Mid Project Report
Volume V

Appendix D
Training Manual

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

By

Egyptian and American Team Members

Egypt Water Use and Management Project

Engineering Research Center
Colorado State University
Fort Collins, Colorado 80523 USA

or

22 El Galaa Street
Bulak, Cairo, ARE

September 1980

ON-FARM WATER MANAGEMENT

PROBLEM IDENTIFICATION MANUAL

CONTENTS

Page

ON-FARM WATER MANAGEMENT

PROBLEM IDENTIFICATION TRAINING MANUAL

PREFACE

A. Objectives of the Manual

This training manual and the training program is central to the purposes of the Egyptian Water Use Project (EWUP). Training skilled personnel in Water Management is essential to the achievement of the project goals and objectives. The stated purposes of the EWUP Project are:

1. "Develop and demonstrate repeatable improved irrigation water management and associated practices that increase agricultural production and improve the social and economic conditions of small farmers."

2. "Increase the institutional capacity to develop and sustain an improved on-farm management program for the betterment of economic and social living levels of small farmers."

Egypt has a noble history of thousands of years of expertise in irrigation and crop production. The research and application of farm water management findings using a process of Problem Identification (PI), Search for Solutions (SS) of irrigation systems and implementation, however, is a new approach to farm water management improvement. Special training, therefore, is needed to increase Egypt's institutional capabilities in the maximization of this new approach. Egypt is one of the first countries where a systematic approach for the evaluation of existing water management systems is being attempted. The particular Research-Development process being used will identify the significant problems, search for viable problem solutions, assess these solutions for farmer use and implement appropriate technologies as a development program. Unlike some approaches, few initial assumptions are made about physical and economic problems prior to PI studies and farmers' attitudes, knowledge, and constraints are not ignored.

As described in this manual, to define how an irrigation system operates requires special technical skills along with a willingness of technical personnel to work closely together as members of a research team. This manual will focus on developing trained personnel to sustain a program of Problem Identification in irrigation systems for the improvement of on-farm water management in Egypt.

The manual is to be utilized as a supplement to a formal training program with the purpose of providing basic materials to accompany lectures and laboratory and field exercises included in the training program. The materials are structured to provide trainees with:

a. An understanding of the process and specific procedures for Problem Identification studies of irrigation systems.

b. An understanding of the principles by which individuals can work closely as members of an interdisciplinary team including farmers.

c. Systematic use of the basic discipline skills and experience at integrating information from all disciplines in Problem Identification.

d. Experience in the definitions, development, and use of field data management systems and procedures to assure data quality control.

e. An understanding of how to utilize PI findings for the Search for Solutions and the implementation of improvements.

B. Philosophy Undergirding the Manual

The basic philosophy upon which this manual is based is described in detail in another publication.* The philosophy undergirding this manual is: a systems approach to farm level irrigation problems, an interdisciplinary rather than a single disciplinary approach to research, team collaboration, and a search for solutions to problems with an on-farm focus combined with a management orientation. Training is given central focus throughout all phases of the process. Both the structure and the format of the manual will reflect these key concepts and major emphases. The major themes throughout this manual are interdisciplinary team work and a management orientation to agricultural production systems.

The manual will focus primarily on skills and skill utilization and will incorporate the development of knowledge and positive attitudes required for successful team implementation of Problem Identification studies. One of the great challenges in this training for EWUP is to create attitudes and behaviors related to the principles and procedures of team building. Unlike formal educational training, this particular type of job training has immediate recognizable usefulness in that it:

1. Is specifically related to defined tasks.
2. Is designed to meet current needs.

---

* A Research Development Process for Improvement of On-Farm Water Management (Clyma, Lowdermilk, and Corey, 1978). Technical Report, Pakistan Water Management Project - AID Contract with Colorado State University, Fort Collins.

3. Has immediate field application.

4. Is a "hands on" skills training.

It is hoped that the philosophy of farm water management and the training of interdisciplinary teams will increasingly become a part of Egypt's research and development activities related to irrigated agriculture.

C. Glossary of Terms Used in this Manual

(Key concepts and terms will be defined in both English and Arabic)

A new approach to research in irrigated agriculture is being taught to individuals from several disciplines whose native language is not English. Thus, it is essential that both trainers and trainees understand the terms used to define the major concepts, attitudes and procedures used in training. Without this shared understanding of basic vocabulary, communication will be poor and misunderstanding can be expected. Both the English and Arabic definitions are given to assure more clarity at the outset.

DEFINITION OF KEY TERMS

Problem Identification

The procedure through which the understanding of an irrigation system is attained in order to define specific shortcomings that prevent the irrigation system from being fully effective in its operation.

المشاكل القائمة :

الطريقة التي من خلالها يمكن فهم نظام الري فهماً واضحاً حتى يمكن
بالتحديد معرفة نقاط الضعف التي تمنع نظام الري من أن يكون مكتمل الأداء.

Systems Approach

A research approach which has as its objective the study of all the component parts pertaining to a specific research problem. With respect to irrigation management such aspects would include physical properties, sociological properties, agronomic properties, economic properties, etc.

طريقة بحثية لفهم موضوع ما :

طريقة بحثية الهدف منها دراسة كل مكونات الاجزاء
المتصلة بمشكلة بحث معينة ، وبالنسبة لإدارة الري لهذه النقاط فهي قد
تشمل الخواص الطبيعية ، الخواص الاجتماعية ، الخواص الزراعية ،
الخواص الاقتصادية ... الخ ...

Interdisciplinary Research

A research approach where different academic disciplines come together to examine a research problem. The output of the study consists of an integrated approach where each discipline takes into consideration the effects of the other disciplines in analysis and in recommendations.

بحث تدريبي مشترك :

بحث لفهم موضوع ما والذي يشترك فيه أكثر من فئة (أو نظام) أكاديمي بحيث يجتمعوا معا لاختبار مشكلة بحثية معينة ونتائج الدراسة تحتوي على مجموعة الاتجاهات للفئات المختلفة والتي أخذ كل نظام في اعتباره تأثير آراء النظم الأخرى في التحاليل والتوصيات .

Research Team

Individuals who work together on a research problem.

فريق بحث :

مجموعة أفراد يعملوا معا في مشكلة بحثية .

Reconnaissance

Preliminary observations of a research area which allows the members of the research team to obtain general information which may serve as a means to provide an initial direction for research activity.

استكشاف أو استطلاع :

ملاحظات أولية على منطقة البحث تسمح لأعضاء الفريق البحثي الحصول على معلومات عامة تساعدهم على تكوين اتجاه مبدئي للقيام بنشاط بحثي .

Water Management

The control and administration of the use of water from the point of storage through conveyance, delivery to farms, application to crops, utilization by plants, and removal or drainage.

إدارة المياه :

تنظيم إدارة استخدام المياه من البداية في الخزان خلال المحولات ثم إلى الحقل ثم كيفية ري المحاصيل ومدى استفادة النبات به حتى طريقة الصرف .

Farmer Client

The focus of a research project which encourages the concentration of the researchers to be on the farmer and also seeks the involvement of the farmer in the research process.

الفلاح المنتفع :

تركيز مشروع البحث الذي يشجع الباحثين على أن يكونوا متفهمين للفلاح وكذلك يشركوا الفلاح في خطوات البحث لإمكانية تحقيق التقدم البحثي .

Action Research

A systematic investigation which is conducted specifically for a defined action program and which does not conclude with the presentation of data collected. Testing is conducted under the real world conditions of the recipient of the research.

فاعلية البحث :

نظام البحث الذي يجري لفرصة تحديد برنامج فعال والذي لا يعتمد على وجود البيانات المجمعة الموجوده . ولكنه يجري ضمن الاختبارات تحت الظروف الحقيقية الطبيعية الموجوده في الحقل ولدى الفلاح .

Applied Research

The direction or utilization of knowledge to the improvement or change of specific materials or conditions.

البحث التطبيقي :

التوجيه أو الانتفاع بالمعلومات لغرض تحسين أو تغيير ظروف
أو مواد محددة .

Evaluative Research

The process in which the scientific method is consciously applied for the purpose of making a judgment about the value of methods, processes, programs, etc., about which there is concern utilizing various types of data, decision rules, and criteria agreed upon.

البحث التقييمي :

الطريقة العلمية المستخدمة في التقييم والحكم على مدى تقدم الطرق والبرامج
التي تدور حول مدى الانتفاع بكل المعلومات المختلفة والقرارات التي يتفق عليها الباحث والفلاح

Adaptive Research

A systematic investigation whose purpose is to fit new technological advances into different environments.

البحث المناسب :

البحث المناسب الذي الغرض منه ملاءمة التكنولوجيا الحديثة المتقدمة
في البيئات المختلفة .

Communication

The transmission of thoughts, ideas, information, etc. from one individual or group to another individual or group.

<u>الاتصالات</u> :

نقل الأفكار والخطط والمعلومات وما إلى ذلك من فرد أو مجموعة إلى فرد آخر أو مجموعة أخرى.

Team Building

The process in which individuals involved in a research program change from single purpose investigations by each participant to an integrated study involving the contributions of all the participants.

<u>بناء الفريق</u> :

هو العملية التي يتغير فيها الأفراد الباحثين لبرنامج بحث من غرضه بحث واحد يبحث فيه كل فرد على حده إلى دراسة شاملة تحتوي على كل خدمات المشاركين.

Conflict Resolution

The process where disagreement among members of the research team is confronted and a decision is made on how that disagreement will be resolved.

<u>تضارب القرار</u> :

عملية عدم موافقة (أو اختلاف) بين أعضاء أفراد الفريق البحث، والتي يتخذ فيها القرار بكيفية العمل على حل ومعالجة عدم التوافق هذه.

Management Focus

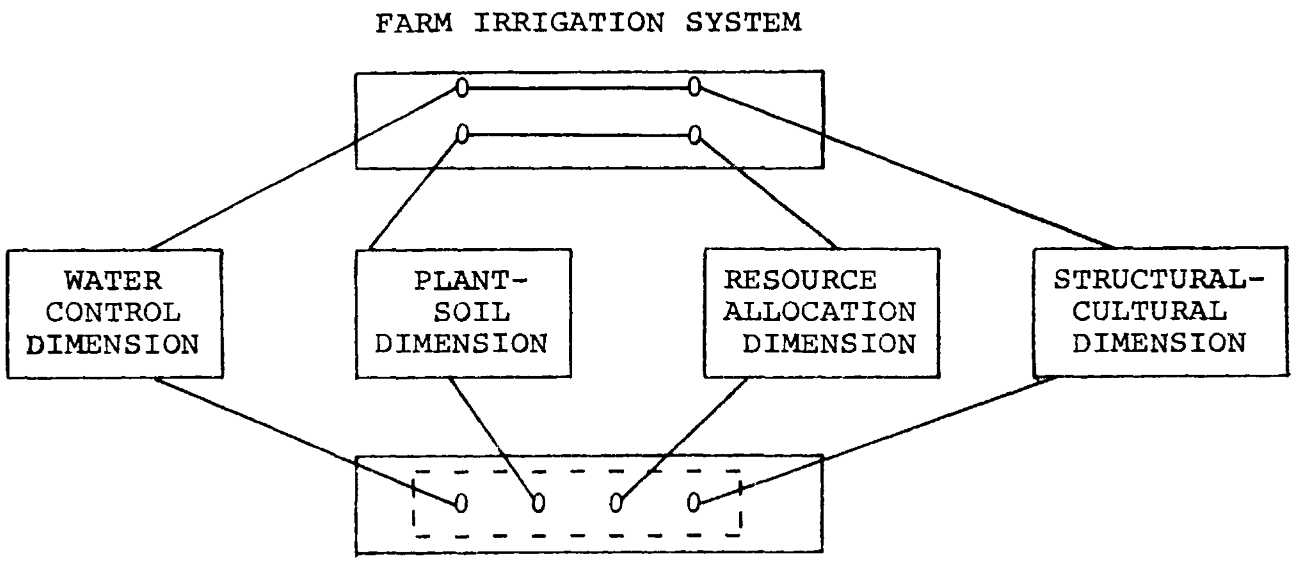
An appreciation by the researchers of the fact that a farmer is a decision-maker on his farm and that the operation of the farm is due to a rational approach of identifying a problem, assessing alternative solutions to that problem, and applying the solution to the farm. Any recommendations by the research group must be analyzed as to their consequences.

مركز الإدارة :

ترحيب من الباحثين بأن يكون الفلاح صانعا للقرار في حقله ، والتي يكون مجال العمل والبحث كنتيجة للتعرف وفهم مشكلة ما ، وتقييم حلول بديلة لهذه المشكلة ، ثم إيجاد الحل وتطبيقه لهذا الحقل . وأي توصيات لمجموعة الباحثين تحلل بالتوالي على حسب أهميتها بالنسبة لهم .

D. <u>Basic Format of the Manual</u>

The basic technical content is presented in such a way as to answer five basic questions. Chapter I is based on the question, "What is Problem Identification?" Chapter II addresses the question, "What are the subsystems (dimensions) that constitute a farm irrigation system?" Chapter II is based on the question, "How is the farmer's decision-making process affected by the interaction between the various subsystems?" These questions are conceptualized as shown in the following diagram:



Chapter I will provide information about the Problem Identification concept. This will include the dimensions of Problem Identification, the procedure involved in the Problem Identification process, and certain aspects of team building and teamwork.

Chapter II will examine the four major dimensions in the farm system: resource allocation, structural-cultural, water control, and plant-soil. Within each of these dimensions, critical elements which constitute the substance of the particular dimension will be discussed. At the conclusion of this chapter, the trainee should be sensitized as to what is included in analyzing a farm irrigation system.

The final chapter examines how the various dimensions are integrated with each other to form the farm irrigation system. What is of crucial concern in this chapter is to examine the complexity of the farm irrigation system in terms of the various dimensions to show what the farmer has to confront in making a management decision pertaining to his crops. Therefore, at the conclusion of this chapter, the trainee should not only be sensitized to the various aspects of a farm irrigation system, but also be aware of the possible interactions which are present in that system and the resulting complexities which plague the farmer in his attempt to produce a crop. From this realization of the farm experience, the need for a systematic interdisciplinary research approach pertaining to the problem of this area of study should become apparent.

The remaining content of the manual will include technical How-To-Do-It materials on specific measurements and methodologies. For example, these will include such How-To-Do-It series as:

How to evaluate furrow irrigation.

How to make a topographic map.

How to do cost-benefit analyses.

How to do social systems mapping.

These "How-To-Do-It Series" will be referred to in the text but described in detail in Volume II.

Where possible, data from recent field studies in Egypt will be utilized. In the presentation of the material several formats will be utilized in the text for increased clarity and usefulness. These will include checklists, flow charts, diagrams, graphic figures, and photographs. The level of English used is geared to meet the need of technical personnel who utilize English as a second language.

This manual contains the basic materials to be covered in a formal training course; however, it is not designed to substitute for such a course. It is prepared to complement structured and non-structured learning situations which include lecture sessions, lab exercises, panel discussions, films and videotapes, field trips, and field exercises.

CHAPTER I

ORIENTATION TOWARD PROBLEM IDENTIFICATION

Summary of Chapter

This chapter will provide the following information:

1. Definition of Problem Identification
2. Essential Components of the Problem Identification Process
3. Value of Problem Identification
4. General Aspects of Problem Identification
5. Management/Organization for Team Work
6. Barriers to Problem Identification
7. Framework for Problem Identification
8. Implementation Checklist
9. Team Builders Checklist

CHAPTER I

ORIENTATION TOWARD PROBLEM IDENTIFICATION

The Problem Identification procedure is a means by which an irrigation system may be evaluated in order to initiate an effective effort to solve particular problems existing in that system. What this chapter will do is to introduce the trainee to the problem identification process in such a manner as to sensitize that individual on how to perform a problem identification task. This procedure will first be defined and its essential components described. After an explanation of the value of problem identification is presented, the general aspects of the procedure will be elaborated which will then lead the reader to the critical feature of managing a team performing a problem identification procedure. Barriers to problem identification will then be examined. All of the material described up to now sets the context of problem identification and serves as an introduction to the remaining sections which define the problem identification frame of action and how to implement the procedure. After completing this chapter, the trainee should be sensitized as to the importance of problem identification and how this procedure is performed.

