis. An additional benefit was to meet the farmers and begin the establishment of a long term relationship with them.

Major Irrigated Agriculture Problems

All of the problems defined in this section were compiled from interviews and questionnaires conducted with individual farmers. They therefore reflect his perception of irrigated agriculture problem and his "felt" needs. The conclusion and discussion raised in this section are given as a result of the research efforts of the sociologists and the economists of the project.

Commercial Chemical Fertilizer

Farmers report that there is an insufficient supply of fertilizer. The fact the free market prices are usually 150 to 180 percent of official prices supports the contention of farmers that there is not enough available. Given the price differential, it is clear they would use more if it were available at official prices. This problem needs further clarification. Soil tests indicate that farmers may be using phosphate in quantities which do not give economical responses. There is also some evidence that nitrogen fertilizer may be wasted through leaching associated with poor water management. At the same time experiments show very high yield reponses to certain micro-nutrients when applied to the plants as a foliar spray. Per-

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haps the problem should be described as inappropriate allocation of fertilization of fertilizer rather than a general shortage.

Increasing Labor Costs

Farmers report that farm labor is becoming scarce and expensive. Many of them give this as the reason for (1) not keeping the private drains clean and (2) poorly time harvesting. The farmers and qualified professional experts who have visited the Abu Raya site seem to agree that the private drains are very inefficient because soil and plant growth is not removed frequently enough. It is also generally reported by farmers and other observers that crop production is lost because harvesting is done too early or too late. Figure 7 indicates the average wage rates for farm labor at Kafr El Sheikh during the calendar year 1978. Wage rates of LE 1.3 occur during peak labor demands of June to November. The peak daily wage for "boys and girls" reaches LE 0.6 per day and LE 0.5 per day respectively for these two peak periods. Although these wage rates are low relative to developed countries they nevertheless present a serious burden to small farmers who need to hire labor for various farming operations. As economic development takes place in Egypt, however, it should be anticipated that farm wage rates will continue increasing. Therefore it seems that appropriate action on the part of farmers would be to gradually adopt capital intensive technology to replace the relatively more expensive labor. This implies finding some means to achieve economies of scale which will permit the adoption of capital intensive technologies.

Crop Allocation System

The farmers are dissatisfied with the crop allocation system which includes: (a) inability to devote a portion of one's fields to crops desired for domestic use without being fined; (a) inability of many to grow crops giving the highest cash returns and/or that demand less routine labor. It may be noted, some of the dissatisfaction with the "block rotation" system results from this being a newer "old lands" area, where factionalization of land holdings, with dispursed small plots, is not as common as in areas that have

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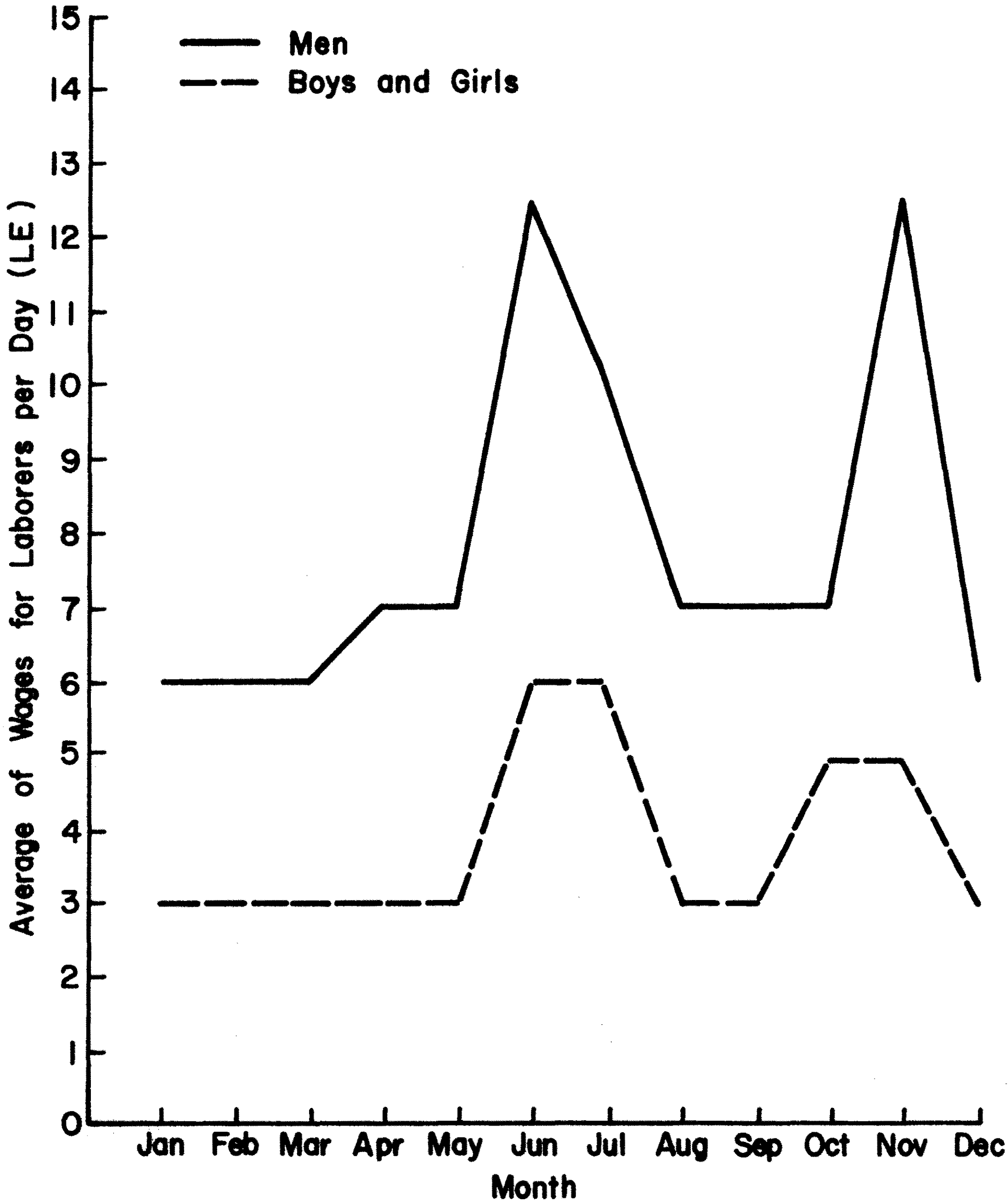

Figure 7. Average Wage Rates for Farm Labor at Kafr El Sheikh (1978)

been operated for more than two generations. Perhaps justifying some official exemptions where consolidation of holding is presently greater.

With respect to (a) above, the farmers experience a shortage of summer feed supplies for animals and would like large official allocation and/or adjustment in the crop assignment system so they could grow more forage during the summer. Based upon data collected from 12 farmers along the Om'Sen and Hammad canals, Tables 8 and 9 show the distribution of types of animal units among these farms and their value. The data show that these 12 farmers have slightly more than one animal unit per feddan. The predominate units being cows, buffalo and calves which produce meat and milk and as well as serve as work animals. The average value that these animals produce per feddan is 112 Egyptian Pounds. This value seems significant when compared with the average farm income shown in table 10. Adequate feed supplies during the summer would no doubt increase the production value of these animals.

Lack of Data for Farm Planning and Feasibility Analysis

With reference to item (a) and (b) for the "Crop Allocation System" mentioned above. Even, if the crop allocation system were modified in their favor, the farmers at Abu Raya are poorly equiped to analyze complex production and marketing alternatives even though they are good at crop and animal husbandry. They lack basic information about input-output relationships and analytical skills to evaluate alternative agricultural systems. Attempts to get data through farmer interviews were frustrated by memory bias, poor communications and general distrust between farmers and professional staff. This problem will be approached in the future through: (1) a farm planning and record keeping activity, (2) cost-return studies of crop enterprises and (3) a continued search of secondary data sources. Such an approach, with appropriate extension programs, should help farmers to allocate production resources into the most profitable crop and livestock enterprises. Tables 11 and 12 indicate differences in the profitability of alternative crops and the need for more planning data. It appears net income may be increased by

.../...

Table 8

AVERAGE ANIMAL UNITS PER FEDDAN

STUDY CASES AT ABU RAYA SITE.