DEFINITION OF PROBLEM IDENTIFICATION

The word problem is difficult to define because each trainee and each discipline will have different definitions. The definition used in this manual is that a problem is the gap or distance between what is and what ought or should be. For example, a farmer might perceive a problem as, "I am not getting enough yields of cotton as I know is possible." An agronomist might perceive a problem as "yields of this crop are not as high as they could be." The simple figure below suggests the problem as what is and what should be.

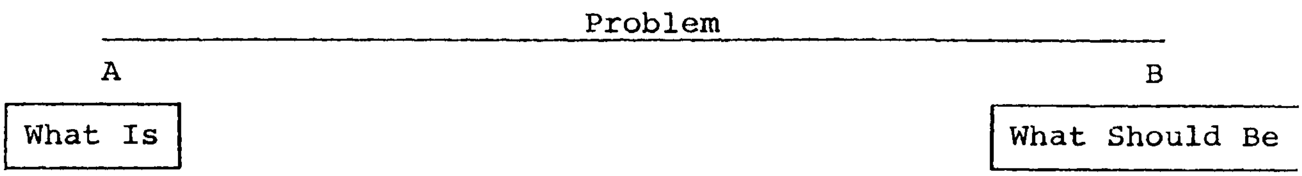


Figure 1.1. Problems.

The gap between A and B could refer to the problem of low yields, low profits, or crop quality. The problem gap represents lack of data, knowledge, or information.

Problem Identification is one phase of a research development process. It consists of an interdisciplinary approach with farmer involvement to achieve and to understand how the farm irrigation system is operating. The end product of Problem Identification is an understanding of why the system is not operating as it should be. Problem Identification includes both quantitative and qualitative methods, as well as techniques for deciding which problem is most important. From these techniques and methods, solutions to the problem can be found later in the process.

ESSENTIAL COMPONENTS OF THE RESEARCH DEVELOPMENT PROCESS

The basic concepts and essential components utilized in the research development process include: a systems approach, interdisciplinary focus, on-farm farmer involvement, management focus, open communication, training of personnel, building institutional capacity, evaluation, and valuation. Of these those which are most essential to the Problem Identification Phase* are: interdisciplinary approach to a known systems problem, and an on-farm involvement.

Interdisciplinary Approach

The interdisciplinary team approach which involves agronomists, engineers, economists, and sociologists working closely together is a relatively new concept for Egypt. The single discipline approach will not adequately identify major problems at the farm level. For example, low conveyance efficiencies may be related to lack of cleaning and maintenance of channels which in turn may be related to lack of adequately

*Other phases include development of solutions, assessment of technologies, and project implementation. A Research Development Process for Improvement of On-Farm Water Management. Clyma, Wayne, Max Lowdermilk, and Gil Corey. Water Management Technical Report #47. Colorado State University, Fort Collins.

enforced regulations or farmer organization. Economic incentives or farmer knowledge may also be closely related to the problem. Almost any problem at the farm level has interdisciplinary implications.

Farmer Participation

The dimension "farmer involvement" is also unique because in most countries research is done without much if any involvement of the farmer. In fact, the farmer is often thought of as an obstruction rather than a participant. The focus of Problem Identification is to involve the farmer on his farm in a search for priority problems and their solutions. It is not enough to identify through measurements or observations that farmers over-irrigate, one must also learn from the farmer how and why he applies water to crops if the purpose is to change his irrigation behavior. Much has been written in Egypt about the lack of understanding by research personnel with regard to the Egyptian farmer. The Problem Identification approach which you are learning, and helping to introduce to Egyptian policy makers and researchers may well be one of the outstanding contributions of the EWUP. With its interdisciplinary and farmer participation focus, the potential to work on a meaningful solution is greatly enhanced over traditional research approaches. A major contribution of the EWUP project will likely be in introducing this new concept of research and development throughout Egypt, as well as in other countries.

A central focus of Problem Identification is to help us understand the farmer and his irrigation systems problems better. We will emphasize several times in this manual that far too often we researchers conduct our work as though we already know what the real problems are. We, therefore, are often tempted to bypass Problem Identification to get on with what we think is the "important business of solving critical problems." There is, however, substantial evidence from research projects around the world that we researchers do not always know what the real problems are and often begin work on the first problem we assume to be important or interesting. This is especially true where most of the research is conducted on a single discipline basis at research stations, in the lab, or under non-farm conditions. We stress the simple fact that the more we are removed from the daily farm situation the more we tend to deal increasingly with assumed problems.

Basically, Problem Identification is a learning process where researcher and farmer client are mutually involved in learning how the system operates and what aspects of the system are not working adequately. Usually researchers approach research and development as though involved in only finding problems and their solutions to teach the farmer. Seldom do the more educated and specialized view the process as one in which there is also something to be learned from the farmer. With such an attitude and approach there should be little wonder why farmers often refuse to adopt our findings which they may perceive as totally irrelevant to their real problems. After all, the farmer is engaged daily at the farm level, and he should have much to teach us about how he views his own situation. We, therefore, strongly advocate an approach to learn what we can from the farmer through the Problem Identification Process.

We make no apology for the position that there is a need to adopt a farming systems* approach whereby researchers and clients learn together how the farm irrigation system operates, what constraints exist, and how they can be removed for improved system performance for farmers. We should also stress that the purpose is not only to identify "problems," but also to discover what is currently operating effectively. Often farmers have evolved good production approaches and procedures which may need to be extended to other farmers.

VALUE OF PROBLEM IDENTIFICATION

Many of you may not agree that little is known about the content and structure of the traditional farming system in Egypt. Certainly specific problems are understood. In Egypt you have done outstanding research in fertility requirements of crops,

---

*The work system refers to a number of components within certain boundaries which interact with one another. These objects work together towards some goal and the entire system is surrounded by a particular environment. A farm system, therefore, might consist of the farmer, his fields, his crops, and his livestock, all of which are surrounded by other farmers and fields. An irrigation system might consist of objects which help in the conveyance, application, use and removal of water. The goal of either the farm system or the irrigation system might be to increase the gross production of the farm.

water requirements of certain crops, seed viability and germination, and many other significant areas. The area that is missing is an approach for understanding the content and structure of the farming system constraints, and solutions to these problems. Note that the focus is on system.

In Egypt there is sufficient farm level data available for planners. Much research takes place in labs, at research stations, and in other places which are far removed from the farm situation. Though we attempt to simulate farm conditions at research stations and often develop sophisticated computer models, we run the risk of misrepresenting acutal farm conditions and problems. This is not to say that research station results, laboratory findings, or computer model results are not useful; however, often wrong assumptions are made because they are not adequately based on farm realities.

Again we stress to you, the trainee, that while much research may be available in Egypt related to farm irrigation systems, it is usaully fragmented and generally it neglects system problems.

A major objection viewed by some is that Problem Identification is costly and requires too much time. After all, "We know the problems at the farm level, so why waste the time and money this process requires?" The time needed for adequate Problem Identification varies greatly depending on previous research and the particular need of a country. Our view is that time spent in adequately defining the system problems is time saved. Often the results of agricultural research are not implemented because the wrong problems were researched. Perhaps you can identify cases of this in Egypt. Also, if the problems have really been known in a country, why has something not been done to solve them? Rather than assume that we know what the problems are, we take the opposite stance that we do not know what the complex and interdependent system problems might be. We go to the farm level to find out, and in so doing we obtain a more valid indication of specific problems which when we try to solve those problems allows for a more effective use of our time, personnel, and resources.

PROBLEM IDENTIFICATION OBJECTIVES

The value of the Problem Identification process may be seen by its objectives:

1. To provide an understanding of the farm irrigation system.
2. To identify the major constraints which currently limit agricultural production.
3. To provide the priority problems for which a search for solutions will be made through more intensive research.
4. To provide data quickly for policy makers about the state of farm irrigation.
5. To provide training for farm level investigators in team approaches to research.

6. To provide base line data that can be used for evaluation of project success.
7. To provide a means by which time and other scarce resources may be used more effectively.

GENERAL ASPECTS OF PROBLEM IDENTIFICATION

Several aspects of Problem Identification include: requisites for Problem Identification, management and organization, farmer involvement, and barriers to Problem Identification.

Requirements

The essential requirements for Problem Identification studies include committed team members, management, team communication, and client involvement.

Each of these are defined briefly:

Commitment - Refers to the professional and personal pledge of team members to Problem Identification as a valuable process, to working on an interdisciplinary team, and to being involved at the farm level in research activities to benefit the chief clients - the farm operators.

Management - Refers to effective, efficient, and judicious use of means which provide all concerned with the facilities, coordination, and incentive to function at a high level of professional productivity providing positive feedback to each team member and useful results which will help the farmer to improve his performance.

Team Collaboration - Refers to close cooperation and team work which makes each endeavor a useful experience.

Communication - Refers to an open process by which information is shared with all parties concerned including researcher to farmer, farmer to researcher, and both to and with authorities. To be successful mutual understanding must occur.

Client Involvement - Refers to the active involvement of the farmers concerned in the Problem Identification Process.

Essential requirements for successful Problem Identification are given below with a list of attributes which suggest the types of things that need to be considered by the team. Examples are provided in the remainder of this chapter about each requisite. (See Figure 1.2.)

Requisites	Checklist of Attributes
a. Commitment	Knowledge and skill in discipline Broad training and experience Respect for contributions of other disciplines Flexibility Demonstrated ability to work well on teams Committed to ID research Commitment to farmer clients Willingness to learn
b. Management	Demonstrated management abilities Skills in program planning Skill in settling disputes Skills in task assignments Gives attention to detail Ability to communicate Does not favor a single discipline Evaluation skills Ability to communicate and skills in human relations
c. Communication	Open communiçation Regular staff meeting for planning Communication to and from clients Communication to and from all team members Communication to and from officials Desire to understand each person and situation
d. Teamwork	Goal setting Developing a framework and design of study Agreement on methodologies Selection of sample Problem solving Evaluation of work Data management plans Analysis of data and reporting

Figure 1.2. Basic requirements for successful team work.

MANAGEMENT/ORGANIZATION FOR TEAM WORK

Organization for team work has the two major dimensions of coordination and integration. Coordination means, "to achieve a harmonious common action or effort." Integration means "to make into a whole by bringing all the parts together into one." While coordination deals more with the basic organizational structure of project personnel, integration refers to the ability of project leaders and team members to achieve unity of purpose. The organizational chart of the EWUP is provided in Figure 1.3. This shows the relative position of project personnel. The organizational chart, however, does not make a team; it simply shows the relationship of project directors, senior research officers, researchers and other personnel. Coordination refers to organizing personnel as well as locating, maintaining, and distributing material and equipment. Logistics which include the procurement, distribution, maintenance, and sometimes retrieval of material and personnel. Unless the team has the equipment it needs, a time frame, and transportation, it cannot do its work. Often a good team may be developed but because of simple transportation problems, it is unable to do its job. A checklist similiar to the one in Annex III, is needed by every team leader for all the equipment required and the logistics needed for Problem Identification studies.

Integration refers to how all disciplines are put together to form a unified team. That all project personnel have their place on an organizational chart and are coordinated by the

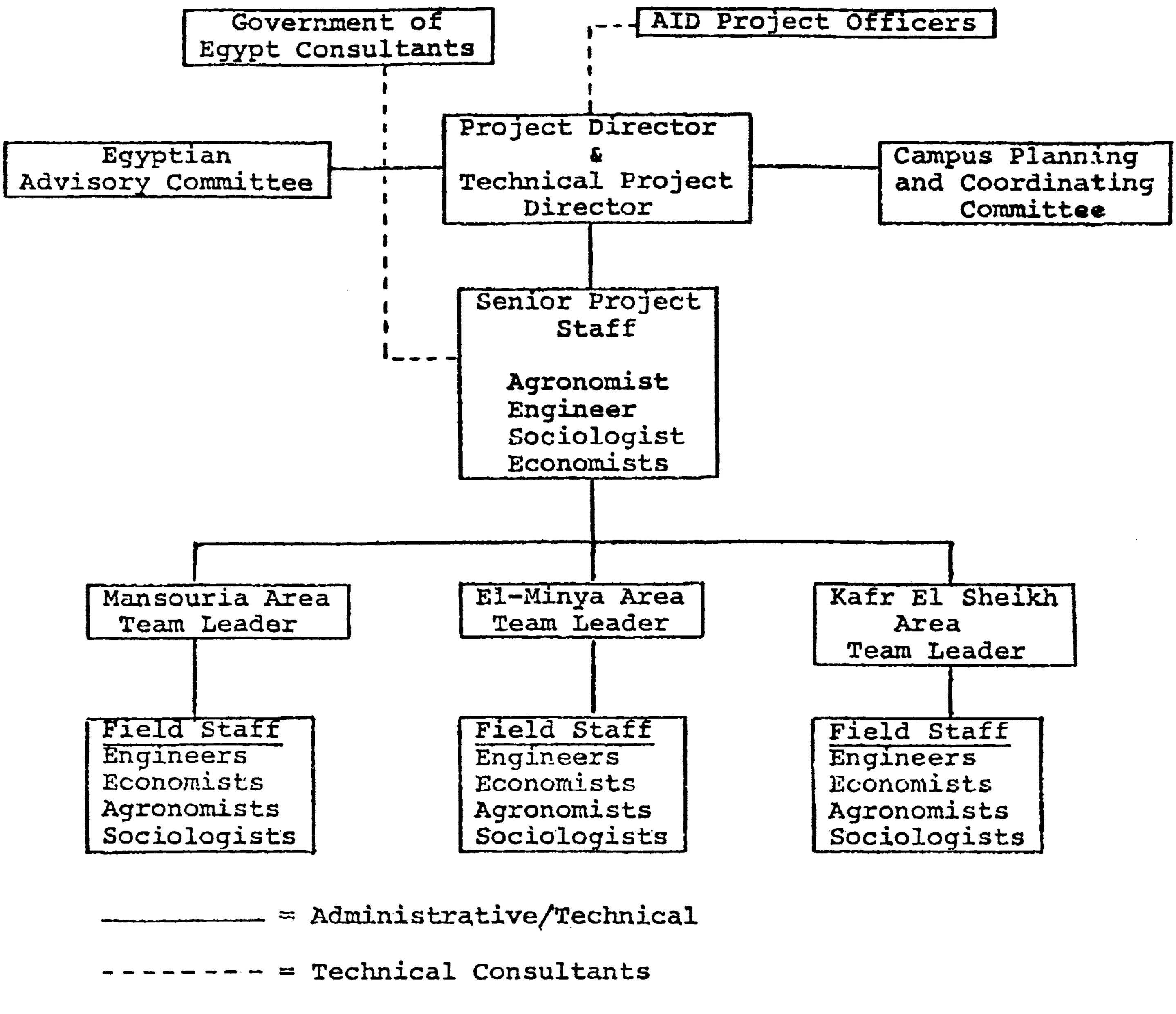


Figure 1.3. Organizational structure of EWUP.

project leaders does not mean they are a team. Even the knowledge of each member's role or responsibilities does not assure a team. There are often soccer organizations which have assembled players but in some games they play as individuals rather than as a team. In Arabic one of the most essential terms is ITAHAD which means unity and cooperation. A well-integrated team is one with ITAHAD where each discipline becomes a vital part of the whole. Integration never just happens, the team leader must continually work at integrating the team. This requires that each member is committed to the same goals, knows his or her specific role, and works for the good of the team. This is often a difficult task because it requires team members who watn to learn, a supportive group climate, motivation, and skills in dealing with people. Needless to mention that if the team leader cannot do this, this team will suffer. Again, let us refer to the soccer team. Unless there is unity of purpose of teamwork even superstars cannot win the crucial games against teams with lesser starts who are well integrated and play together.

In the Hadith, one of the Holy Books of Islam, there is a significant statement about learning that relates to Problem Identification studies. It is translated as "If there is knowledge in China, go there and learn." We are saying to all researchers, "There is knowledge at the farm and village level and from the farmer; go there and learn how the farm irrigation system works." We are asking all of you and ourselves to be true Talib Elm, searcher of knowledge, and search for knowledge at the farm and village level and from the farmers involved. The Problem Identification process focus is on the farm level conditions and the farmer client. This also implies focus on the village level, however, the central focus is on the farmers at the meska level.