Farm No.	Cow		Buffalo		Calve		Donkey		Camel		Goats & Sheep		Poultry		Total animal units	Area		Ave. A.U. Per Feddan	
	No.	A.U.	No.	A.U.	No.	A.U.	No.	A.U.	No.	A.U.	No.	A.U.	No.	A.U.		Fed	Kar.		
1			2	2	1	1	2	1.6					39	0.39	4.99	6	9	0.78	
2	1	1	1	1	4	4	2	1.6							7.60	6	19	1.12	
3	2	2	1	1	2	2	2	1.6					8	0.08	6.68	8	8	0.80	
4	1	1	1	1			1	0.8							2.80	4	-	0.70	
5	1	1	1	1			2	1.6							3.60	6	16	0.54	
6	4	4	2	2	3	3	2	1.6					10	0.1	10.70	10	18	0.99	
7	1	1	1	1	1	1	1	0.8					3	0.03	3.83	4	14	0.84	
8	2	2	1	1	2	2	1	0.8	1	1.1			33	0.33	7.23	10	6	0.70	
9			2	2	2	2	1	0.8					22	0.22	5.02	3	-	1.67	
10	1	1	1	1			1	0.8	1	1.1			500	5	8.90	3	-	2.97	
11			2	2	1	1			1	1.1			25	0.25	4.35	3	4	1.38	
12			2	2	3	3	1	0.8					37	0.39	6.17	3	4	1.95	
Total		13		17		19		12.8		3.3				6.77	71.87	A.U.			

Animal units are based on the following multiplicative factors
camèl 1.1 cow, buffalo 1.0 donkeys 0.8 goats, sheeps 0.1 poultry 0.01

Table 9: Average Value of Livestock Production Per 1 Animal Unit

No. of Study Cases	Total Area		Total Animal Units	Average animal unit per fed.	Total value of livestock Production L.E.	Av. production per 1 A.U.* L.E.	
	F.	Ker					
12	70	2	71.87	1.02	8084	112.48	

* A.U. Animal Unit

Table 10:

Average net farm income per feddan and average net farm income per person from the Study Cases at ABOU RAIA SITE

No. of Study Cases	Total Area		Total income L.E.	Av. of total income per fed. L.E.	Total expenses L.E.	Av. of total expenses L.E.	Total net farm income L.E.	Av. net farm income per fed. L.E.	Total family members	Av. net farm income per person L.E.
	F.	Ker.								
12	70	2	20284	289.44	9807	132.8	10977	156.6	106	103.5

Table 11:

PROJECTED INCOME AND EXPENSES FOR ONE FEDDAN OF WINTER CROPS, ABOU RAIA, 1979

Crop or Crop Combination	Products	Units	Usual Yield Per Feddan	Price Per Unit	Gross Income Per Feddan	Expenses	Return to Land & Management	Months for One Crop	Average Return Per Month
				L.E.	L.E.	L.E.	L.E.		L.E.
Berseem	Forage	Kt. Cut	72	1.500	108.0				
	Seed	Kaila	8	4.000	32.0				
	Straw	C. Load	4	1.250	6.0				
					146.0	58.6	87.4	7	12.5
Broad Beans	Beans	Ardab	3.5	20.000	70.0				
	Straw	C. Load	5	4.000	12.0				
					82.0	42.0	40.0	6	6.7
Wheat	Grain	Ardab	8	9.000	72.0				
	Straw	C. Load	5	7.000	35.0				
					107.0	65.0	42.0	7	6.0
Flax	Seed	Kilogram	500	0.200	100.0				
	Straw	Ton	1.5	30.000	45.0				
					145.0	82.0	64.8	6	10.8

Table 12:

PROJECTED INCOME AND EXPENSES FOR ONE FEDDAN OF SUMMER CROPS, ABOU RAIA, 1979

rop or Crop ombination	Products	Units	Usual Yield Per Feddan	Price Per Unit	Gross Income Per Feddan	Expenses	Return to Land & Management	Months for One Crop	Average Return Per Month
				L.E.	L.E.	L.E.	L.E.		L.E.
Maize	Grain	Ardab	12	7.800	93.6				
	Green tassles	Feddan	1	5.000	5.0				
	Straw	C. Load	6	1.000	6.0				
					104.6	73.3	31.3	4	7.8
Cotton	Lint	Kentar	5	33.000	165.0				
	Stalks	C. Load	5	3.000	15.0				
					180.0	122.7	57.3	8	7.2
Rice	Grain	Ton	2	55.0	110.0				
	Straw	Feddan	1	4.0	4.0				
					114.0	82.7	31.3	5	6.3
Egg Plant	July picking	kilogram	7200	.035	252.0				
	Aug. picking	kilogram	900	.040	36.0				
	Sept. Oct. picking	kilogram	4800	.050	240.0				
					528.0	426.5	101.5	7	14.5

Table 13. Financial Statement and the Agriculture Rotation for the Selected Farmers at Abou Raia Site

Farmers			Area			Livestock								Land & Livestock Value	Crops Rotation																				Family Members		
															Winter Crops										Summer Crops												
															Wheat		Flax		Berseem		Bean		Veg.		Cotton		Rice		Maize		Veg.				
No.	Name	Address	F.	K.	Total Value	Cow	Buffalo	Calve	Donkey	Camel	Goat & Sheep	Poultry	Total Value L.E.	L.E.	F.	K.	F.	K.	F.	K.	F.	K.	F.	K.	F.	K.	F.	K.	F.	K.	F.	K.	Male	Female	Total
1	Shams El Deen	Abou Raia	6	9	11750	-	2	1	2	-	-	39	596	12345	1	15	-	15	4	2	-	-	-	-	2	20	2	21	-	16	-	-	6	3	3
2	Marey Yosef	" "	6	19	13583	1	1	4	2	-	-	-	898	14481	2	16	-	12	3	10	-	-	-	-	1	2	3	16	-	10	1	12	2	4	6
3	Serreya Abdo	" "	8	8	14800	2	1	2	2	-	-	8	652	15452	1	12	1	12	4	8	1	-	-	-	2	-	5	8	1	-	-	-	7	11	18
4	Hamed El Behary	" "	2 1	12 12	5000	1	1	-	1	-	-	-	405	5405	2	-	-	-	3	-	-	-	-	-	1	12	2	-	-	12	-	-	4	4	8
5	Abdel Hamid Shaban	" "	4 2	16 -	8000	1	1		2	-	-	-	410	8410	1	-	-	12	4	16	-	12	-	-	3	16	2	-	1	-	-	-	4	6	10
6	Ahmed Abdel Baki	" "	10	18	21500	4	2	3	2	-	-	10	1864	23364	1	-	2	-	5	6	-	-	1	-	5	6	4	-	-	-	-	-	6	2	8
7	Gaber Abou Seef	El Raghama	4	14	9170	1	1	1	1	-	-	3	499	9669	-	14	-	-	2	19	-	-	1	5	-	-	1	14	-	10	2	14	2	2	4
8	Ahmed Shoaib	Abou Raia	10	6	22000	2	1	2	1	1	-	33	1021	23021	3	3	1	12	4	22	-	17	-	-	3	6	5	14	1	10	-	-	15	6	21
9	Salem Mariy	Farag Kobra	3	-	6600	-	2	2	1			22	809	7409	1	-	-	-	2	-	-	-	-	-	1	-	1	-	1	-	-	-	3	2	5
10	Mohamed Mariy	" "	3	-	6500	1	1	-	1	1	-	500	1280	7780	-	-	-	12	1	16	-	-	-	20	2	12	-	12	-	-	-	-	3	1	4
11	Abdel Aziz Mariy	" "	3	4	7100	-	2	1	-	1	-	25	1025	8125	-	18	-	-	2	10	-	-	-	-	2	10	-	18	-	-	-	-	2	3	5
12	Aly Mariy	" "	3	4	7180	-	2	3	1	-	-	37	946	8046	1	-	-	9	1	19	-	-	-	-	-	-	2	8	-	20	-	-	4	4	8

F = feddan
O = owned

Table 14: Summary of planned production and net farm income at ABOU RAIA SITE, 1979

Planned production and disposition of crops						Planned production and disposition of livestock							Summary of planned farm income and expenses								
Fed. to Live-stock	Used in Home	Dona-tion & wages	crops sales	Total value of produc.	Av. value per fed.	live-stock& prod. used in Home	Live-stock & prod. sales	total value of prod.	prod.* minus crops fed.	cost pur-chased feed	Gain** over costs of all feed	Value of total prod/ fed.	Crops Sales	live-stock &prod sales	prod used in home	misc. in-come	gross farm in-come	farm expen ses	Net farm in-come	Total family mem-bers	Av. net farm income/ person
LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE
350	292	56	691	1389	218	241	35	276	-74	4	-78	43	691	35	533	56	1315	528	787	9	87
275	199	51	804	1329	196	65	738	803	528	212	316	118	804	738	263	–	1805	923	882	6	147
305	327	103	891	1626	195	265	184	449	144	4	140	54	891	184	592	–	1667	751	916	18	51
162	186	55	469	872	218	182	64	246	84	4	80	61	469	64	368	–	901	471	430	8	54
213	176	48	889	1326	199	239	118	357	144	6	138	54	889	118	415	–	1422	770	652	10	65
202	256	108	1660	2226	207	651	390	1041	839	38	801	97	1660	390	907	70	3027	1260	1767	8	221
228	144	36	629	1037	230	239	30	269	41	3	38	59	629	30	383	–	1042	277	464	4	116
339	660	113	1263	2375	232	523	295	818	479	6	473	80	1263	295	1183	100	2841	919	1922	21	91
206	116	37	287	646	215	312	116	428	222	3	219	143	287	116	428	–	831	274	557	5	111
63	38	5	751	857	286	348	2048	2396	2333	1387	946	798	751	2048	386	130	3314	2316	997	4	250
97	61	27	579	764	242	266	68	334	273	58	215	69	579	68	327	130	1104	534	570	5	114
202	204	72	243	721	227	342	325	667	465	5	460	210	243	325	446	–	1014	284	730	8	91

* Total value of livestock production minus the value of crops produced on the farm and fed to the Farmer's livestock.

** Including the costs of purchased feed.

as much as 100 percent for individual farms through selection of the most profitable crops.

The data were collected from 12 farmers in Abu Raya regarding their financial situation and planned income for 1979 as shown in tables 13 and 14.

The variability in crop and livestock production per feddan indicates the potential income gains which may be possible through better planning. Summaries of farm record data will eventually provide more reliable data sources.

Owner-Tennant Relationship

Problematic law of owner-tennant relationships, favor the tennant eg., low permitted rental rates encourages owners to continue marginal operation of land that they would prefer to rent. The law, in other ways, favors the owner who can sometimes benefit from some agricultural inputs intended for the rented land. In either case, production suffers.

Table 15 indicates that most farms in the Abu Raya area are owned by the operators. As a matter of fact 96 percent of the farmers on record at the Abu Raya cooperative own their own land.

Table 15: Farm Tenure at Abu Raya Cooperative, Kafr El Sheikh

Size Class	Number of farmers	Number of owners	No. of renters	No. of squatters
Less than 1 fed	59	59	0	0
1 to 3 feddans	430	417	10	3
3 to 5 feddans	284	274	4	6
5 to 10 feddans	124	116	2	6
10 to 20 feddans	30	26	0	1
20 to 50 feddans	6	5	0	1
Total	933	897	16	20
Percentage	100	96	2	2

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Marketing

The farmers at Abu Raya complain about poor prices and marketing services. They seem to support Dr. H. A. El Tobgy's contention that "... satisfactory cooperation marketing operations must await the development of a truly efficient agricultural cooperative system and a sound and fair price policy".[1] EWUP personnel can help restructure marketing institutions by becoming familiar with the operations of the local cooperative and providing leadership for analyzing problems and helping farmers to participate in the affairs of the local cooperative.

Excessive Costs for Lifting Water

Our research at Kafr El Sheikh is consistent with our previous work at Mansouria, viz. farmers who lift water with tambours and sakias incur excessive costs of production. Water lifting at Abu Raya is done almost exclusively by sakia (each one of the twelve case study farms uses sakias). Some farmers indicate they are ready to change this practice by to date there is very little use being made of diesel and/or electric pumps for lifting water. Experience gained at Mansouria indicates it will require a major effort to organize the small farmers into groups large enough to make pumping economically feasible. On the average, net gains associated with shifting by diesel or electric pumps should exceed LE 20.00 per feddan. An additional benefit could be the gain from better irrigation efficiency through using larger flows of water.

Inequitable Official Treatment of Farmers

Examples of inequitable official treatment, include: (A) illegal intakes being ignored when set by persons of local power/influence; (B) gatekeepers showing favoritism at precise times some farmers have arranged to irrigate, sometimes providing levels which permit gravity delivery to field at meska heads; (C) some favoritism by the coop peronnel/council (eg. priority access to equipment and services, unequal inspection enforcement, and considerations in crop allocation, inputs supply and market provisions), etc. We have no hard evidence on these matters beyond some farmers complaints.

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[1] H. A. El Tobgy, Contemporary Egyptian Agriculture, Ford Foundation, Beirut, Lebanon, 1977.

Ineffective Cooperative

Generally the coop is not being as effective as it should ideally be, particularly since the loss of basic functions to the non-local village bank. It is limited in the services and equipment it can provide and has no extension officer, etc.

Sociological Factors and Problems

From the vantage point of the sociologists who have worked with the farmers through questionnaires and various interviews the following comments are offered.

1. Abu Raya farmers do indeed, often suffer from a weaker sense of self respect and self-confidence than is supportive of highly-rational farm management practices (which depend upon personal inclination to plan, experiment, and understand better farm operations, as well as demonstrate the discipline born of independant convictions). Given the social science doctrine of the "looking-glass itself" (eg., we think of ourselves as we think significant others think of us), systematic project attention should be given to bolstering the farmer's self respect and confidence by: (A) acting toward them with respect and confidence, and (B) arranging experiences in planning, experimenting, and understanding in which they are guaranteed reassuring success in response to their own personal initiative and effort.

2. There seems among Abu Raya farmers to be too great a lack of confidence in the government officials who have the responsibility of supporting their irrigated agriculture activities. As a result, the farmers do not typically have an optimistic view of their potentials for improving agricultural production or profit, which is usually a prerequisite in the development process. Instead, they tend to aspire more, on average, to reducing the effort they must invest in their operations. They seem to assume that they will "get by" (perhaps with sustained/ greater government support and assistance), but that the real opportun-

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ity for a good life (for their children, for instance) lies elsewhere. Whether or not this mind-set is realistic, it is not healthy for them or the nation.

Confidence in those government personnel and the program intended to encourage and facilitate irrigated agriculture development on established lands can presumably best be advanced by: (A) a stronger administrative attitude of "working partnership" with the farmers (vs. direction and control of their activities); (B) their spending more time in informal field contact with their rural constituency; and (C) increasing the effectiveness of their service to the farmer under conditions of very limited resources by emphasizing field-level extension, teaching "appropriate technology" and self-help strategies in agricultural development. Strengthening functions and effectiveness of the local coops and district-level irrigation and agriculture departments would facilitate this process most dramatically, but they must be supported by strong and sincere proclamations of understanding and support from the national level.

3. Social organization and effective (i.e. meaningful, non-superficial) communication patterns among neighboring farmers, and within the village area as a whole, should be strengthened for the success of low-capital-resource irrigated agriculture development efforts. Presently, congenial social relationships dominate functionally viable ones in Abu Raya. Yet cooperation in timing irrigations, sharing equipment and labor, planning crops, etc. depend upon good communication and informal organization. There is recognition of this among Abu Raya farmers, but since they give priority to congenial interpersonal relations, they must depend upon others, such as the coop and the project, to take the lead in this process. Presently, the cooperative is not strong enough, and, perhaps does not know enough about procedures to effectively pursue this challenge. The project is, for other reasons, not now in a good position to take the lead. Presumably, project assistance in supporting the coop's effectiveness and functional

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viability is the most appropriate strategy in the shorter run. During the project's initial period in the area, attention has been given this approach with substantial progress being made in the service areas of agronomic practices, farmer organization and farm machinery.

4. In the case of Abu Raya, a labor shortage for periodic labor-intensive farming operations (i.e., rice transplanting and cotton harvesting) suggest the need for: (A) increased availability of some available machinery that would help during high-labor demand times without displacing laborers who depend upon steady employment for their support, and (B) developing new "low technology" technique and equipment to ease the seasonal high-labor demands. Both, of course, are being done by the project in coordination with coop personnel. Doubtless, developing new "appropriate" technology and practices should receive much greater emphasis by the project in the future, given very limited local investment capital resources, which ultimately must be the basis of irrigation and agriculture development efforts in Abu Raya and similar areas of Egypt and elsewhere.

In conclusion it must be added that a review of these farmer's perceptions of agriculture operations problems show their concerns largely focus on the implementation of government policies and practices. Although the project's research effort by several disciplines show most of their concerns are at least partly justified, it must be recognized that these are matters the project cannot do much to change in the shorter run. Nevertheless, we should investigate such matters further, and, as data are available for documenting an objective case, attempt to sway government policy and its application toward approaches which will better serve the interests of the nation and the farmer.

In the meantime, we must remain sensitive to the "felt needs" expressed by the Abu Raya farmers. In many ways, we can capitalize on their frustrations and desires in order to involve them in a vigorous partnership for development of the area's water and agricultural resources which involve

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innovative farm management alternatives to reduce problematic consequences of some policies and administrative practices that are bothersome to them.

To the extent that we can encourage their individual and collective initiative in making their on-farm managmenet practices more productive, profitable and pleasurable, we must concentrate our efforts there. To the extent that we can facilitate their individual and collective self-help efforts, we must give them our full support. To the extent we can strengthen their local institutions, organizations and leadership, we must do so without hesitation. To the extent we can informally contribute to their creative understanding of efficient, rational grass-roots management and problem solving processes in irrigated agriculture and other life-sectors as well, we must make it a total educational effort, conceived and implemented to ensure their success and satisfaction.