This is why we view Problem Identification as a learning model. Figure 1.4 below represents a very simple diagram which emphasizes mutual learning on the part of the farmers and the researchers.

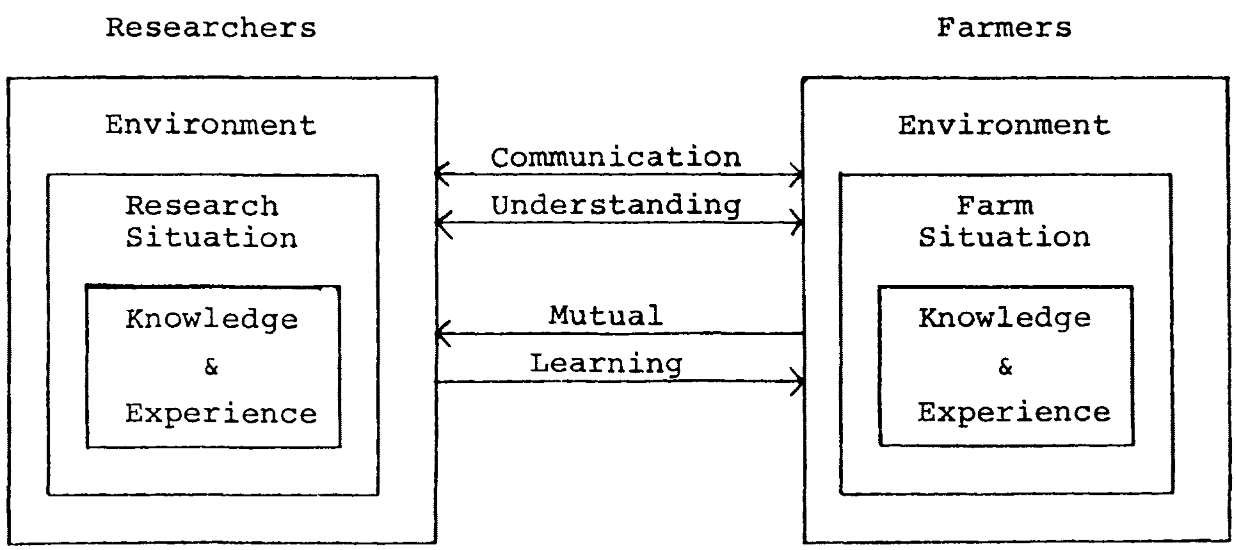


Figure 1.4. Mutual learning model.

Unless the environments of the researchers and farmers are linked properly, then learning is inhibited. Unless the research situation is geared to the real farm situation, it is unlikely that farmers can be significantly helped by researchers.

If mutual learning is accepted as basic to Problem Identification, then the following general principles should prevail throughout the training:

1. Problem Identification should involve teamwork and include all disciplines required as well as farmers to assure that a systems approach is made to a systems problem.
2. Problem Identification should be task oriented rather than discipline oriented.
3. Problem Identification should be a learning experience for researchers and farmers alike and lead to greater understanding of the farm system and its subsystems.
4. Problem Identification should be experimental in the sense that it is never final in the research and development process. At stages other than problem identification, the researchers may have to go back and search for the sources of problems ignored earlier.

BARRIERS TO PROBLEM IDENTIFICATION

Problem Identification is a process whose origin is based on certain assumptions and whose procedures demand certain criteria to be followed. What follows is a list of situations, attitudes, and behaviors which are barriers to the effective use of the Problem Identification procedure.

1. Inability to see the system as a system.
2. Confusion of the researcher's image of how the system should work with how the system really works.
3. Lack of interaction and communication among researchers in planning for Problem Identification.
4. Lack of patience for identifying the real problems first before solutions are sought. Attitude of "Let's go on with the real work."
5. Trained inability to appreciate the contributions of other disciplines.
6. Assumptions that the "expert" should know what the problem is and how to solve it without verification in a specific situation.
7. Lack of appreciation of folk knowledge which clients have acquired and of the client's role in decision making.
8. Assumption that development problems can be solved quickly by application of more technology without need to consider the social factors.
9. Lack of understanding and sensitivity to cross-cultural differences that exist between researchers and clients and among farmer clients.

FRAMEWORK FOR PROBLEM IDENTIFICATION

This section outlines some of the procedures involved in Problem Identification field studies. Figure 1.5 provides a flow of major activities for Problem Identification. The basic

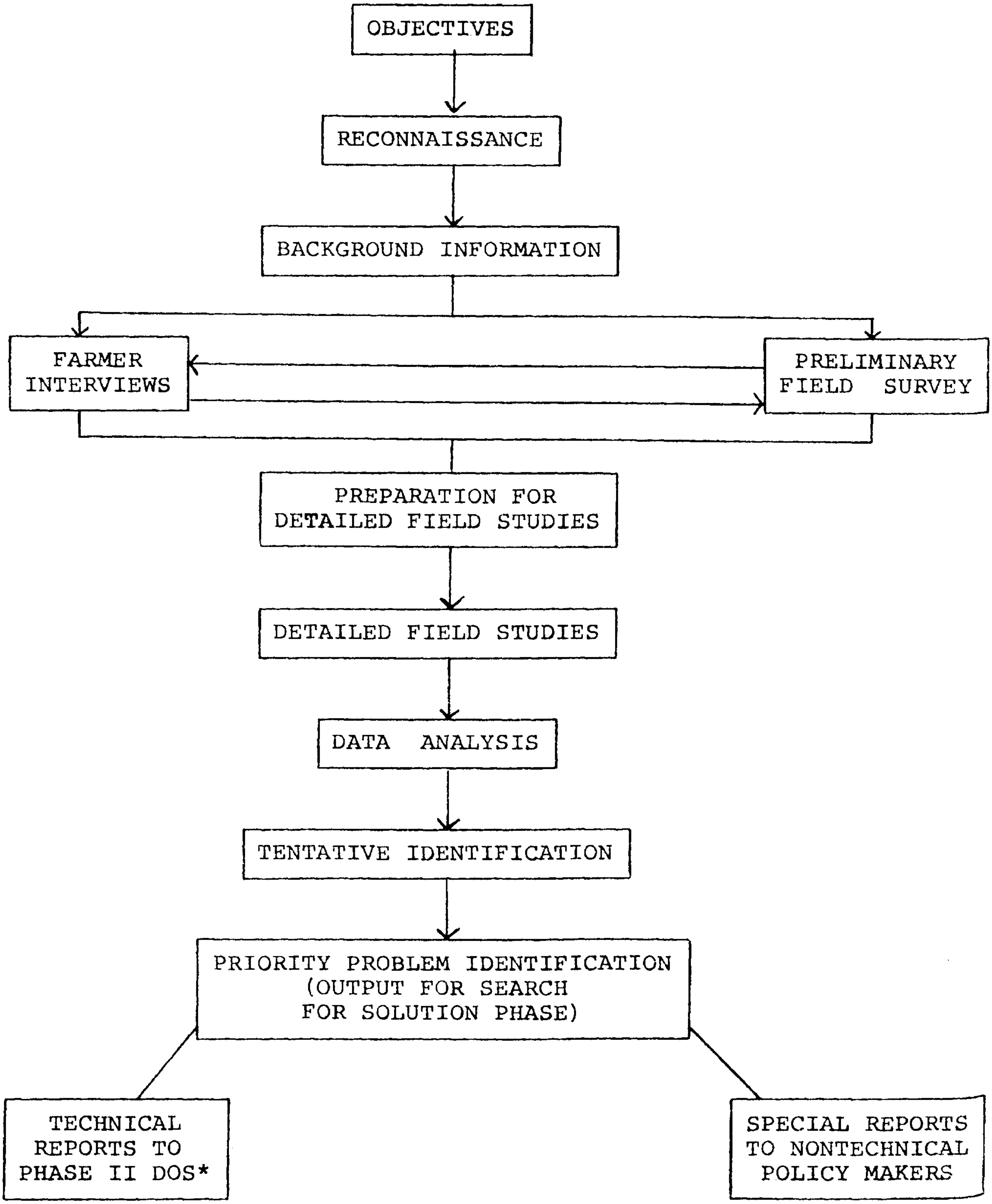


Figure 1.5. Flow diagram of major activities for identification of farm production constraints in Egypt.

dimensions of Problem Identification include the following activities:

a. Clear statement of objectives of Problem Identification.

b. Reconnaissance activities.

   1. Gather background information.

   2. Farmer interviews.

   3. Preliminary field survey.

c. Review of findings for preparing the detailed Problem Identification study.

First, there is a need for clearly stated objectives. The goals of the project are increased food production, and improved level of living for small farmers. This is too general for Problem Identification studies. The more specific objectives of Problem Identification listed earlier are:

a. To gain an understanding of how the organization of the system and the conditions of the situation influence farm decisions.

b. To identify the major physical, biological, socio-economic, and organizational constraints in the farm system which limit agricultural production.

c. To determine which problems are most important so that more intensive research can be done for solution of problems.

These objectives are such that they provide definite focus to those involved. The focus is on-farm, constraints to agricultural production, and developing a priority list of problems which limit production for more intensive research. This indicates that Problem Identification is not to include intensive research at the Research Station but to determine what the major problems are.

The Reconnaissance phase is basically a learning situation which provides an overview of the farm situation for the team members. This includes getting background information from previous available research which should be summarized in usable form. An agronomist, for example, will want to have information on climate, soils, current soil-water management practices, and levels of current yields. Reconnaissance visits should be arranged with selected officials of organizations related to agriculture such as governmental departments, universities, and selected personnel at research institutes. Team members must remember in such visits, however, that there is usually an "official view" which may or may not represent completely the "real world view." Team members involved in Problem Identification should remain objective and reserve their views about the "real problems" until empirical field data document what the real problems are.

Reconnaissance activities also include informal interviews with selected farmers where information is sought about the farmer's views concerning crop production levels and constraints, management practices, economic and sociological aspects of his operation. Experience in Egypt has shown that the number of researchers approaching the farmer should be relatively small so as not to overwhelm or frighten the farmer. Questions should be carefully prepared in advance to yield useful information. Also, those who interview farmers should be skilled in interviewing techniques. The team must prepare for these farmer interviews and not simply ask what is of interest to only a few team members. The information obtained from the farmer should be compared to that provided by officials and research stations by team members who should conduct meetings at the end of each day's activities.

Reconnaissance also includes preliminary field surveys which are not to be confused with the more detailed surveys to be conducted later. The preliminary field survey is designed to provide an understanding and <u>overview</u> of the farm and general areas where more intensive focus may be needed in the detailed survey to follow. For example, the agronomist will want to gain understanding of the general soil and water conditions, the growth status of various crops and current cropping practices. Likewise, the engineer may want to learn about current irrigation practices, flow rates, and other factors. Prior to the field visit each team member should have gathered sufficient background information to develop a checklist of things to observe or questions to ask to acquire information. For example, the agronomist may want to observe plant growth characteristics. His experience will help him decide if growth is "normal" or "abnormal." He may want to observe "above ground characteristics" such as status of plant nutrition, water relationships, pest infestation, or weeds. The agronomist may also want to make observations of root systems, crop stands, physical soil characteristics, and current crop management practices.

Each member of the team will collect preliminary data which is to be used for planning the detailed field studies. Remember that for reconnaissance purpose there is always the danger of collecting too much data or information. Remember that the purpose is to collect information from farmers, farmer's fields, selected individuals who work directly with farmers, and officials about the farm level situation. This information will be utilized in preparation of the more detailed or formal Problem Identification field study.

Figure 1.5 shows another set of activities as preparation for detailed field studies. This is a basic planning activity where what has been learned from reconnaissance is utilized as input for the more formal studies. Decisions on specific Problem Identification objectives, site selection, methodologies, data management, responsibilities of personnel, time frames, and the logistics must be carefully planned. (A checklist is provided on pages 25 to 26 of some of the activities which are planned by the team in close collaboration.)

The detailed field studies are then implemented to confirm constraints to production, some of which may have been tentatively identified in the informal preliminary survey. Using the example from agronomy again, more detailed measurements may be needed to ascertain the following data: yield and quality of crops, plant nutrient status, infiltration rates, soil water salinity and sodicity, soil pH, irrigation practices, crop variety adaptability, and classification of pest infestations and control measures. Engineers, sociologists, and economists will also make more detailed measurements of significant variables and their interactions growing out of insights gained from reconnaissance activities and experience.

After the data are collected, data analysis must be completed. Data analysis, however, must be carefully planned long in advance if it is to provide useful findings. Most often data management including analysis is not planned. After the data are collected it may be too late. Individual researchers may know how they will analyze "their" data; however, they seldom know how the data of several disciplines will be analyzed as a whole.

As seen from the Mansouria case study (see Annex I), inadequate preplanning was done; therefore, each discipline was forced to analyze its particular data separately. Using such an approach definite problems result for team research. For example, we may want to know what the major factors are which influence the yields of specific crops. Data may be available on fertilizer use, seed rates, water application, sowing dates, and farmer extension contacts from several of the participating disciplines. In order to run a multiple regression or a step wise regression, these date have to be such that they can be correlated. It is not sufficient to have data on the above factors. Unless data are in a form where correlations can be made with the dependent variables, many types of analyses cannot be complted. In other words, data never speak for themselves; they must be analyzed and interpreted objectively and correctly.

In brief, data analysis should be designed in such a way that the results will indicate what the priority farm problems are which limit production. To provide a long list of problems without showing their relative significance in relationship to each other is not sufficient. Problems or constraints to crop production must be ranked in relationship to specified criteria, such as constraints to crop production, or levels of living of small farmers. Quantitative analysis alone will not necessarily provide the ranking of problems for it must be remembered that all research findings evolve from the value judgments of the researcher and will be interpreted along the lines of those judgments.

Figure 1.5 provides only a broad general framework for Problem Identification studies. While a more detailed explanation is provided in this manual, the point to stress here is that the framework presented <u>does not</u> imply that P.I. is a "locked step" sequence of events. Often several activities will overlap, others may take place simultaneously, and usually there will be a process of going back and forth between the steps or phases shown in Figure 1.5.

IMPLEMENTATION OF PROBLEM IDENTIFICATION

While there are no fixed steps for conducting Problem Identification field studies, the following sequence is given with the understanding that steps often overlap. Often several activities take place simultaneously. A step is not necessarily completed for one may go back and forth among steps as more information is made available. The idealized list of steps is given in the form of a checklist to help team members organize their activities.

a. Preparation for Problem Identification Studies

- ___ Selection of Investigators
- ___ Selection of a Team Leader
- ___ Team Building Training
- ___ Discipline Training in Field Techniques
- ___ Setting of Purposes and Objectives of Problem Identification Studies

b. Gaining an Overview of System

- ___ Identification of Available Research
- ___ Discussion with Officials of Relevant Organization about their Values
- ___ Obtaining Maps and Other Relevant Resources
- ___ Development of Checklists of Possible Problem Areas
- ___ Development of Lists of Other People to Contact

c. Organization of Initial Field Visits

___ Criteria for Field Sites to Visit

___ Responsibilities of Team Members for Initial Field Visits

___ Logistics for Initial Field Visit

d. Implementing Initial Field Visits (activities and procedures)

___ Visits to Farms

___ Observation Methods for All Team Members

___ Nonstructured interviews with Farmers and Those Who Work with Farmers Directly

___ Selected Measurements

___ Team Work and Preparation of Preliminary Report on Initial Field Visits

___ Establish Criteria for Selection of Sample Sites for Formal Problem Identification Studies

e. Design of Formal Problem Identification Studies

___ Decisions on Site Selection

___ Develop Objectives for Confirmation/Delineation of Problems

___ Decision on Methodologies

___ Design and Test Survey Instruments

___ Design Selection Criteria for Field Workers

___ Establish Responsibilities for All Field Workers

___ Design Evaluation Methods for Field Workers

___ Develop Checklist for Equipment Needs and Logistics

___ Establish Time Frame for Problem Identification Studies

___ Establish Data Management Plans

f. Implement Formal Field Investigation

___ Develop Physical Maps Required

___ Develop Methods for Data Quality Control and Field Supervision

___ Collect Data

___ Analyze Data and Interpret

___ Write Team Report on Findings

___ Rewrite Report for Selected Audiences

g. Establish Criteria for Selection

___ Explain Assumptions Used

___ Clarify Quantitative or Qualitative Methods

___ Rank Problem in Terms of Criteria

As explained earlier, the sequence of activities is not established as an inflexible set of steps. Rather, it is to be utilized as a guide or checklist to keep all team members headed in the right direction. The checklist may be added to/or changed and refined depending on the particular circumstances confronting the team.

<u>Initial field visits, or reconnaissance, provide the team an overview of the system</u>. This phase provides input into the design of the formal Problem Identification studies. Reconnaissance

is essentially a scanning process as used often by the military. Before a battle there are usually scouts who attempt to scan the enemy to find the most vulnerable places for a campaign. Reconnaissance is to determine major boundaries, problem areas and possible variables to be investigated. It is not an exhaustive exercise where the system is examined in detail. An analogy is the use of two types of cameras on weather satellites. One camera (reconnaissance) takes broad angle pictures covering large portions of the sky in order to gain a broad picture. Where there is an indication from cloud formations and other phenomena that there is a likelihood of a storm, the other camera on the weather satellite (detailed investigation) focuses in on the potential trouble spots and investigates the smaller segments in greater detail. Thus, the Problem Identification process constitutes two different phases, reconnaissance and detailed investigation, both of which when properly used help the researchers to delineate problems in a most effective manner.

A successful Problem Identification venture is contingent upon all members of the research group working as an integrated team. Teamwork is crucial for the effective gathering, utilization, and analysis of necessary information which will be used for the proper identification of specific problems. Special sessions will be provided for the discussion of team building during the training program and the following checklist will provide some of the guiding principles behind proper team building. Despite these guidelines, the best way to learn team building is by participating on a team.

TEAM BUILDER'S CHECKLIST

___ 1. Does each team member, including myself, have a clear understanding of the agreed goals of the team?

___ 2. Is every team member, including myself, sufficiently committed to the team goals to devote the necessary effort to achieve them?

___ 3. Does every team member, including myself, clearly understand his or her assigned role on the team and the the importance of that role to team success?

___ 4. Is every team member, including myself, committed to fulfilling his or her assigned role to the best of his or her ability?

___ 5. Does every team member, including myself, clearly understand the plan for reaching team goals and, especially, does every team member understand precisely the part of the planned activity he or she is responsible for?

___ 6. Does every team member, including myself, accept the performance standards for individual activity and the total team activity necessary for the team to achieve its goals?

___ 7. Am I sharing information on each team member's performance, and the team as a whole on team performances?

___ 8. Am I providing the coaching and supervision necessary to help each team member and the group as a whole reach the required performance standards?

___ 9. Am I providing the initiative, the enthusiasm, the sense of purpose, and an example of the appropriate behavior and attitudes that team members expect of their leader?

___ 10. Am I helping to support group activities, and am I controlling the group process?

Problem Identification is a procedure which comprises many different aspects that must be taken into consideration before it is successfully completed. What this chapter has presented is the nature of the Problem Identification procedure and how that procedure is performed. A principal focus of this procedure is on team management and teamwork. The remaining chapters in this manual will elaborate this theme. Chapter II will present in more detail the input of the four major dimensions of an irrigation system into the Problem Identification process and Chapter III will concentrate on how these dimensions must be integrated in order for any Problem Identification study to be effective.

CHAPTER II

APPLICATION OF PROBLEM IDENTIFICATION PROCEDURE

Summary of Chapter

This chapter will focus on the following major subject areas:

- Systems Environment of a Problem Identification Study
- The Physical and Institutional Environments of the Farmer
    - The Physical System: Water Control Dimension
        - Water Use Subsystem
        - Water Application Subsystem
        - Water Delivery Subsystem
        - Water Removal Subsystem
    - The Physical System: Plant-Soil Dimension
        - Physical
        - Chemical
        - Biological
    - The Institutional Environment
        - Structural-Cultural
        - Economics

APPLICATION OF
PROBLEM IDENTIFICATION PROCEDURE

Chapter I describes the process of problem identification and explains several major concepts important for successful team work in understanding and identifying priority irrigation systems problems.

This chapter will examine the general situation of the problem identification process. Two critical features of the problem identification study will be emphasized in this chapter. These are: (1) the study will take place in an environment which is composed of identifiable subsystems and their components which interact with each other in a systems framework; and (2) the successful completion of any problem identification study must incorporate the principle of interdisciplinary teamwork. Both features will now be discussed in terms of how problem identification study may be applied.

Systems Environment of a Problem Identification Study

Based on the assumption that the focus of the situation is concerned with on-farm practices, Figure 2.1 shows that a problem identification study will be located within the farmer's situation. That situation depicts the major factors which influence a farmer's behavior. The component parts of the diagram and how those parts are integrated into a systems will now be examined.

The central focus of a problem identification study is the behavior of a particular unit, whether it is to be an organization, a village, an individual, water, soils or crops. Such behavior is evaluated and if farmers, researchers, officials, or all parties determine that there is a gap between <u>what is</u> and <u>what should be</u> then the setting for a problem identification study is established. The investigators are to analyze the factors that influence such behavior and the conditions that can change such behavior.

Figure 1 depicts a farmer or a group of farmers and the situational factors which operate as incentives or disincentives in his management decision making for crop production. As shown in Figure 2.1 the farmer or farmers are influenced by two major environments: (1) the physical and (2) the institutional. These environments comprise the limits and conditions which the farmer must manipulate or which manipulate him in crop production.

The <u>physical environment</u> includes the water control dimension and the plant-soil dimension. Further discussion of this environment is included in Chapter II. The major factors in the physical environment are: the type of soil that the farmer has, the nutrients in the soil, the climate, how the water is delivered, applied, used, and removed from the field, and the crop itself. It should be understood that the farmer both manipulates and is manipulated by these factors. Each farmer in his own environment exercises various degrees of

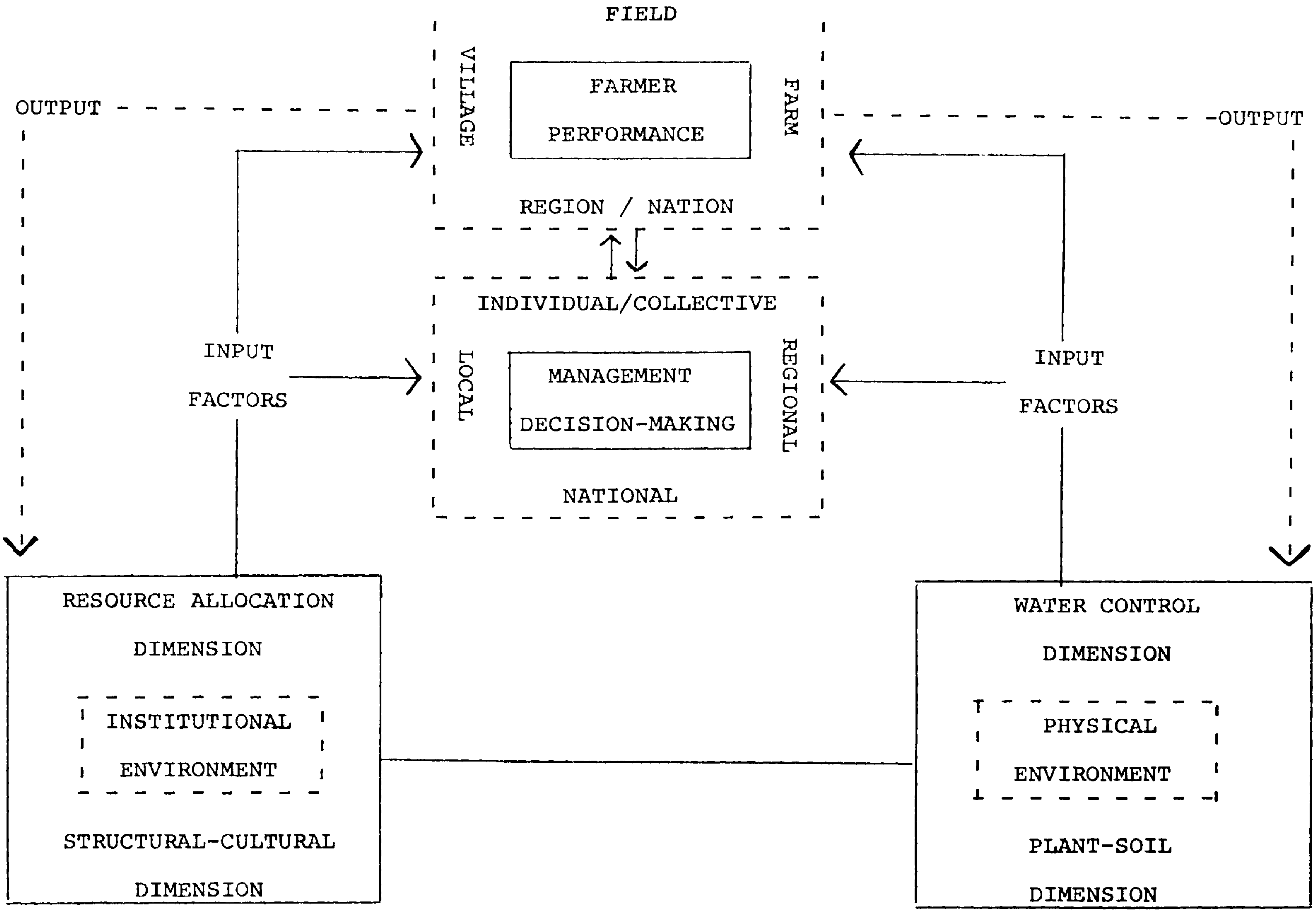

FIELD
VILLAGE
FARMER
PERFORMANCE
FARM
OUTPUT
OUTPUT
REGION / NATION
INDIVIDUAL/COLLECTIVE
INPUT
FACTORS
LOCAL
MANAGEMENT
DECISION-MAKING
REGIONAL
INPUT
FACTORS
NATIONAL
RESOURCE ALLOCATION
DIMENSION
INSTITUTIONAL
ENVIRONMENT
STRUCTURAL-CULTURAL
DIMENSION
WATER CONTROL
DIMENSION
PHYSICAL
ENVIRONMENT
PLANT-SOIL
DIMENSION

Figure 2.1

control over these and other factors. For example, he may have little or no control over climate or price policy, some control over application of water to crops, and much control over the organic and inorganic fertilizer to be applied to a particular crop.

In addition to being placed in a physical environment, the farmer is also part of an institutional environment. Again, a more detailed discussion of the institutional environment will be included in Chapter II. The major dimensions to be considered in the institutional environment are: the economic and the socio-cultural. The economic dimension involves the allocation, and use of the specific resources which the farmer requires. In the socio-cultural dimension, key factors include: the rules, relationships, and characteristics that influence farmer behavior, and social organizational factors which interact with the farmer. Such factors will center on the individual and the organizational network surrounding the individual farmer. The theoretical premises of human behavior are summed up in the following statements: (1) behavior takes place in situations; (2) behavior is regulated by norms or rules; (3) behavior is goal oriented; and (4) behavior requires motivation or energy. Therefore, an Egyptian farmer has a goal of increasing his crop production and is motivated to do so because he wants his family to have a high level of living. His behavior in working toward this goal takes place in a physical and institutional setting. In reaching the goal his behavior is regulated to some degree by the rules of society and his social organization which he is part, as well as organizations which may nor may not provide incentives and services for improved production possibilities that also regulate the farmer's behavior.

Thus, the farmer is placed within these two environments, the physical and the institutional, where certain key factors operate to influence his farm management practices, at a given point in time. While the manual's focus is primarily on individual farmer behavior and the on-farm level of management and performance, as the diagram in Figure 1 suggests, we can "think up" to collective behavior of groups of farmers, villages, regions, or the nation. We do stress that decions made at the highest levels of government in Egypt, such as policy and programs, strongly influence each farmer's individual decision making behavior.

What is of importance in Figure 2.1 is that all of the factors shown in the diagram are placed within a system perspective. Therefore, we will utilize the word systems often as well as an interdisciplinary approach to a definite farm irrigation system. We strongly urge each discipline member of a team not only to look to his subsystem, but understand how each subsystem and the factors involved act and react in relationship to each other. We stress that the farm irrigation system designed by and for man's benefit is a dynamic system which can be improved and maintained by man for greater benefits to farm families and the nation.

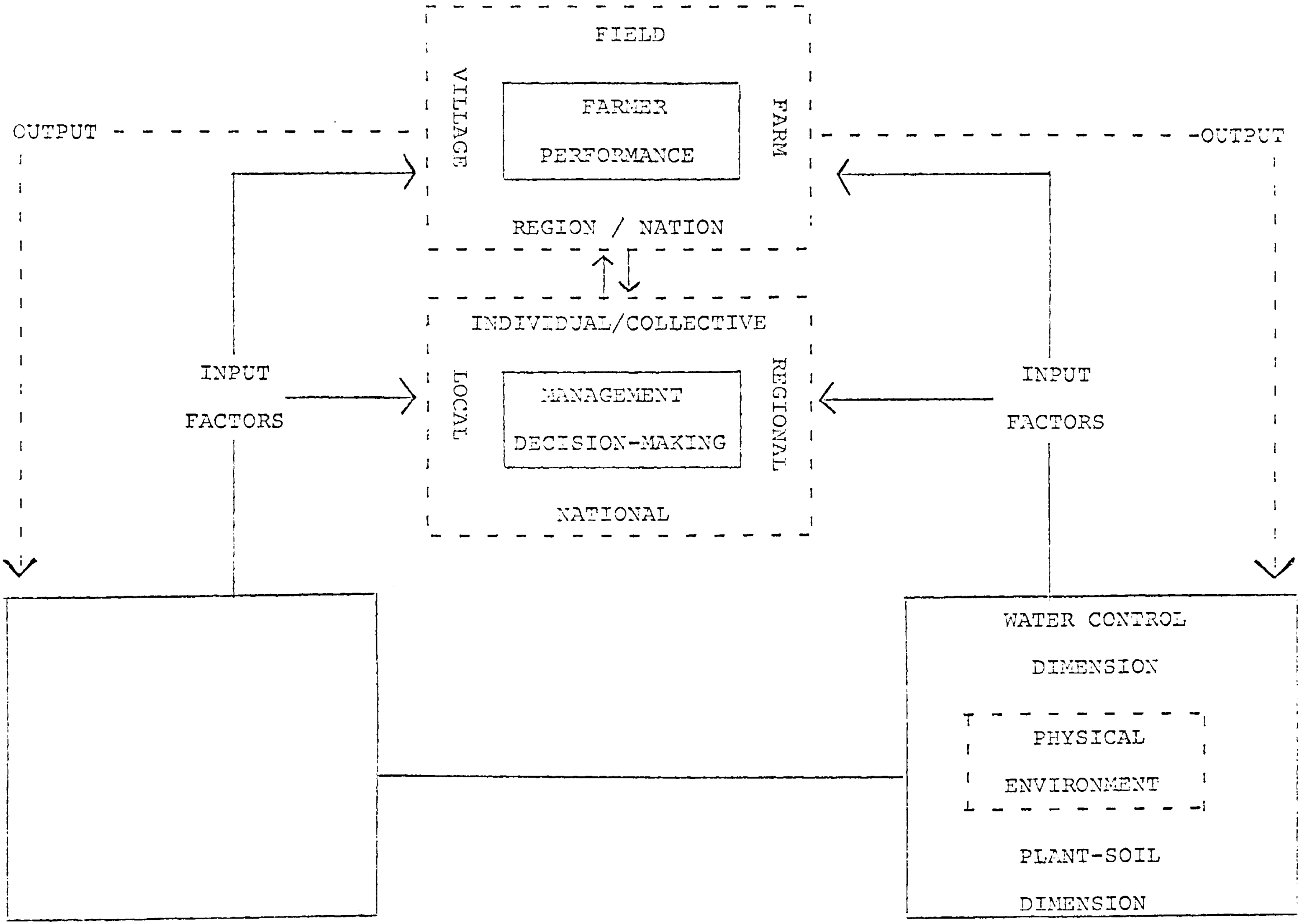

FIELD
VILLAGE
FARMER
PERFORMANCE
FARM
REGION / NATION
OUTPUT
OUTPUT
INPUT
FACTORS
INPUT
FACTORS
INDIVIDUAL/COLLECTIVE
LOCAL
MANAGEMENT
DECISION-MAKING
REGIONAL
NATIONAL
WATER CONTROL
DIMENSION
PHYSICAL
ENVIRONMENT
PLANT-SOIL
DIMENSION

Figure 2.2

We now turn to the physical and institutional environments of the farmer and discuss in detail some of the critical factors which influence farmer behavior.