Of course, the phrase "to the extent ..." implies that our contribution to the process be a highly sensitive, incremental one, similar to that which skilled musicians term "playing it by ear" or experienced pilots call "flying by the seat of one's pants". The general comments contained in the section above dealing with our sociological insights from interview data and field observations highlight our judgement of priority matters for project attention in Abu Raya's irrigated agriculture development.

Agronomic and Engineering Problems

Most of the technological problems can be grouped into two general categories; agronomic and engineering. This section discusses problems that have been identified by the agronomists and engineers. Most of the problems presented are actually interdisciplinary and overlapping with respect to disciplines. The common denominator of all these problems to be mentioned is "water management". However, since the above two staff disciplines arrived at these problems by disciplines they shall be referred to as such herein.

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Agronomic Problems

Crop productivity in Abu Raya area is high and this can be attributed to the relatively fertile alluvial soils, the adequate amount of good quality irrigation water, the ample amount of sunlight, freedom from killing frosts which permits year round cultivation and skilled farmers. Despite all of these favorable attributes there still remain several serious constraints to maximizing crop production. Listed below are some of the constraints identified:

1. Problems of minor soil element deficiencies
2. Lack of adequate plant populations in certain crops
3. Salinity problems

Problems of Minor Soil Element Deficiencies

Next to nitrogen and phosphorus deficiencies, minor element deficiencies are important nutritional factors limiting the growth of many important Egyptian crops such as rice and cotton. Deficiencies in these elements at times are not visible but they do restrict crop growth by not allowing plants to give maximum response to macro-nutrients such as nitrogen and phosphorus.

One of the best ways to evaluate the status of micronutrient level in soils is to determine crop response by field trials. This was done during the 1978 rice and cotton growing season and the effect of zinc and Bayfolan on these crops were evaluated. The details of this field test will appear as a seperate EWUP publication.

Rice and Cotton Studies

The rice belt in Egypt is restricted to the northern half of the Delta due to its special irrigation needs. The rice grown in this area is the short grain variety and its is grown in paddies during the summer months. When a soil is flooded for relatively long periods of time it undergoes chemical reductions that can strongly influence the availability of certain minor elements.

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In field trials conducted at Abu Raya, the addition of zinc sulphate to the field prior to transplanting of rice, increased yields by 28% compared to those fields not treated with zinc. When zinc was applied to the nurseries, yield increases in rice grain were on the order of 40%. Not only were increases reflected in grain but straw yields increased also. Where zinc was applied in the filed, straw yields increased by 36% and with zinc applied in the nurseries the straw yield increased by 59%. These responses occurred with no change in water management practices, macro-fertilizer practices, or soil preparation, outside of the application of zinc sulphate to the field at rates of 10 kg. per feddan or in the nursery at 20 kg. per feddan.

The application of foliar fertilizer (Bayfolan) to cotton was also evaluated during the 1978 season. Where the foliar fertilizers were applied twice during the growing season yield increases of 28% were recorded. This translates into an average increase of 353 kgs. of seedcotton per feddan. In addition, these increases in yield resulted without the addition of any extra irrigation water as the farmers used their normal management practices.

From these studies it is evident that the minor element fertility levels in northern delta soils are an important constraint to maximizing crop production. One can speculate that by the addition of minor elements and small amounts of macro-nutrients, causes an increased efficiency in the use of nitrogen and phosphorus as they alone can not account for the large increases in yield. In addition, these increases were obtained without any increase in the amount of water applied thus increasing the efficiency in water use.

Plant Populations

Plant population is a very serious constraint to maximizing crop production. Results obtained in Abu Raya confirm those obtained in the Mansouria area. Forty five individual farms in the Abu Raya were sampled for the number of cotton plants per feddan as well as for the yield of seedcotton. In evaluating the data there was a significant positive correlation of 0.73

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between seedcotton yields and plant populations. The mean for number of plants per feddan was 34,879 while 1064 kgs. per feddan was the average yield. The range in plant numbers was from 18,750 to a high of 46,350 while in seedcotton yields ranged from 488 kgs. to 1613 kgs. Data clearly show that yield of seedcotton is highly dependent upon the number of plants present at harvest time in the field. Similar studies on corn indicated that as population increased subsequent increases in yield occurred.

Salinity Problems

Soil salinity and sodicity can be a serious constraint to crop production. As described earlier in the section dealing with soils of the Abu Raya area, a significant number of soil samples are still moderately saline in the root zone. A highly significant positive relationship exists between soil salinity and yields. However, the relationship is complicated by the presence of sodium. For example 44% of the soils in Abu Raya had low EC values that could be considered as class I. Furthermore, the mode of frequency distribution of salinity if these soils would lead one to believe that there are no salinity problems for 44% of the cultivated area as shown in figure 8. However, rice paddy production in 1978 for Abu Raya was not favorable. Figure 9 shows paddy rice production for these categories of soil salinity. Obviously, soil sodicity have had an important effect upon yield, other things being equal.

Rice Cultivation Problems

Rice is the second most important export crop of Egypt and occupies an area of more than one million feddans. Because of its special irrigation needs and that it lends itself to land reclamation, it is restricted to the northern half of the Nile delta. The most common method of cultivating rice in the delta is to transplant from nurseries rather than to broadcast seeds directly onto the fields.

After seeds are grown under normal conditions in the nursery, seedlings are manually pulled, the mud is washed from their roots and they are moved

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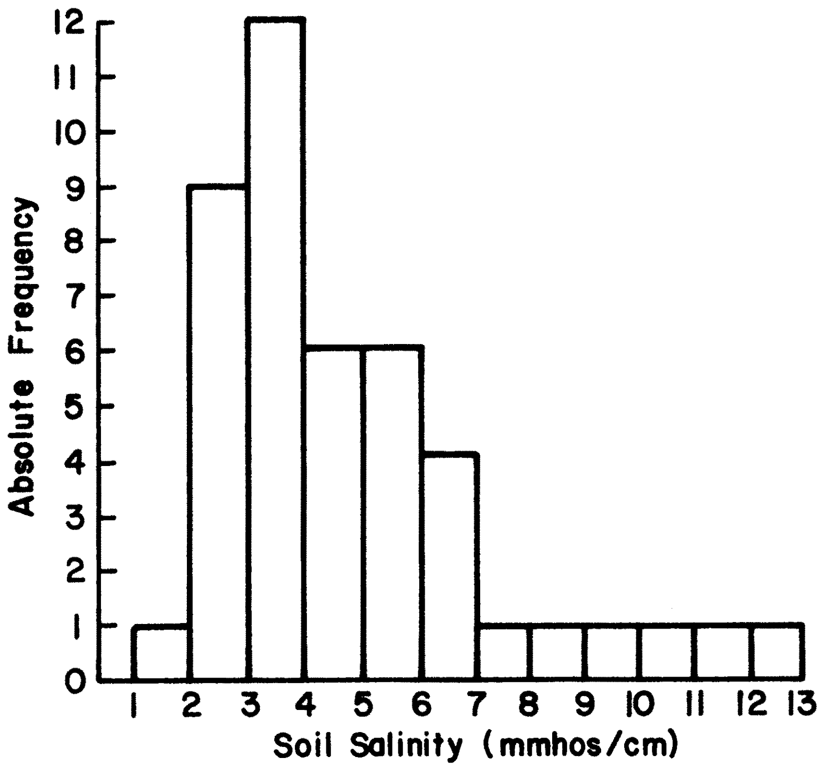

Figure 8. Distribution of Salinity Levels for Abu Raia Soils, (1978)