THE PHYSICAL SYSTEM:
WATER CONTROL DIMENSION

The primary purpose of the water control dimension is to supply water to an area for crop production. This dimension contains four subsystems: water delivery, water application, water use, and water removal.

The purpose of each subsystem is as follows:

Water Delivery: Convey water from the water supply source to the field.

Water Application: Distribute water over the field to fulfill the water requirements of the crop.

Water Use: Storage and supply of water to plants for crop production.

Water Removal: Remove excess water for optimum crop production.

The water control dimension consists of subsystems as a flow process shown in Figure 2.2. By accomplishing the water use subsystem the goals of all other subsystems (delivery, application, and removal) should be met. Thus, the effective operation of the overall water control system depends on the water use subsystem.

The performance of the water use subsystem is tied to each of the other subsystems. For example, if stress reduces yield, then the most efficient delivery subsystem will not

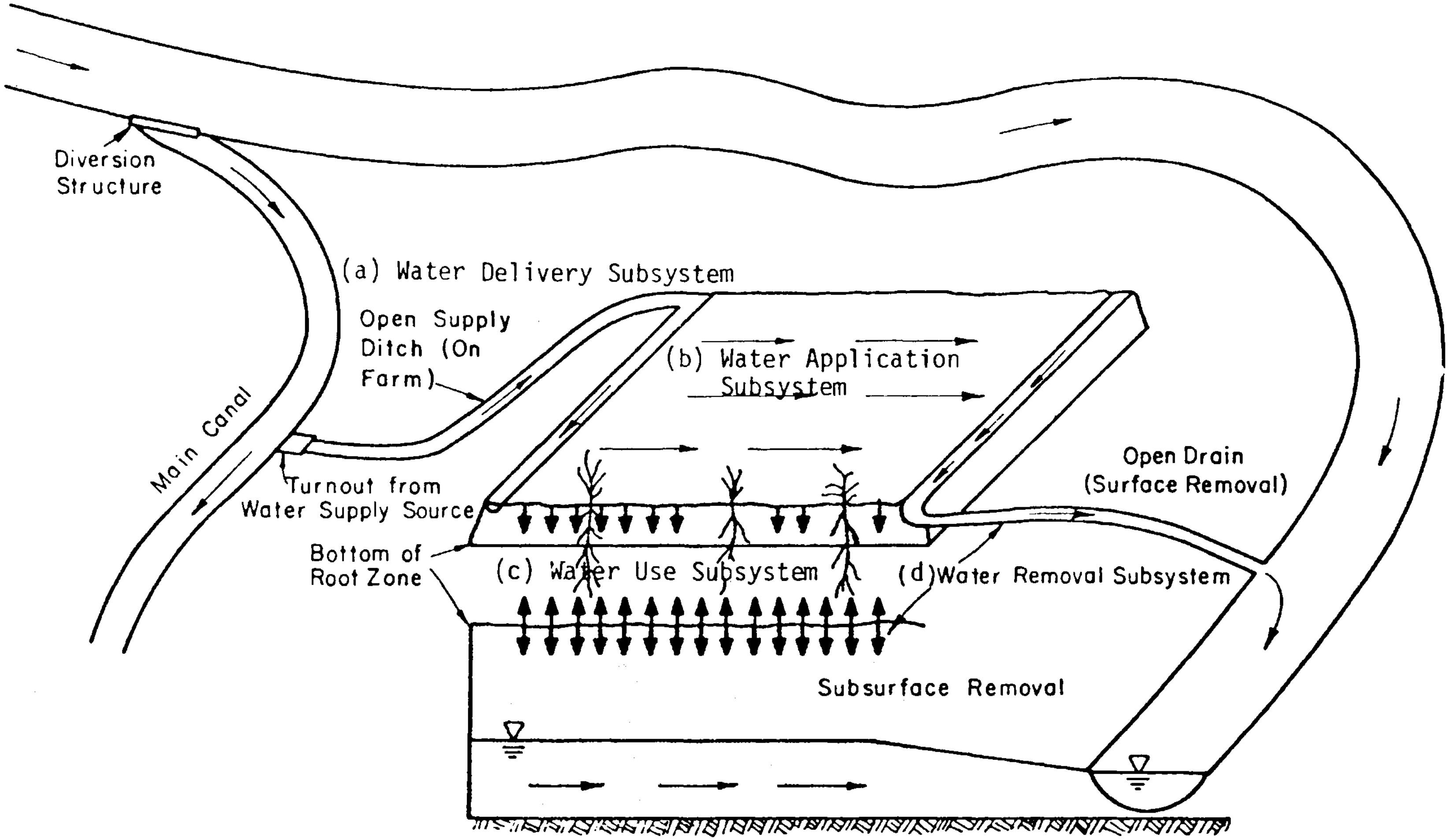


Figure 2.3. The water control subsystems: (a) water delivery, (b) water application, (c) water use, and (d) water removal.

produce optimum crop production. The functions of the water use subsystem become functions for each of the other subsystems. In fact, in a series, the output of each subsystem must be regulated by the functions of each succeeding subsystem as the output becomes the input to that subsystem. The water use subsystem will be discussed first because of its key role in the water control system.

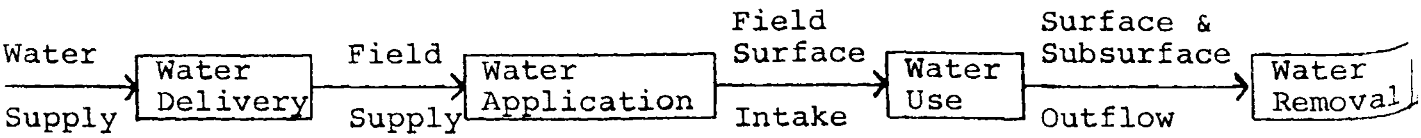


Figure 2.1a. The water control system.

The Water Use Subsystem

The water use subsystem (Figure 2.4) accepts water from the water application subsystem and transmits water through the soil for storage or deep percolation. The subsystem transports water to plant roots through the plant structure and then leaves where it is transpired and to the soil surface where it is evaporated. The excess water flows through the root zone as deep percolation and it is the input to the drainage or water removal subsystem.

The water use subsystem has the following functions:

1. Supply the water requirements for crop growth (quantity and quality) for:
   a. The peak rate of use.
   b. The total seasonal requirement.

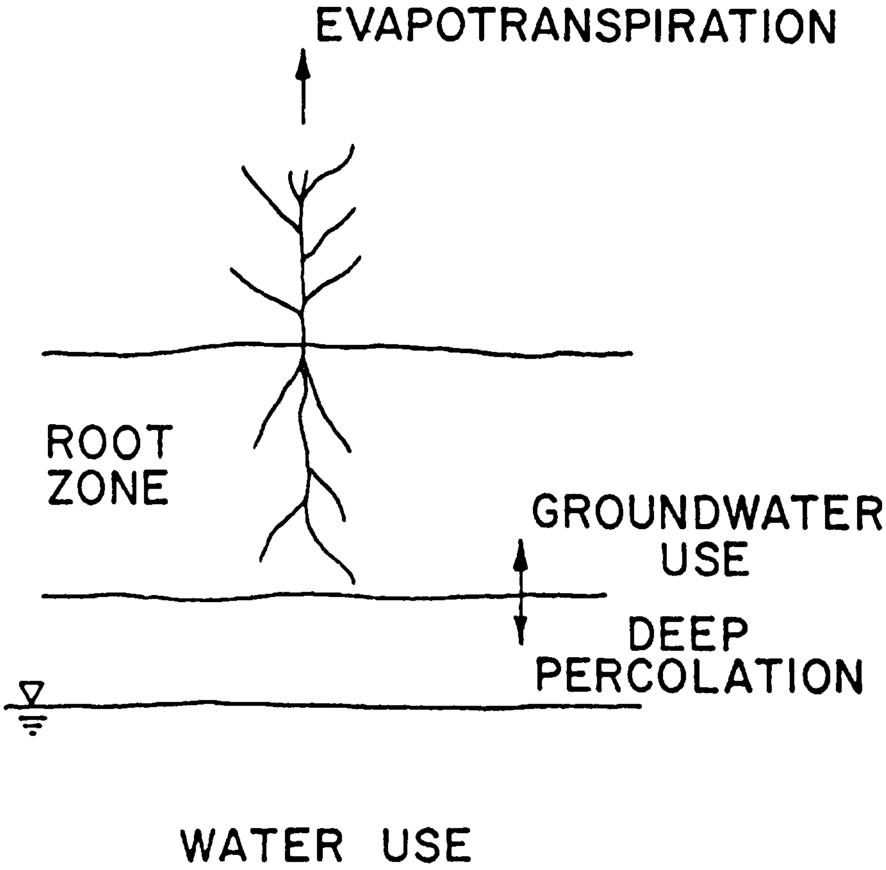


Figure 2.4. The water use subsystem.

c. To prevent excessive stress.

d. To provide adequate aeration and acceptable inundation.

2. Maintaining acceptable levels of soil salinity.

3. Maintaining appropriate environmental (soil and air) temperatures.

4. Insuring adequate nutrients.

5. Providing soil conditions for:

   a. Plant support.

   b. Preventing soil crusting.

   c. Facilitating tillage or harvesting operations.

   d. Providing water for germination and seedling emergence.

Function 1 and its subset are of direct concern to the management of the water use subsystem. Generally the soil water deficit at the time of irrigation determines the desirable amount of water to apply. Exceptions do occur, such as when the inundation time to permitting the desired amount of water to infiltrate is too long and would cause crop damage. In high frequency irrigation, maintaining some soil water deficit may utilize rainfall more effectively. Knowledge of the soil water deficit directly or indirectly specifies the amount of water to be applied.

Crop stress is a function of a number of factors. Primary factors are as follows:

1. Crop and stage of growth.
2. Soil.
3. Climate.
4. Irrigation System characteristics.
5. Economic.

Comparing different crops, a given level of stress has more of an effect on the yield of one crop as compared to another. Wheat, for example, is irrigated at an availability factor (f) of 0.5 while corn is more commonly irrigated at 0.4 or even 0.3. Sorghum, a drought resistant crop, may produce well if irrigated at f=0.6. The stress level for a given crop without reducing yield usually varies throughout the season. Corn, for example, appears to yield best with f=0.3 during the silking through soft dough stage. Early in the season f=0.5 does not appear to significantly affect yield. The most sensitive stage of growth for most crops appears to correspond to the period of peak consumptive use.

The soil type also affects the level of stress for a given availability of water. Fifty percent available water for a clay as shown in Figure 2.5 occurs at a tension of 3 bars. In a loamy sand, 50 percent of the available water occurs at a tension of 0.5 bars. Thus, 50 percent of the available water is obtained at a higher tension in the finer the textured soil.

Climate affects the amount of water available at a given tension. In Figure 2.5a, the interaction of evapotranspiration

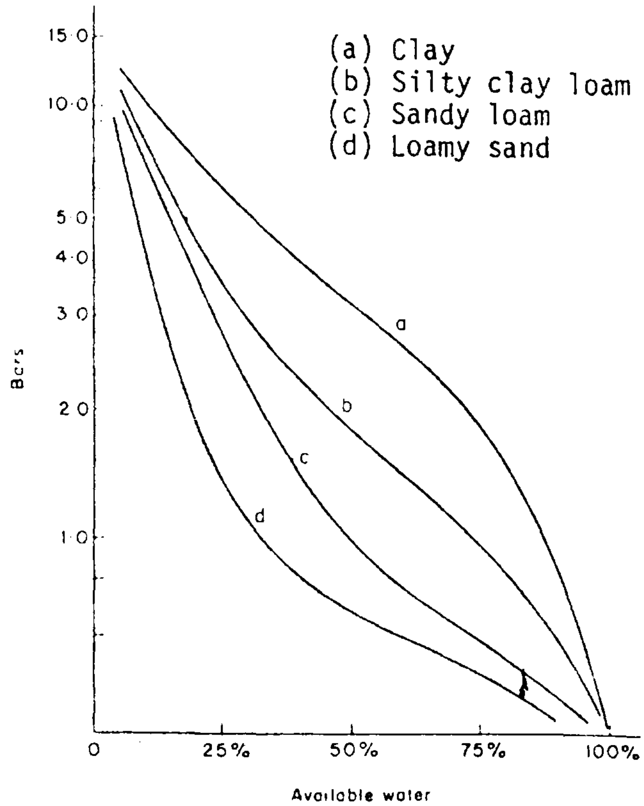


Figure 2.5. Available water as a function of soil moisture tension and soil type (Withers and Vipond, 1974).

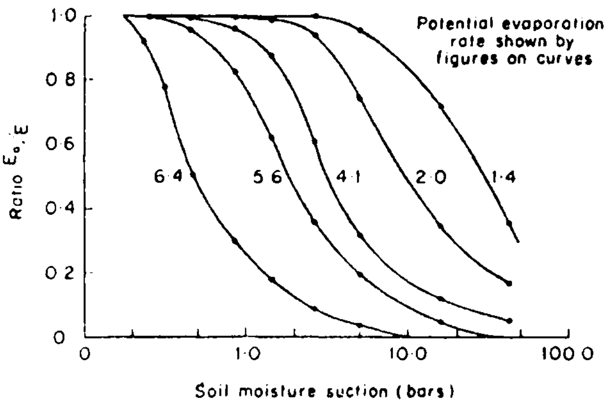


Figure 2.5a. Relative evapotranspiration as a function of soil moisture tension and rate of evapotranspiration (Withers and Vipond, 1974).

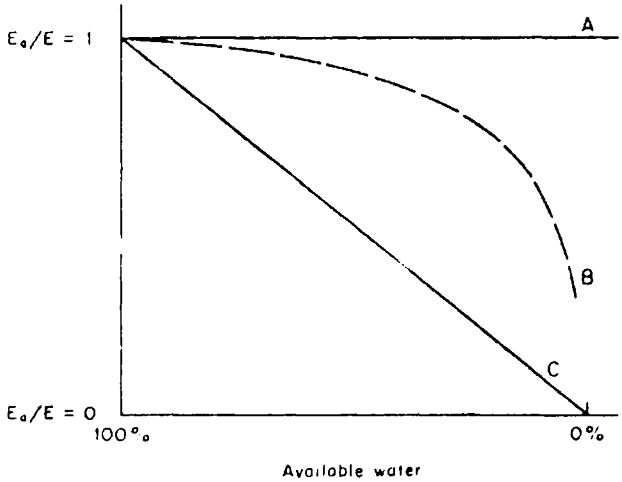


Figure 2.5b. Relative evapotranspiration as a function of available water for different theories of water availability to plants (Withers and Vipond, 1974).

rate with soil moisture tension is illustrated. At a slow rate, 1.4 mm/day, soil moisture tension approaches 8 bars before evapotranspiration is reduced. When the rate is 6.4 mm/day, the rate is reduced at a tension of approximately 0.2 bars. Thus, a given stress criteria in a humid climate may produce maximum yields which in an arid climate could result in excessive stress and a yield reduction.

Considerable discussion has occurred in the scientific literature concerning the relationship between water availability, stress, and rate of evapotranspiration. Figure 2.5b illustrates the three most common and contrasting theories. Line A represents the theory that water is equally available to plants at all levels of stress up to wilting and then is not available. A linear decreasing availability of water as stress increases is illustrated by line C. Line B suggests that at high levels of water content only limited reductions in water availability occurs until at high tensions a rapid reduction occurs.

Given the interaction of soil moisture tension with evapotranspiration rates, these interactions affect yield, however, there are contradictions in the literature which result from different methods of measurements. Thus, other factors contribute to the contradictions. First, the method of tension measurement is an average over some relatively large volume. Roots would appear to experience much higher tensions in their immediate vicinity. Results would also appear to be affected by rooting depth and root density. These are not measured usually in most of these studies. Most engineering criteria for times of irrigation are related to the availability factor, f. Until more adequate criteria are available, these criteria are recommended for design and management of irrigation systems.

System Constants, Variables and Performance Parameters

The soil-air-water (water use) subsystem is illustrated in Figure 2.6. In this diagram the different components are separated instead of mixed as they occur naturally. These components are then used to define the system constants as illustrated in Figure 2.6. System variables are also given for both the atmosphere and the soil. A more detailed discussion of the constants and variables are given by Corey and Hart (1976).

System performance is measured with the parameters given in Figure 2.6. These parameters allocate water for storage in the root zone, deep percolation and runoff. When less water than the requirement is applied then the water requirement efficiency gives the system performance.

Knowledge of the system variables for the water use subsystem defines the state of the subsystem. The availability factor, f, defines when a farmer irrigates and the water requirement is determined from an analysis of the water application subsystem.

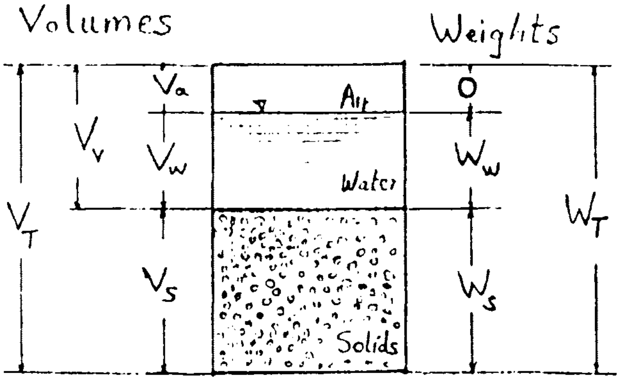


Figure 2.6. Definition of constants and some variables for the soil-air-water subsystem.

Soil-water-air Subsystem

Symbols

V_a = volume of air

V_v = volume of voids

V_w = volume of water

V_s = volume of solids

V_t = total volume

Constants

Porosity, $\phi = V_v/V$

Particle Specific Gravity, $\gamma_s = W_s/V_s\gamma_w$

Bulk Specific Gravity, $\gamma_b = W_s/V\gamma_w$

Field Capacity, FC

Permanent Wilting Point, PWP

Total Available Water, TAW = FC - PWP

Variables

Water Content, $W = W_w/W_s$

Volumetric Water Content, $\theta = V_w/V$, $\theta \leq \phi$

Degree of Saturation, $S = V_w/V_v$

Readily Available Water, RAW = f(FC - PWP)

Soil Water Deficit, SWD = FC - W

Electrical Conductivity, EC

Sodium Absorption Ratio, SAR

Availability Factor, F = RAW/TAW

Evapotranspiration Rate, ET

Transpiration Rate, T

Evaporation Rate, E

Water Application, D_a

Water Requirement, D_{ou}

Water Requirement Supplied, D_{au}

Deep Percolation, D_d

Runoff, D_r

Performance Parameters

Application Efficiency, $E_a = D_{au}/D_a$

Water Requirement Efficiency,

$E_r = D_a/D_{au}$, $D_a \leq D_{au}$

$= D_{au}/D_a$, $D_a \geq D_{au}$

Deep Percolation Ratio, $E_p = D_d/D_a$

Tail Water Ratio, $E_t = D_r/D_a$

Distribution Uniformity Coefficient, UCH

The variables which define the state of the water use subsystem describe the static condition of the system. Models are available which describe the steady-state and dynamic operation of the system. Changes in the static condition of the system are obtained by defining time distributed inputs and outputs of the water application and water removal systems. The water application system, for example, applies 25 mm of water as an output which is an input to the water use subsystem.

Water Application Subsystem

The water application subsystem supplies water to the water use subsystem by distributing the water over the surface of the field (Figure 2.7). Water application must provide water for the functions of the water use subsystems as well as fulfill the functions of water application. The traditional functions of the water application subsystem are as follows:

6. Distributes the desired amount of water with the designed uniformity.
7. Satisfies erosion control standards.
8. Provides necessary surface drainage.
9. Is economically appropriate and socially acceptable to the management abilities of the farmer.

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

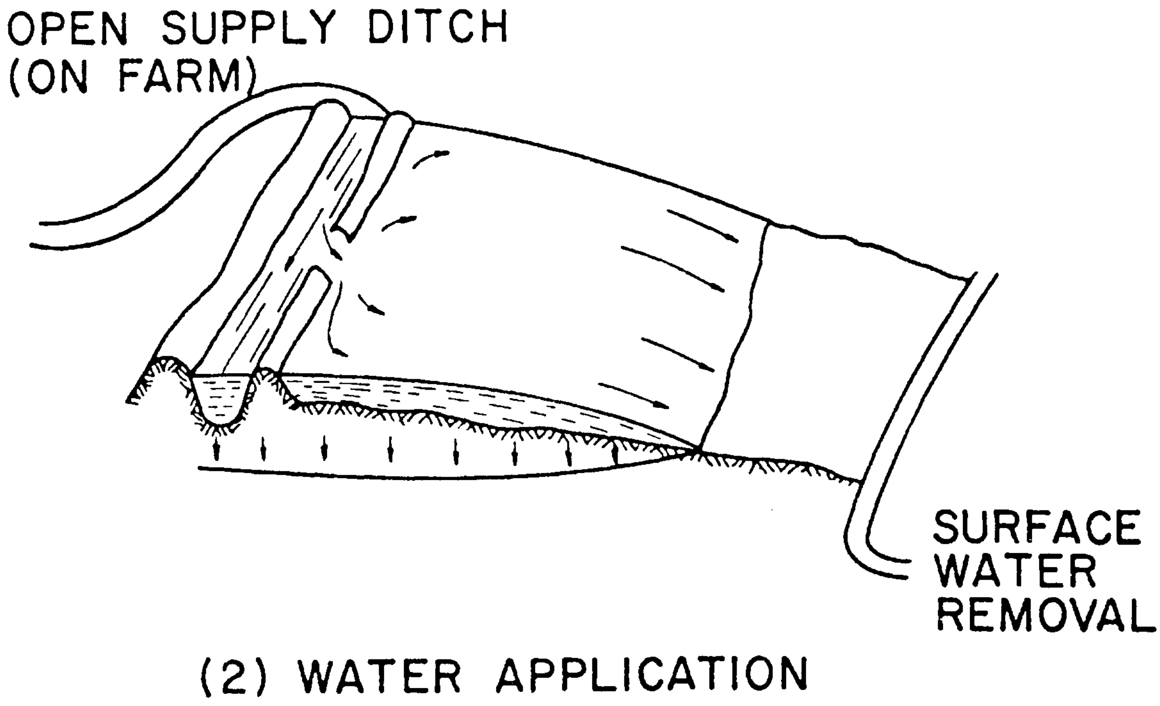


Figure 2.7. The water application subsystem.

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

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

Water application subsystem is accomplished by the farmer by operating the system to meet functional objectives (usually unstated) of both water use and application. 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?

Performance standards include an analysis of the effectiveness (technical, social, economic) of the water application system. Performance parameters for the water application subsystem are included in those previously defined for the water use subsystem.

The operation of the water application subsystem can be described by measurement of the subsystem state variables.

Knowledge of the appropriateness of these variables can be determined by comparing the existing values with the values of an appropriate design. Performance can also be determined by measurement of the state variables.

The Water Delivery Subsystem

The water delivery subsystem is that structure which delivers a water supply to an area served by the water supply source. The area served by the water supply is the fields receiving irrigation water. The water supply source may be a well, a storage reservoir, or a canal, and may be operated by a private, public, or governmental organization. The purpose of the on-farm water delivery subsystem is to convey the water from the water supply source to the field based upon the functional requirements of the water application and use subsystems.

The water delivery subsystem serves both the water application subsystem and water use subsystem. The functions of the water use subsystem and the water application subsystem must also be provided by the water delivery subsystem. For example, a major design variable of the water application system is the design water application rate for a border. This specifies a desired flow rate that is necessary to properly irrigate a field. Thus, a primary function of the water delivery subsystem would be to supply this design flow rate to the field. Likewise, the water use subsystem must supply the peak consumptive use rate for a field. Thus, the flow rate through the water delivery subsystem must be sufficient to supply this peak demand by the water use subsystem. All other defined functions of the water use and water application subsystems must also be met by the water delivery subsystem.

The additional functions of the water delivery subsystem related to convergence of water from the supply source to the field in relationship to the following conditions:

a. At a constant, regulated rate.

b. At the proper elevation.

c. With seepage controlled.

d. Without excessive erosion or sedimentation.

e. At appropriate water quality.

f. With safety (cross flows, accessibility, drainage damage).

The subsystem must be built, maintained, and operated within socio-economic limitations. These functions are performed by a delivery system based upon the physical and management factors which influence water delivery.

System State Variables

The factors or state variables which influence water delivery are as follows:

1. Flow rate.
2. Cross section

3. Hydraulic radius.
4. Roughness.
5. Slope.
6. Seepage rate.
7. Management.

The seventh factor which influences water delivery is reflected in the management decisions of the farmer as affected by the allocation rules and operational norms for the system. The first five physical factors are the basic parameters in Mannings equation and are used for design of the delivery channel. The sixth factor, seepage rate, affects all aspects of the previous five primarily by increasing or decreasing the flow rate. How the above factors affect the operation of the water delivery system will now be discussed.

The flow rate supplied to the field must be regulated according to the following factors:

a. Total quantity.
b. Supply peak demand (rate).
c. Constant flow at an appropriate time for application.
d. Dependable flow.

The total quantity of water supplied by the delivery system must be sufficient to meet the seasonal volume of water requirements for the particular crop. The quantity of water supplied must also meet the other functions, such as the crop consumptive use rate and/or the water application rate. These are key factors which establish the capacity of the delivery system.

A dependable flow rate must also be insured by the water delivery system. Figure 2.8 illustrated the seasonal range flow rates delivered at the field as monitored for a water delivery system in Pakistan. The variation in flow during the season varied by greater than an order of magnitude (10 times) as indicated by the distribution of average flow rates. This extreme variability in flow rate makes it impossible for the farmer to quantitatively apply water since the only alternative to knowing the flow rate is to provide a means for flow measurement. If a regulated flow rate is provided, then time could be used as a substitute for slow measurement. With such variability in the flow rate, however, the farmer cannot quantitatively supply water to the field. Another major effect of the variability of the flow rate is that the appropriate flow rate for proper application of water to the field cannot be provided. Under the functions of the water application system, a particular flow rate is needed for efficient application of water. When the flow rate varies from turn to turn in such fluctuating manner, then this appropriate flow rate for water application is not provided. When faced with a fluctuating water supply rate, the farmer must manage his irrigation practices dependent upon the minimum flow rate. The result is that crop area and crop requirements will be a function of the minimum flow rate and all flows delivered above this minimum flow rate will tend to be excess.

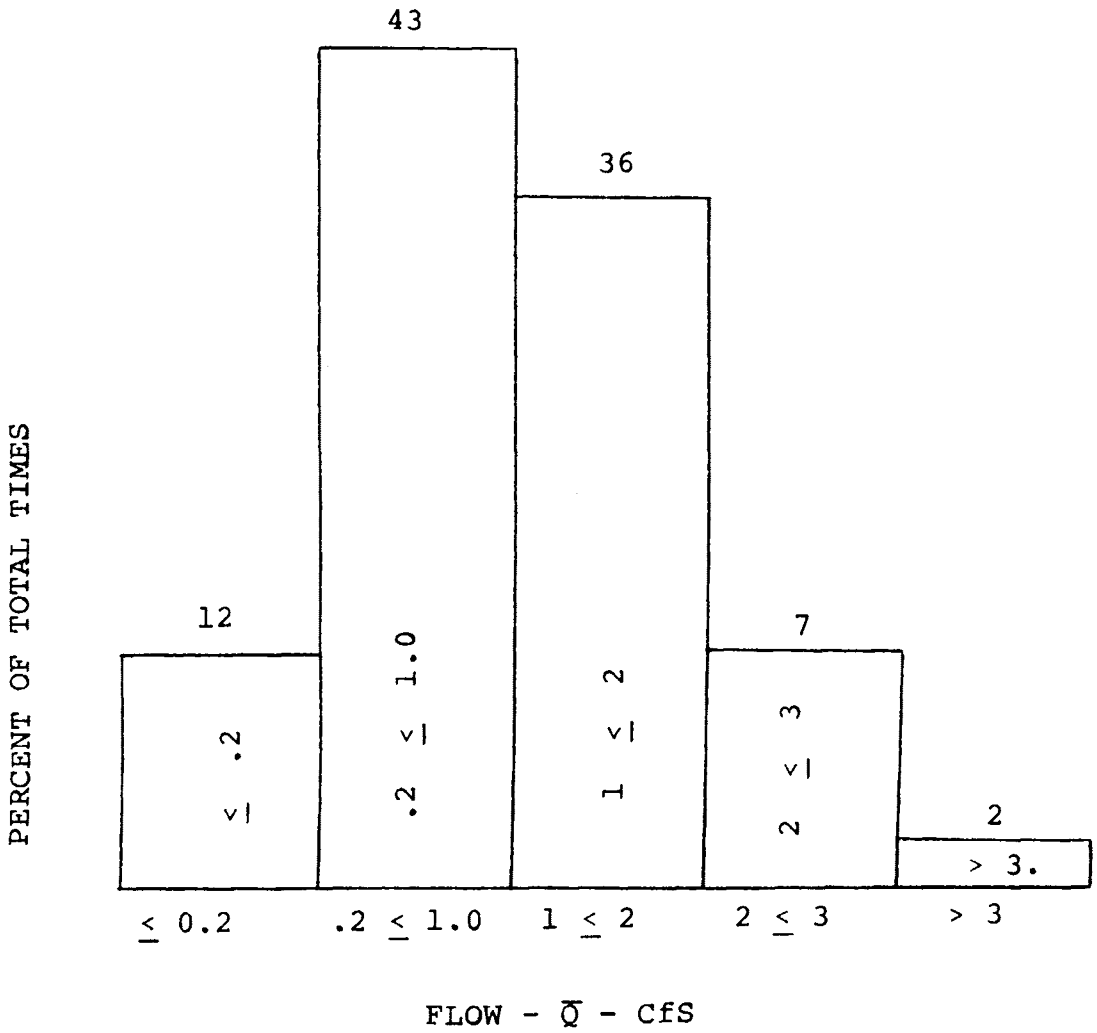


Figure 2.8. Seasonal frequency distribution of average flow rates at a field for a farm in Pakistan (Clyma et al., 1979).

An appropriate, constant cross section must be provided to maintain a head and to deliver water at an appropriate elevation. The cross section must also be provided for the design flow rate as defined by the functions of the various subsystems.

The hydraulic radius should be a minimum for the design flow in order to minimize the cuts and fills associated with channel contruction as well as to minimize the cost of construction. When unlined channels are used for the delivery system, the minimum cross section also provides minimum seepage.

The Mannings n or roughness for a channel must be carefully selected for the design. A range in n between $0.02 \leq n \geq 0.10$ is a common range used for design. Thus, the appropriate n must be carefully selected.

The design slope is important in maintaining the minimum cross section in order to reduce the cost of channel construction and to ensure that sedimentation or erosion does not occur also. For some water delivery systems such as those using siphons, a level or nearly level section must be provided to supply water to the field. Thus, the selection of the design slope is important to several aspects of the operation of the water delivery and water application subsystems.

The seepage rate accepted for the design should first consider that losses in delivery water are an important factor in the operation of the water delivery subsystem. A very high loss rate accepted for design will likely affect the dependability of the delivery of the water supply. Also, the effect of the seepage rate on the depth, in-channel storage and operational losses of the delivery system should be evaluated and explicitly included in the design. Realistic assumptions concerning the system's maintenance should also be considered in selecting design seepage rate that will be included as part of the design parameters for the subsystem.