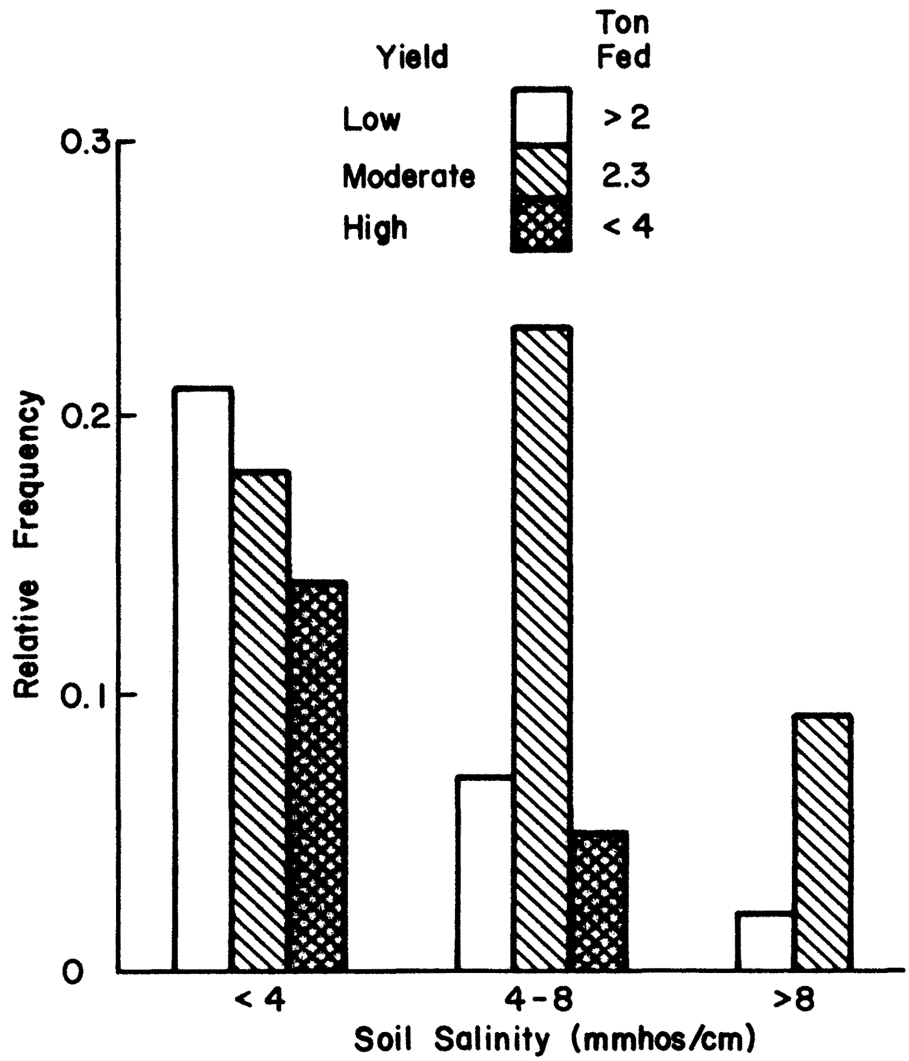

Figure 9. Rice Production in Abu Raia Area on Soils Grouped into Three Categories of Salinity, (1978)

to the main field. Eight well trained young laborers can transplant one feddan of rice seedlings per day. These laborers can maintain a standard of a certain number of seedlings per hill and a certain spacing between hills and rows. Studies have shown that 3 plants per hill, with 15 cm. between hills and 20 cm. between rows are best for optimum production. Field uniformity promotes maximum tillering for all hills and facilities manual weeding between rows. This uniformity can't be approached by untrained young labroers. Since 1960, well trained transplanters have been migrating to the cities. They receive higher wages for easier work. The younger laborers nowadays are reluctant to be trained as transplanters. The shortage of well trained transplanters is now a major constraint in paddy rice production. Farmers cultivate their nurseries from May 1 to May 30. It is recommended that rice seedlings be transplanted between June 1 and June 30. When farmers cannot complete transplanting their fields during this period because of the shortage of transplanters, they must either use a larger number of untrained laborers or transplant their fields late. Every week's delay in transplanting results in an appreciable reduction in paddy production. A shortage of skilled laborers, resulting in a larger input of unskilled laborers, results in reduced productivity and increased production costs. The following table shows the increased costs for transplanters over the past 13 years.

Year	Money paid to one transplanter LE/hr	No. of transplanters needed for one feddan	Cost per feddan - LE
1965	0.15 - 0.25	14	2.10 - 3.80
1970	0.40 - 0.60	16	6.40 - 9.60
1978	1.00 - 1.50	18	18.00 - 27.00

Egyptian farmers usually level their land under flooded conditions before transplanting rice seedlings. This process is called "Talweet". It is carried out by using animals to draw a heavy piece of wood over the saturated soil. This process compacts the soil more than when water is simply added

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to a well granulated soil without "Talweet".

When water is added to soil, the soil aggregates absorb moisture and swell. At the moisture equivalent most of the soil water is held in pores of capillary dimensions and as a film in the micro-pores. With continuous flooding, free water moves through the soil pores vertically and laterally. Such movement increases with increasing porosity. As described above, the farmer, by means of "talweet", reduces the porosity of the soil surface (10 cm). The mechanical forces cause compaction of the top soil and in turn reduces both the rate of percolation and of infiltration. After "talweet" and immediately after transplanting the farmer maintains a 5 cm head of water on the soil surface. Without "talweet" he can only approach and maintain this depth after excessive daily irrigations. For this reason, farmers who broadcast rice seeds on granulated soil and grow seedlings under lowland conditions can not maintain this water depth unless he can irrigate daily for 30 days. Thus, farmers are reluctant to follow the broadcast method in spite of saving time and labor required for transplanting rice.

Even with the process of "talweet" large quantities of water are required by the farmers along any given water course during and after the time of transplanting. This high demand for water during "talweet" and transplanting time of rice causes farmers to feel a severe water shortage. The situation is further aggrevated when more than 50% of the land along the water course is in rice cultivation. Obviously scheduling and planning would alleviate this apparent water shortage problem.

The data in figure 10 show cummulative depth of irrigation water applied to a rice paddy as a function of time after planting rice. The slope of the curve is the sum of the deep seepage rate and rate of evapotranspiration. A total of 213 cm of water was applied over 113 day period. It appears that after nearly 60 days the rate reduces to its smallest value and becomes constant.

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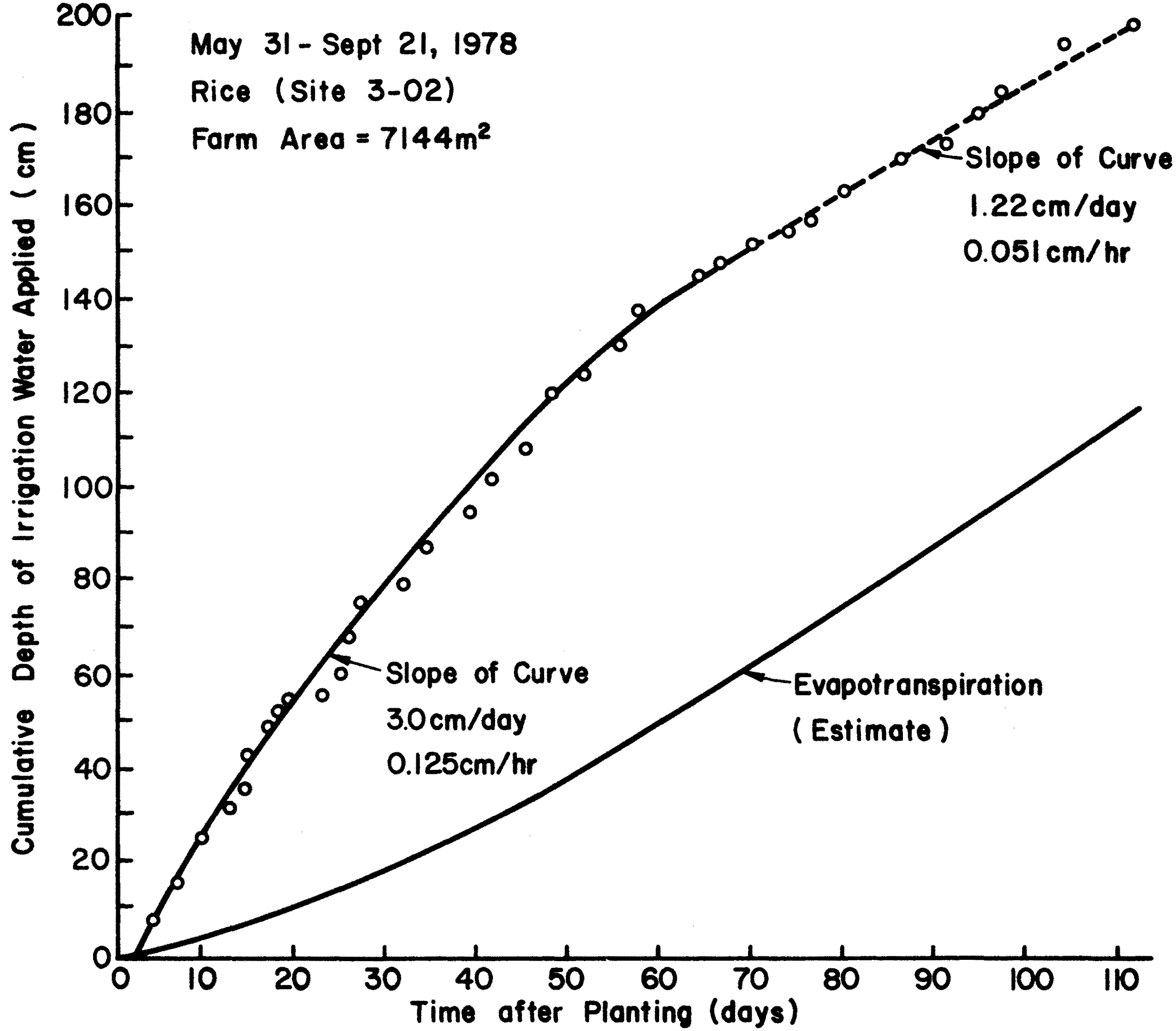

Figure 10. Cummulative Irrigation Water Applied to a Rice Field During the Growing Season

If one assumes that evapotranspiration is relatively small immediately after transplanting, Deep seepage is nearly 3 times greater immediately after talweet than the combined ET and deep seepage rate during the last 30 days of irrigation. From the soil hydraulics point of view, it would be expected that the seepage rate would be small near the end of the irrigation season and rate of irrigation water applied would be approximately the evapotranspiration rate, (1.2 cm/day). These data shown in fig. 10 do not account for any water drained from the field to the drain. If such occurred, the magnitude of the analysis above would not be as large. However, the data illustrate the relatively large quantities of water used for rice during early stages of culture by one particular farmer.

Engineering Problems

A considerable effort was spent by the engineering discipline in measuring water on and off of farm sites selected on the Om'Sen and Hammad Canals as well as hundreds of observations regarding irrigation practices. The detailed analysis of these measurements will be published as EWUP technical reports at a subsequent time. From these observations and measurements the following problems have been defined that deal with the management of water to and on the farm.

1. The proportion of land occupied by canals, ditches, and drains is relaively large.

   The following calculations from the rice area in Site 1 on the Om'Sen Canal and from the cotton area on Site 3, Hammad Canal show the magnitude of this problem.

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Site No.	Total area owned	Area in branch canal & Community drain	Gross area remaining	Gross area remaining	Area in sakia, ditches, & drains	Cultivated area remaining	Cultivated area remaining	Cultivated area remaining
	fed.	fed.	fed.	%	fed.	fed.	% of gross	% of total
1	10	1.1	8.9	89	1.6	7.3	82	73
3	8.97	0.88	8.09	90	1.15	6.94	86	77

On Site 1 the width of borders ranged from 12 to 15m, and the width of the drains paralleling the borders averaged 2.2 m. If we assume a typical border total width is 13.5 m plus 2.2 m, and if we replace the drain ditch with a dike that occupies only 0.7 m, then we have gained 1.5 m and have increased the effective growing strip width from 13.5 to 15.0 m, a gain of 11%. Additional, smaller gains could perhaps be obtained by replacing the sakia with a pump and by replacing the head ditch with a pipe.

For the cotton field on Site 3 the potential gain is greater. Borders are somewhat wider, ranging from 14 to 20 m. However, if the side drains were eliminated they would not need to be replaced by a dike, and perhaps the marwa in the center could be eliminated if the fields were leveled. If we assume a typical border has a cropping width of 17 m, and that the marwa reduces its effective width to 16.5 m, and if we assume that eliminating the side ditch would increase the growing area by 1.8 m, then the potential increase of cropped area by eliminating these two ditches is

$$\frac{0.5 + 1.8}{16.5} = 14\%$$

2. In some places, the water table fluctuates close to the soil surface.

Two observation wells in the corn field on Site 4, at the end of

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Hammad Canal, revealed the following water table positions:

Water Table Depth Below Ground Surface, Meters

Well No.	Range of Measurements before irrigation	Range of Measurements after irrigation
4	0.43 to 0.49	0.15 to 0.24
5	0.51 to 0.56	0.07 to 0.29

The rise from just before irrigation to one day after ranged from 0.19 m to 0.45 m.

In the cotton field on Site 2 near the end of Om'Sen Canal two observation wells located near a marwa and near a small field drain respectively showed similar readings, but a well in the center of the field showed a deeper water table before irrigation.

Water Table Depth Below Ground Surface, Meters

Well No.	Measurements before irrigation	Measurements after irrigation
Near ditch	0.66 to 0.86	0.28 to 0.40
Center	1.01	0.35

These water table positions are close enough to the surface to cause an accumulation of salt on the surface without adequate leaching, and may also restrict soil aeration enough to limit crop yield.

3. There are severe weed problems, especially in the drains.

Weeds come back quickly into canals and drains after cleaning. Drains are less likely to be cleaned regularly than canals.

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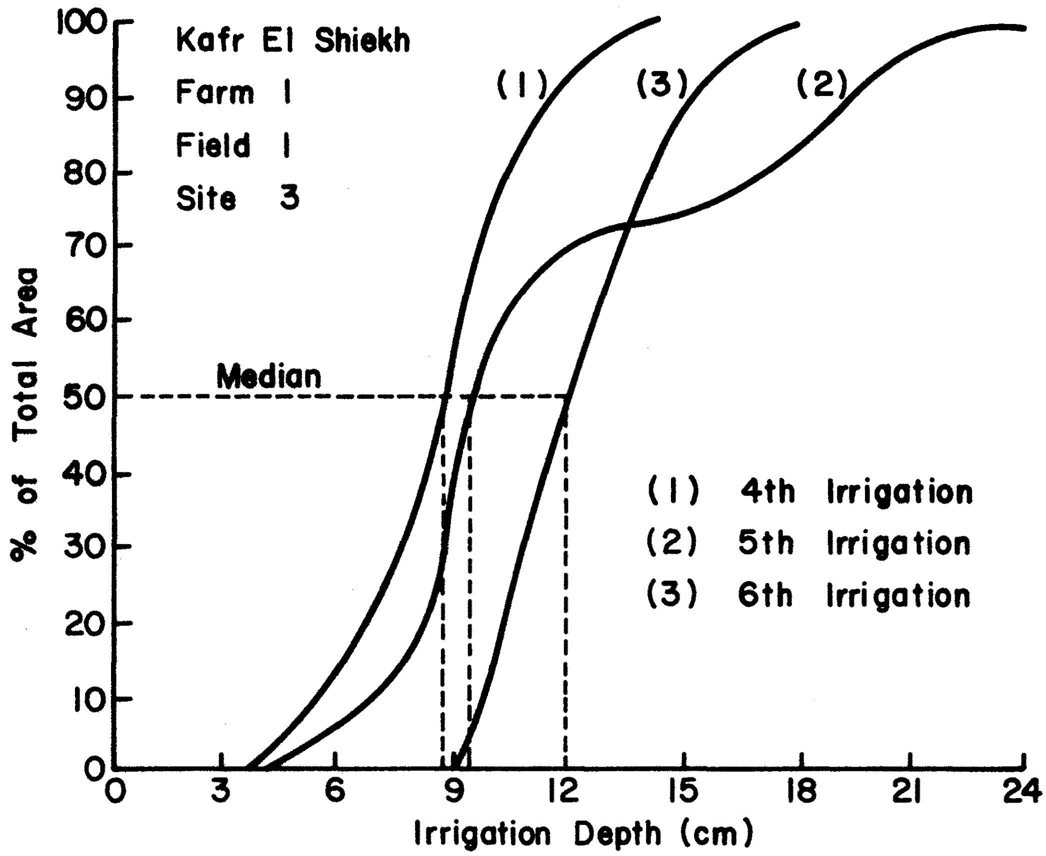

Figure 11. Distribution of Irrigation Water Over a Farm Area for Various Irrigation Sequences

Gadalla drain, for example, has been observed backing water into small field drains, and even spilling excess water into the Om'Sen Canal. A method of keeping weeds continuously under control is needed.

4. The distribution of irrigation water over a field is not always uniform.

When a system of small basins supplied by a marwa down the center of a field is used, it is possible to estimate the depth of water applied to each basin by noting the size of the basin and the length of time that a steady stream of water is diverted into it. During a test a special effort can be made to keep a sakia turning at a relatively constant speed. Figure 11 shows the results of such a test during three irrigations in a cotton field on Site 3, near the inlet of Hammad Canal.

The curves show the uniformity of distribution among the basins. During the fourth irrigation, the median depth applied was slightly less than 9 cm. However, 10% of the field received less than 6 cm and 20% received less than 7 cm. Also, 10% received more than 11 cm, according to this curve. Actually, this uniformity is not too bad, and the 6th irrigation is even better. The median was 12 cm and only 30% of the field received less than 11.

The 5th irrigation was somewhat of a disaster by comparison. With a median about 9.5 cm, the curve shows that 20% of the field received more than 17 cm. The excess must go to surface runoff or to the water table.

Perhaps more damaging at times is the unlevel character of the soil surface within a basin. Noticeable differences in vegetative growth have been observed between the high spots and the low spots. Identification of the highs and lows has been observed in the field in the fol-

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lowing ways:

a. Watch when the water recedes after irrigation, exposing only the high spots.

b. Notice the salt appearing on high spots first.

c. Notice the darker color of the soil in the low spots.

d. If the soil is permitted to dry before harvest, notice that the high spots dry first.

e. Notice that the plant color becomes a darker green on the high (dry) spots as the drying continues.

5. The conveyance loss from sakia to field can be excessive.

Because one sakia is used to serve several fields, the elevated ditch carrying the water may be quite long and thus lose much water to seepage. Perhaps an even greater loss occurs as a result of the storage remaining in the ditches after an irrigation. The water lost in storage is greatest when the long field drains are deliberately filled during an irrigation, as an aid to water distribution. It is assumed that most of the water stored in the drains seeps to the water table, and that the remainder evaporates.