Because of the influence of seepage rate on the various functions of the water delivery subsystem, alternative systems such as pipelines or a lined channel should be considered when the effects of seepage losses that are high are explicitly considered. Selection is frequently based on the best benefit: cost ratio.

The Water Removal Subsystem

The water removal subsystem is defined as the removal and disposal of surface and subsurface waters from land to improve agricultural operations. The objective of drainage is to provide an environment for plants that will result in optimal production of crops. The sources of water may be from precipitation, irrigation, seepage from ponds and canals, seepage from adjacent aquifers, floods and application of water for special purposes such as temperature control. In most irrigated areas, natural drainage is adequate and drainage systems are needed to supplement natural drainage. We must be careful, however, to identify drainage as either a problem or a symptom of another problem such as over-irrigation or an undesirable leaky canal system. The major components of the water removal subsystem are depicted in Figure 2.9.

The water removal subsystem has the following primary functions:

1. Maintain given salinity levels within the soil profile.
2. Provide proper root aeration.
3. Improve workability of lands.

1. Maintain given salinity levels within the soil profile:

All irrigation waters contain salts which, if allowed to accumulate within the root zone, will reduce crop yields. Some water must be allowed to percolate through the root zone to the level within the root zone. This excess water must be removed from the area either naturally or by artificial drains in order to prevent waterlogging.

The amount of water that must pass through the root zone to keep salinity at acceptable levels is called the leaching requirement. To evaluate this, we need to know the following information:

a. Amount of salts in the irrigation water.
b. Evapotranspiration rates.
c. Crop type to select appropriate salinity levels within the soil.

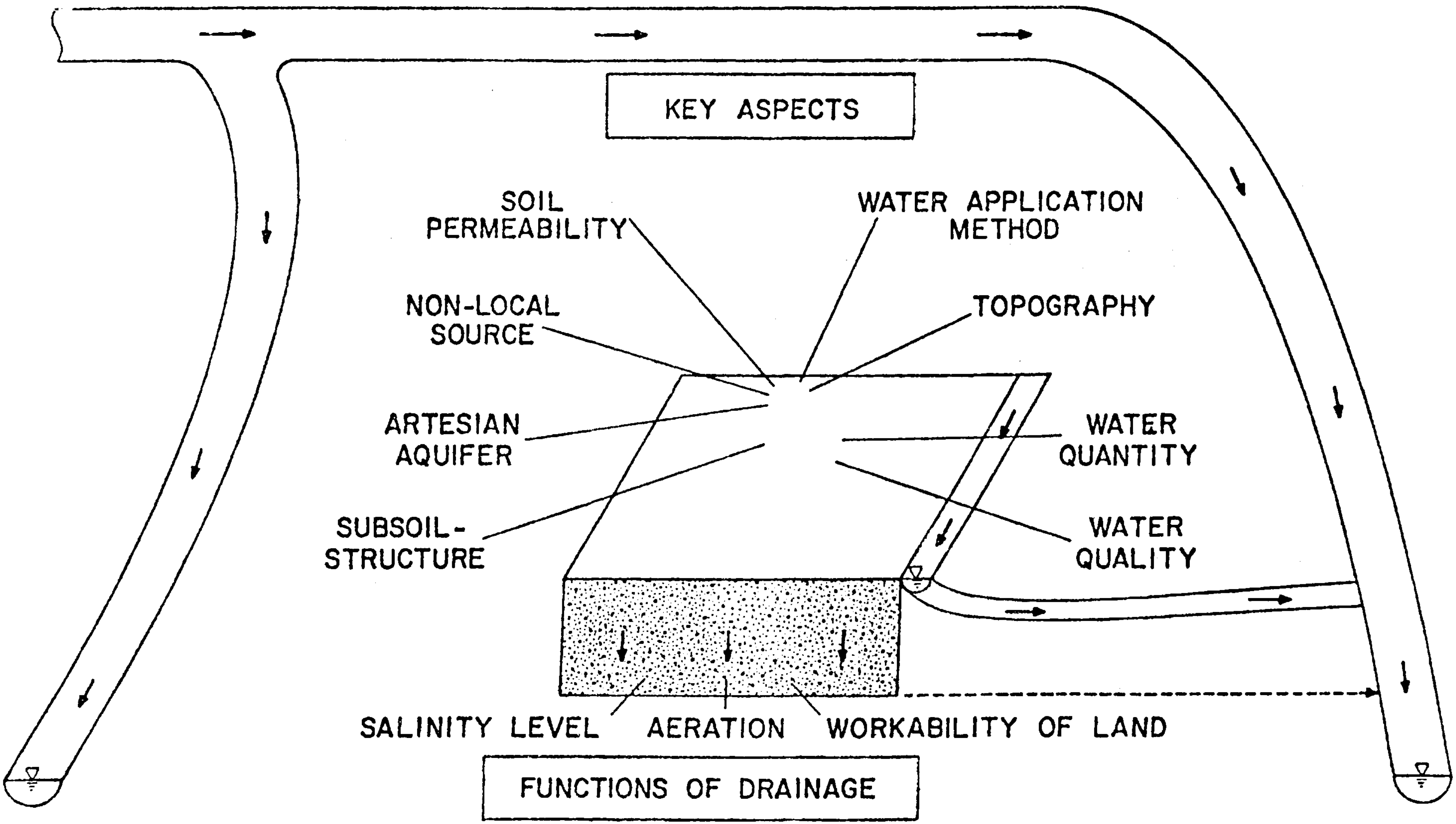


Figure 2.9. Components of the water removal subsystem.

d. Disposal site.

On a unit area basis, the amount of salts entering the soil is roughly proportional to the product of electrical conductance of irrigation water EC_i and the volume of applied water D_i. Additional salts may be added due to sources such as fertilizers but this will be small compared to that added by the irrigation water. The amount of salts leaving is proportional to the product of electrical conductance of the drainage water (or ground water) and the volume per unit area of drainage water D_d. Salts removed by the harvesting of crops is small and may be neglected.

The leaching requirement, LR, is:

$$LR = \frac{D_d}{D_i} = \frac{EC_i}{EC_d} \qquad (2.1)$$

if the period of time considered is too long. EC_i and EC_d are average values during the period.

Over a sufficient period of time, water added which is not removed by evapotranspiration will drain out of the root zone. In other words:

$$D_d = D_i - D_e \qquad (2.2)$$

where D_e is the volume per unit area of water representing evapotranspiration. Since D_d may be evaluated in terms of LR by Equation 2.1, then

$$D_i = \frac{D_e}{1-LR} \qquad (2.3)$$

for a situation in which a given level of soil salinity is being maintained. An equivalent equation in terms of electrical conductivity is:

$$D_i = D_e \frac{EC_d}{EC_d - EC_i} \qquad (2.4)$$

If the value of EC_d currently is too high, then water in excess of that given by Equation 2.4 will have to be applied until a new equilibrium is established at a lower value of EC_d. Acceptable guides for the selection of permissible values of EC_d are given in Table 2.1. Except in very special cases, it is probably not feasible to permit EC_d or EC_i to exceed about 4,000 micromhos (umho) per cm. This is equivalent to about 2,600 ppm total dissolved solids.

The permissible value of EC_d depends in part upon the kinds of salt as well as the type of crop. A high percentage of sodium, in particular, results in a smaller permissible EC_d. An index of the sodium hazard is the sodium-absorption ratio, SAR, given by:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{CA^{++} + Mg^{++}}{2}}} \qquad (2.5)$$

where concentrations are expressed in milliequivalents per liter. If EC_d is greater than about 200 umho per cm, the SAR value should not be greater than about 23 even for the most tolerant of crops. For crops having a low tolerance, an SAR of about 4 should not be exceeded, if the EC_d is greater than

Table 2.1. Relative tolerance of crop plants to salt[1].

Vegetable Crops		
EC X10^3 = 12	EC X10^3 = 10	EC X10^3 = 4
Garden beets	Tomato	Radish
Kale	Broccoli	Celery
Asparagus	Cabbage	Green beans
Spinach	Bell pepper	
	Cauliflower	
	Lettuce	
	Sweet corn	
	Potatoes (White Rose)	
	Carrot	
	Onion	
	Peas	
	Squash	
	Cucumber	

Fruit Crops		
High salt tolerance	Medium salt tolerance	Low salt tolerance
Date palm	Pomegranate	Pear
	Fig	Apple
	Olive	Orange
	Grape	Grapefruit
	Cantaloupe	Prune
		Plum
		Almond
		Apricot
		Peach
		Strawberry
		Lemon
		Avocado

[1]The numbers following EC X10^3 are the electrical conductivity values of the saturation extract in millimhos per centimeter at 25°C associated with 50 percent decrease in yield.

Table 2.1. (continued)[1].

Forage Crops		
EC X10^3 = 18	EC X10^3 = 12	EC X10^3 = 4
Alkali sacaton	White sweetclover	White Dutch clover
Saltgrass	Yellow sweetclover	Meadow foxtail
Nuttall alkaligrass	Perennial ryegrass	Alsike clover
Bermuda grass	Mountain brome	Red clover
Rhodes grass	Strawberry clover	Ladino clover
Rescue grass	Dallis grass	Burnet
Canada wildrye	Sudan grass	
Western wheatgrass	Hubam clover	
Barley (hay)	Alfalfa (California common)	
Birdsfoot trefoil	Tall fescue	
	Rye (hay)	
	Wheat (hay)	
	Oats (hay)	
	Orchardgrass	
	Blue grama	
	Meadow fescue	
	Reed canary	
	Big trefoil	
	Smooth brome	
	Tall meadow oatgrass	
	Cicer milkvetch	
	Sourclover	
	Sickle milkvetch	

Field Crops		
EC X10^3 = 16	EC X10^3 = 10	EC X10^3 = 4
Barley (grain)	Rye (grain)	Field beans
Sugar beet	Wheat (grain)	
Rape	Oats (grain)	
Cotton	Rice	
	Sorghum (grain)	
	Corn (field)	
	Flax	
	Sunflower	
	Castorbeans	

[1]The numbers following EC X10^3 are the electrical conductivity values of the saturation extract in millimhos per centimeter at 25°C associated with 50 percent decrease in yield.

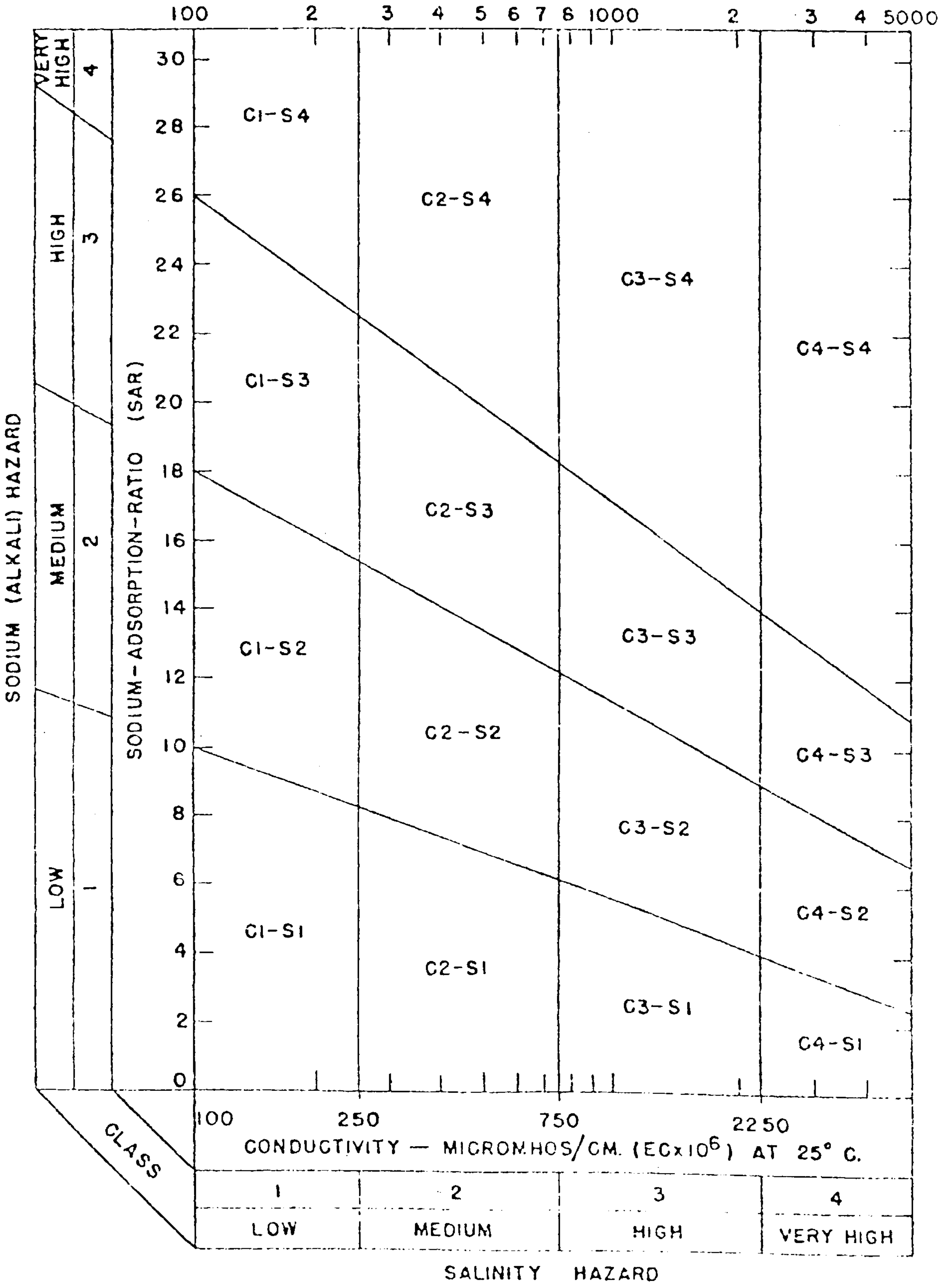
2,000 umho per cm. Figure 2.10 may be used as a conservative estimate of permissible values of EC_d.

Normally the conductivity of the drainage water is less than that of water obtained from the saturation extracts. Soil samples should be taken to assure that the desired salinity level within the soil profile is maintained.

It should be pointed out that the drainage water must go somewhere and many times one man's drainage water is another man's irrigation water. Consequently, the disposal and quality of drainage water must be considered in terms of downstream users.

2. Aeration Requirements

Excess water in soils will prevent the development of an adequate root zone. If the gaseous phase does not exist throughout the soil profile, oxygen will not diffuse through the root zone at a rate sufficient to supply respiration needs of the plant. Carbon dioxide and other products of metabolism will not diffuse away as fast as it may be produced by micro-organisms and the plant roots may then accumulate in toxic concentrations. Anaerobic decomposition may occur and produce toxic gases and chemicals such as sulfides and methane. Also, some minerals may become insoluble and consequently unavailable to plants. All of these factors limit production of most crops.



gure 2.10. Diagram for the classification of irrigation waters.

A notable exception is rice which is able to survive in submerged soil for long periods of time due to the fact that diffusion of gas can also take place through the plant structures. In addition, oxygen can diffuse from one portion of the root to another, through the intercellular ventilating system.

Plant species vary widely in ability to transfer gases from atmosphere to root tips and to withstand the products of anaerobic conditions. Although some plants will grow only in soils submerged in water, the majority require aerated soil. All plants, however, are able to extend their roots into unaerated soil for a limited distance.

It has been estimated that if the soil contains air to fill approximately 15 percent of the void space then aeration problems are minimal. To provide the proper aeration zone requires that the depth to water table be maintained at an adequate level. In order to do this one must know the following information:

a. Capillary pressure head - moisture content relation.

b. Depth to water.

The capillary pressure head - moisture content relation is needed to evaluate the moisture content at given heights above the water table. Figure 2.11 gives qualitative relations between two extreme types of soils.