One calculation of the combined conveyance loss due to seepage and storage in ditches was made for a rice field in Site 4. During those irrigations when the field already contained ponded water, an average quantity equivalent to 5.62 cm of water was lifted by the sakia whereas an increase of only 3.44 cm depth of water average at each irrigation was measured onto the field. The difference amounted to 39% of the lifted water unaccounted for. The unaccounted for portion however, did also include the deep percolation from the

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field during the irrigation and any loss through the dikes that occurred during the irrigation. In this case the elevated supply ditch between the sakia and the field was 187 m long. The observed storage in this ditch at the end of the irrigation and the seepage loss from it during irrigation are believed to be the major components of the water not accounted for.

6. Of the water successfully ponded in a basin during an irrigation, a large fraction is released to surface drains.

Very few measurements of surface runoff were made, but many observations indicate that the losses are significant for both cotton and rice.

Farmers know, or at least believe, that irrigation water must not stand too long in a cotton field. A typical irrigation practice is to fill two basins with the stream coming from the sakia, then divert the stream into the next two basins. However, by the time the second two basins are filled, the irrigator may have already cut the bank and released the water from the first two to the drain. Perhaps one reason for his action is that the land within the basin is not level, and the water will damage the plants in the low spots if it is allowed to remain longer. Perhaps he may also know that he has applied more water than the necessary to fill the root zone, and wishes to remove the excess.

In rice fields, surface water is deliberately drained on occasion to permit agronomic practices such as spreading fertilizer and killing algae. Perhaps most of these occasions are necessary, but in anticipation that water will be in increasingly greater demand to irrigate new land, field trials to seek alternative practices may be justified. Already some farmers drain their fields less frequently than others.

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An unintended loss from the ponds of water in rice fields results from seepage through the dikes. Often this occurs from a break in the dike which could have been prevented.

The quantity of water applied to three rice fields in 1978 illustrates the importance of various drainage practices. The measured applications were about 5,000, 8,000, and 10,000 m^3 per feddan respectively in the three fields (about 1200, 1900, and 2400 mm depth). According to prior studies made by the Water Distribution and Irrigation Methods Institute on economical water duty for rice at Kafr El Sheikh experiment station over a period of about 20 years, the 8000 m^3 per feddan figure is the most logical. The field which received only 5000^3 had little opportunity to remove excess water because the level in the adjacent drain was too high. In the opinion of the engineer in charge of the measurements, the difficulty of removing water accounted for most of the 3000 m^3 reduction in the amount applied to this field. Other components of the difference could be errors in water measurement and differences in the infiltration rates of the two fields.

Consumptive use of rice in Kafr El Sheikh was measured by Abdel Hafez to be 1026 mm in 1978. Comparing this to the 1200 mm measured application suggests that on this field the loss to deep seepage and lateral seepage was very small. Further measurements would be required to confirm this. Field trials would also be needed to find out how yield could be affected by the various water management practices.

7. The first irrigations tend to exceed the soil moisture deficit.

The first irrigation after land preparation, perhaps at planting time, is often greater than the storage capacity in the soil. One reason is a desire by the farmer to wet the soil at the surface

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thoroughly so the clay clods will soften. Another may be the higher intake rate that occurs as a result of the recent tillage. Still another is the desire to leach salts from the profile.

Most of the early irrigations occurred before water measurement began, but on one cotton field, estimated applications for the first four irrigations, between March 15 and May 29, ranged between 12 and 24 cm at each irrigation. There is no way consumptive use during this period, while the plants are still small, could have equalled this application rate.

As the cotton plants grew larger, there appeared to be less tendency to over-irrigate, as indicated in figure 12 and 13. In one field site, the accumulated water application curves, shown in figure 12, gradually exceed the measured soil moisture extraction, but for the other field site, the daily-rate curves suggest that two of the irrigations may actually have been inadequate. However, the two relatively high values for soil moisture extraction raise some doubts concerning validity of the extraction data.

8. Rice is irrigated much more frequently than the 8-day rotation period.

In figure 14, frequency of irrigation is plotted as a function of number of days.
As the following frequency curve shows, about 44% of the irrigations on this particular rice field were performed after an interval of only 2 days and 88% had an interval not exceeding 6 days. These data are typical of all fields monitored. The rotation schedule assumes an interval of 8 days (4 on...4 off).

The high occurrence of the 2-day interval suggest that water is available during the off-period. Observations confirm that this can and does happen, since there is available storage in canal due to over-excavation. It may also be abetted by a leaky gate on occasion. The over excavation apparently results from ditch

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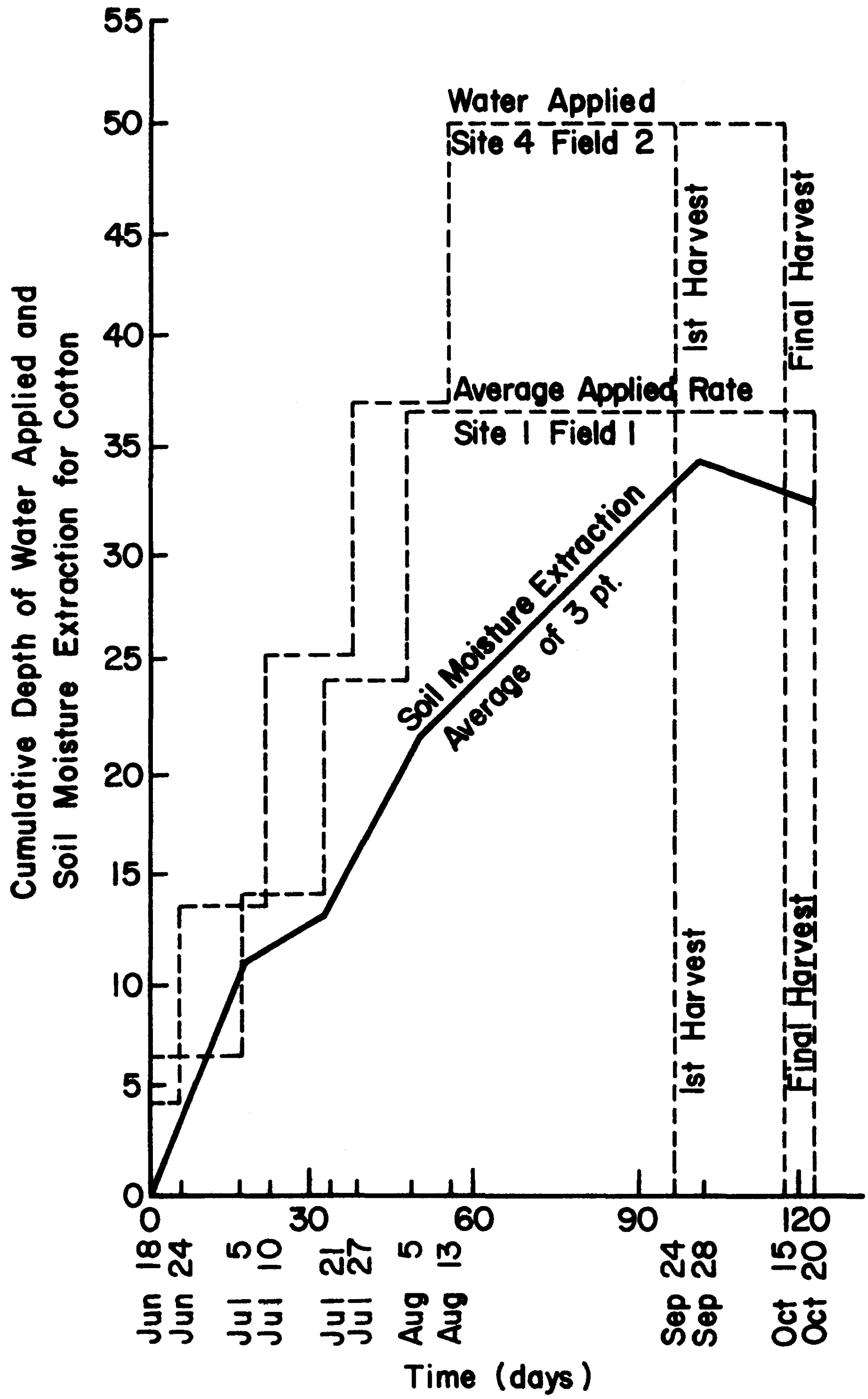

Figure 12. Cummulative Irrigation Water Applied to Cotton and Soil Moisture Extraction as a Function of Time for two Field Sites

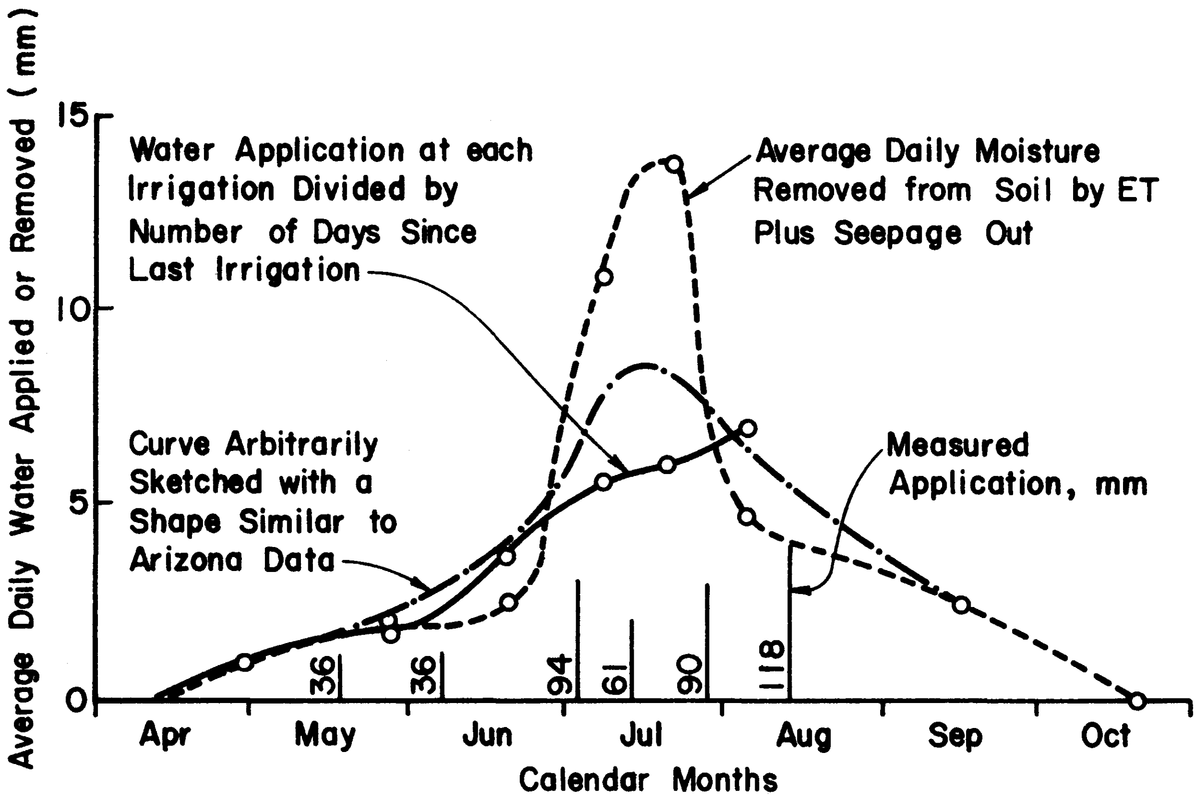

Figure 13. Water Applied to and Soil Moisture Removed from a Cotton Field

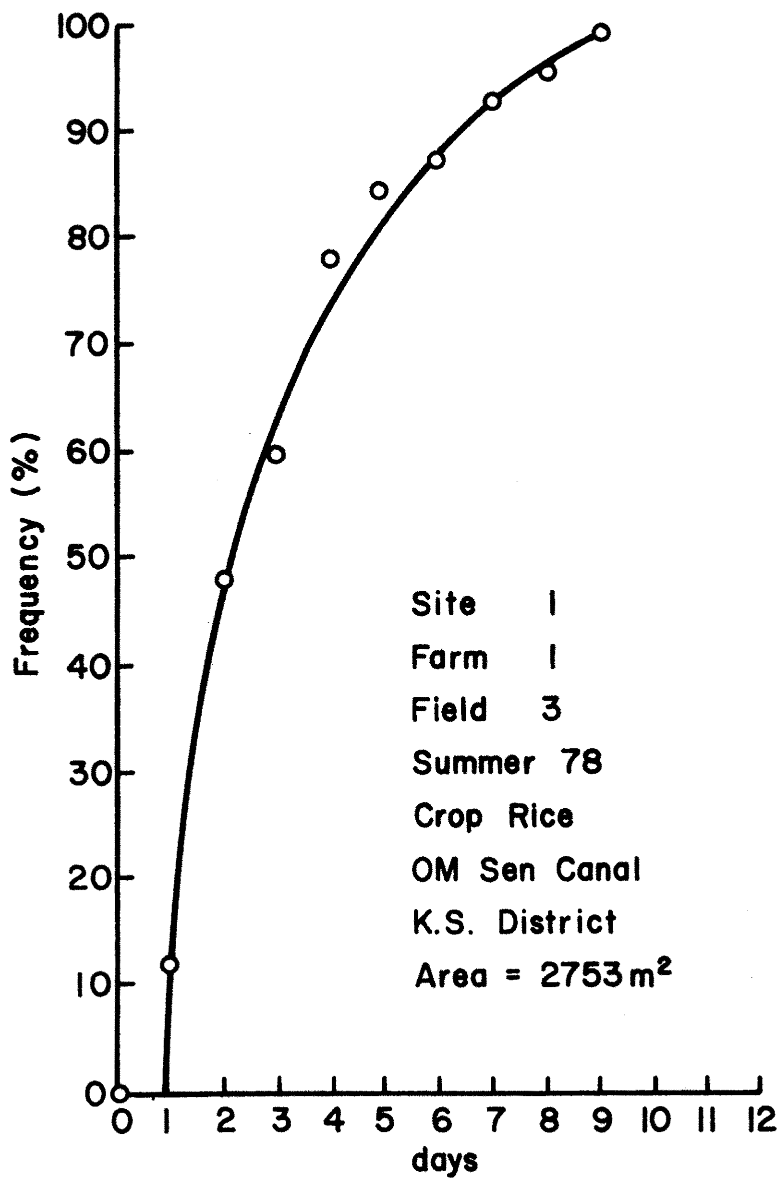

Figure 14. Frequency of Irrigation for Rice

cleaning, prompted partly by the need for material for making bricks.

The penalties to be paid for too-frequent irrigations include the extra labor required and the extra water applied, most of which apparently reaches the water table. The extra water is required to fill the supply ditches each time.

Records kept on one farm indicate that this farmer desires the ponded depth in his field to be between 3.43 and 6.87 cm. Perhaps a field trial could show that a slightly lower depth would be adequate if the field were level.

Further investigation might also show that irrigations would be less frequent if a dependable water supply were available continuously instead of on rotation.

9. The farmer has no modern methods available for helping him decide when to irrigate and how much to apply.

Modern techniques could perhaps increase his yield and reduce the water he applies. They might effect a lowering of the water table and reduce the danger of excess moisture stress in the root zone.

Note that items 4 through 9 above all deal directly or indirectly with saving water and increasing yield.

10. While the water in the canals is of high quality, the drain water is much less suitable for irrigation.

The EC of the irrigation water averaged about 0.54 millimhos for the period of measurement, with relatively low sodium. It classifies as $C_2 - S_1$ by the U.S. Salinity Lab system, which means

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moderate salinity. While the salinity is greater here than in Mansouria, the calculated leaching requirement does not exceed 15%. The sodium hazard is low.

The average EC at the various sampling points in the drains ranged from 1.06 to 3.26 millimhos. The highest were Drain No. 7 at 2.23 and Gadalla Drain at 3.26. Drain No. 7 classifies as C_3 - S_2, moderately high salinity with moderate sodium hazard. The calculated leaching requirement is 56%, which suggests that a bit more water is required for leaching than for consumptive use. The Gadalla Drain classifies as C_4 - S_2, very high salinity, and should not be used for irrigation if there is any other alternative.

11. Considerable skilled labor is required for irrigation.

A minimum of two irrigators are required in order to obtain a relatively high efficiency using present methods and practices. One irrigator must be skilled at handling the stream of water as it is diverted from one basin or one set of furrows to the next. He must be equipped with a time piece and must understand how long the stream should be applied to each basin or furrow or strip.

The second irrigator must keep the sakia running and must continually police the supply ditch to prevent bank failures and/or seepage through the banks. Often a small boy is used for this task and falls short of fulfilling all requirements. In fact, any time the sakia is left unattended even for a few minutes, the animal may slow down and interrupt the stream flow. Therefore two men and a boy would be an even more adequate team.

12. Many factors thwart the efforts of the district to delivery adequate water to all areas. They include:

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a. Obstruction deliberately placed in canals, such as dams and nets for fishing.

b. Incedental obstructions, such as tree roots, kenaf steam, tree branches, and weeds.

c. Floating debris in canals, including grass, weeds, and tree branches.

d. Leakage through gates during the time they should be closed.

e. Erroneus gage readings that allocate too much water to some areas, leaving too little elsewhere.

f. Sloughing of canal banks.

g. Over-excavation of some canals to clean the canal and obtain material for making bricks. For a given discharge, this tends to lower the head available at the intakes to private ditches.

h. Inability to accurately anticipate the demand one day or one week in advance.

i. Fluctuating supply of water.