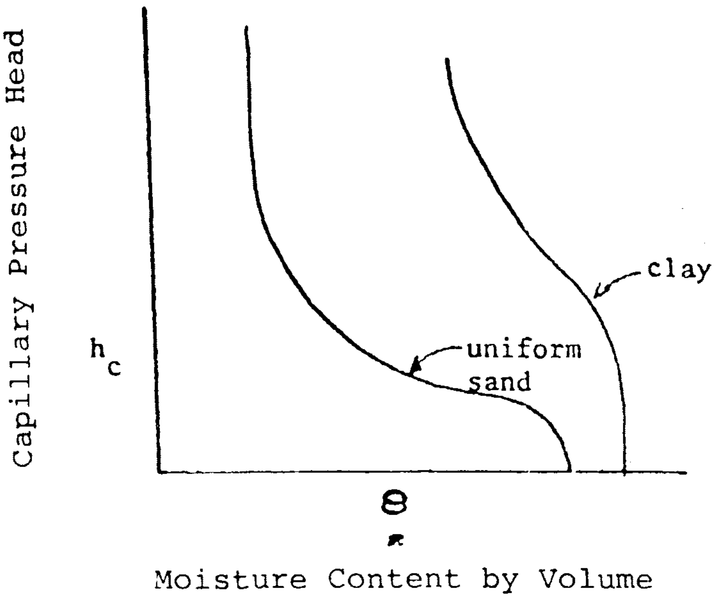


Figure 2.11

To provide adequate aeration, approximately 5 percent of the bulk volume should be air for most of the root development period. Thus, for a soil having a point of 0.35 aeration will not be a problem if the maximum moisture content of 0.35 - 0.05 = 0.3 or less is maintained throughout most of the root zone. For a given capillary pressure - moisture relation one can estimate the desired depth to water table to provide adequate aeration. Figure 2.12 shows moisture distribution above the water table for the static case (i.e., several days after irrigation).

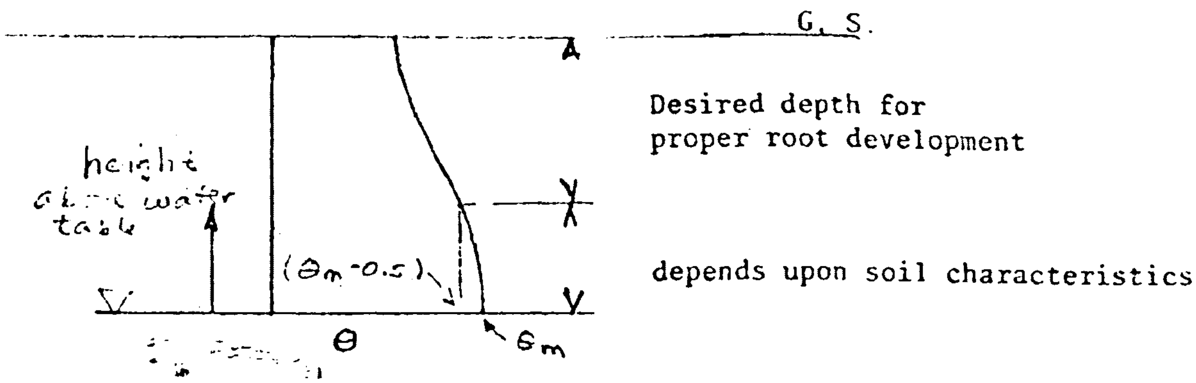


Figure 2.12

The depth to water table should be considerably greater for heavy clays as opposed to uniform sands. The zone of aeration will be more difficult to maintain for clay than for sand due to capillarity. It should be pointed out that the soil was assumed to be fairly homogenous while in nature we would expect layering and consequently less permeable zones may restrict and even prevent downward movement of the excess water. This will create local perched water table conditions and will have the same effect as high water conditions on a regional basis. We would want to maintain a depth to water sufficiently large to provide an adequate zone of aeration for the root system.

3. Workability of Lands

The presence of water in soils reduced the capacity of soils to resist shearing and compressive stresses. When plowed or worked over by other equipment in a wet state, soil compresses. Upon drying, the compressed soil may form hard clods and less permeable dense layers below the cultivated layer. Large clods would interfere with the preparation of the seed bed, and the dense, less permeable layers would interfere with normal root extension, thus reducing the volume of soil that may be occupied by roots. It is desirable to have a well-drained soil so that cultivation or other soil preparations can proceed with a minimum delay following rains or irrigations. The effect of water on compressibility of soils is more important as the amount of clay in the soil increases.

Another mechanical effect is the increase in heat capacity due to the presence of water and more heat is required to raise the temperature of wet soil than would be required for the same volume of dry soil. Furthermore, evaporation of water requires heat and may take place without change in temperature. The combination of these factors results in wet soils remaining colder during periods of increasing atmospheric temperatures and can delay seed germination during the planting season as well as retarding growth after germination. Conversely, wet soil remains warmer during periods of decreasing atmospheric temperature and can reduce the effects of freezing conditions.

The concentration and type of salts in the water affect the mechanical behavior of soils due to the reaction of clay minerals to electrolytes in solution. Three general types of clays are recognized and differ in chemical composition. In addition, there are many sub-types differing in respect to crystalline form. The three main types are: kaolinite, montmorillonite, and illite.

Of these three types, montmorillonite is the most sensitive to variations in salt content; kaolinite is least sensitive and illite is intermediate. The ion exchange capacity of montmorillonite is large and is due to the fact that clay will swell and disperse when water enters the space between the clay plates.

Water that is highly concentrated with electrolytes has less potential for entering space between the clay plates. In addition, some ions such as Al^{+++} inhibit swelling and dispersion more than for example Ca^{++} of NA^{+}.

In the dispersed state, the clay will have lower permeability and poored aeration due to the fact that the clay plates would tend to occupy the large pore spaces. Dispersed soils are not desirable for optimal crop production and should be avoided. If these soils are to be used for agriculture, and the water contains excess sodium, it is particularly important to provide good drainage in order to avoid salinity problems.

A given field may contain one or more problems in that the excess water may be due to one or more sources. The identification of the problem and a solution to the problem depends on the source of the excess water. In most cases it is necessary to control the water table from rising too high for too long a period of time. Specific sources of problems may be:

a. Impermeable substratum - The source of the excess water is local and enters the area by infiltration from the ground surface. The impermeable substratum is too shallow and level over a large area so that the perched water cannot drain sufficiently under natural conditions.

b. Artesian aquifer - Excess water enters soil due to water pressure in an artesian aquifer below the agricultural lands. The source may be local in that it enters the soil at the point near where the problem exists.

c. Non-local Source - Seepage from canals, lakes, etc. flows through the soil to a lower spot where an excess amount accumulates.

d. Low Permeability - The soil will not transmit water adequately to provide proper aeration and/or leading.

e. Excess Application - Water is supplied in excess of that which normally good drainage can remove in a reasonable period of time.

f. Large Level Area - Hydraulic gradient of subsoil aquifer is too flat to remove water as fast as percolation to the water table takes place.

g. Elevation too Low - Land may be at an elevation too near that of a nearby lake, sea, or ocean. There is no subsoil outlet at a sufficient low elevation.

h. Basin - Subsoil of surrounding land all drains towards the area. There is no natural drainage away from the area.

The need for drainage will be evident from:

a. Shallow root penetration.

b. Prevalence of plants normally found in swamps, such as cattails.

c. Soil mottling (soil marked with spots of different colors, usually gray and bluish gray) due to reduced compounds.

d. An odor of methane or other gases of reduced compounds.

e. Soil which dried slowly, even during prolonged dry periods.

f. A high water table, that is, water stands in open holes and ditches at a depth less than a meter below the surface.

g. Presence of salts on the soil surface.

h. Standing water for prolonged periods of time.

To properly identify the drainage problems, the following items should be determined during the reconnaissance phase:

a. The extent of the existing and probable problem area.

b. The possible sources of excess water.

c. The extent of a salinity problem.

d. General topography and geology.

e. The elevation of water in observation wells in the area.

f. Present crop productivity and an estimate of maximum productivity if the land is drained.

g. Existence of adjacent drainage projects which may indicate effectiveness of drainage.

h. Water quality of all waters.

i. Hydraulic characteristics of typical soil types such as:

   1. Hydraulic conductivity

   2. Pressure-moisture content of the soils

j. General direction of sub-surface flow.

k. Soil profile data to depth of 5 to 10 meters.

l. Bulk density or porosity to depth of 5 to 10 meters.

Data Analysis: For Water Removal Subsystem

a. Mapping (base)

The extent of the existing and probable problem area should be located on suitable base maps. The purpose of this would be to provide a means for location drainage systems. On this map, all structures (above and below ground) should be identified and properly located. This map will be used for constructing other maps such as water table contours.

b. Identification of Sources of Excess Water

This is important as the nature of the sources will dictate the type of removal system. For example, if a pond or ditch is identified as the source, an interceptor drain will be used to cut off the water before it reaches the affected area. If the source is over irrigated, then relief drains will probably be selected to lower the water table. Some of the sources of excess water can be identified by constructing water table elevation contours described in part e.

c. Salinity Problem and Leaching Requirements

Data required for identifying the salinity problem are:

1. Chemical analysis of all waters such as irrigation water, saturation extract, groundwater, and drainage water.
2. EC measurements of surface water and groundwater with time at various locations. This EC should be calibrated with the chemical analysis to obtain total dissolved solids in ppm (as a guide, 640 ppm ≐ 1 mmohs/cm).
3. Base map.

The saline areas are identified by plotting EC contours on the base map. Areas of high EC may require leaching of the soil profile in order to maintain acceptable salt levels.

d. Topography and Geology

A topographic map showing all physical features should be constructed. It should show details such as existing drainage facilities, wells, area boundaries, and distribution network. Major elevation differences should be noted on the topographic map as well as ground surface elevation contours.

The topographic map will be used to locate drainage facilities, outlets and inlets for the water budget and drainage problems. Maps of bedrock elevations, soil classification, and geological features should be constructed using the base map.

e. Water Table Elevation

Water level elevations above a common datum along with ground surface contours will provide data on depth to water. This should be plotted on the base map to help identify where high water table may be a problem. The direction of flow as well as gradients can be obtained from this contour map.

Water levels are measured in observation wells which are located at critical locations in the field.

h. Hydraulic Conductivity K

The hydraulic conductivity is determined by the auger hole test. Normally a grid system of auger holes is used and contours of equal K values are plotted to get estimates of K at other locations. The location of the auger holes depends upon field conditions and accessibility. A heterogeneous area requires more auger hole tests than for homogeneous areas. The amount of auger hole tests conducted depends upon the variability of the hydraulic properties of the soils within the area. This data along with data obtained in e and g can be used to evaluate groundwater flows.

g. Bulk Density Data

Bulk density (p_b) data are needed to determine the porosity of the soil. For most purposes the density of the soil grain may be taken as 2.65 and the porosity θ is given by $\theta = 1 - \frac{p_b}{2.65}$. Once porosity is obtained, the maximum moisture content (by vol) would be equal to the value of porosity. If no data are available for residual moisture content, one may assume as a guide, a residual moisture content of 1/3 θ max. The apparent specific yield, S_{ya}, may be calculated by:

$$S_{ya} = (\theta_m - \theta_r)\ (1 - \frac{z}{zd})^{-\lambda}$$

where θ_m = residual moisture content

(assume $\theta_r = 1/3\ \theta_m$ if no data are available)

λ = pore size distribution index

(assume $1.5 < \lambda < 3$ if no data are available)

$$zd = 9.7\ [\frac{K}{\theta_m - \theta_r}]^{-0.4} \text{ in. cm}$$

K = hydraulic conductivity in cm/sec

z = distance from water table to ground surface

The apparent specific yield is the amount of water released (or stored) per unit of soil for a unit decline of water table. If the water table is close to the ground surface, S_{ya} would be very small since most of the pores above the water table will be filled with water held by capillarity. S_{ya} would increase as the depth to the water increases and would reach maximum values of $S_{ya} = (\theta_m - \theta_r)$ when z is very large. Below is a definition sketch of the capillary fringe (Figure 2.13). The pore size distribution index is the slope of the line of the log-log relation between capillary pressure head and effective moisture content, $\theta_e = \frac{\theta - \theta_r}{\theta_m - \theta_r}$.

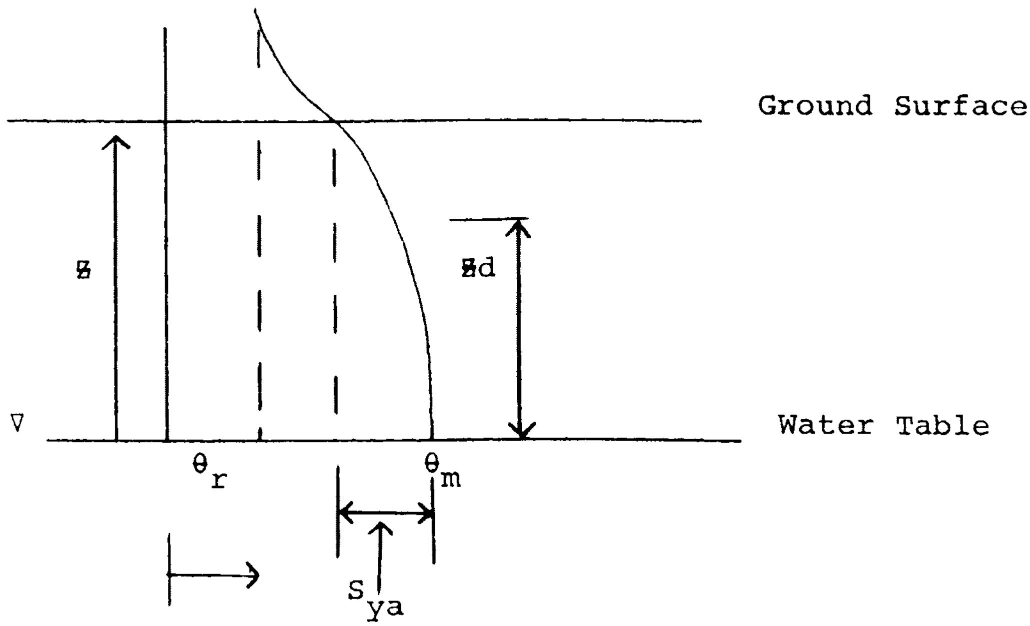


Figure 2.13

THE PHYSICAL ENVIRONMENT:
PLANT-SOIL DIMENSION

This section will describe the plant-soil subsystem of the farm irrigation system. First, a general overview of the subsystem is provided. Second, the major natural resources are described, followed by a description of important agronomic components. Finally, the operation or management components of the subsystem are described.

Subsystem Overview

The objective of the plant-soil subsystem is to produce food, fiber, oil, and specialty crops at optimum levels with the desired quality to ensure long term productivity.

An analysis of this objective will provide an understanding of the individual components of the plant-soil subsystem and the interrelationships between them. The actions undertaken to modify the environment and manage a crop are termed agronomic practices. These practices are the basic agricultural or farming practices for the crops that are produced in a particular area.

The function of the agronomic subsystem is to utilize the natural resources of an area by the proper management of the physical, chemical, and biological resources to produce food, fiber, oil, and specialty crops at desired levels. The crop production should be done in a way to ensure the long-term productive potential of the farm resource base. Some of the major physical, biological, and chemical factors, which must be carefully managed for the subsystem to function adequately, are shown in Figure 2.14.

The agronomic subsystem will function without human involvement; however, the system may not meet the demands of people or livestock without strong human intervention. For example, under natural conditions an area will support a varied plant community with each type of plant in competition with each other. Intervention into natural plant communities with domesticated plants combines the system's natural resources with management practices and new plant varieties for man's purposes. Some areas will produce no useful plants under natural conditions, and other areas will produce only a few with low-level production under natural conditions.

Farming activity uses the natural environment with certain modifications to produce crop plants yielding much higher levels than normal. Farming, as we use the term, includes the entire range of agricultural activities and support operations that man uses to produce crops. The purpose is not only to produce higher yields of desirable crops, but also to maintain these yields under varying environmental conditions and to improve quality. The wise management and conservation of these natural resources in order to ensure sustained production over time is also an important concern.

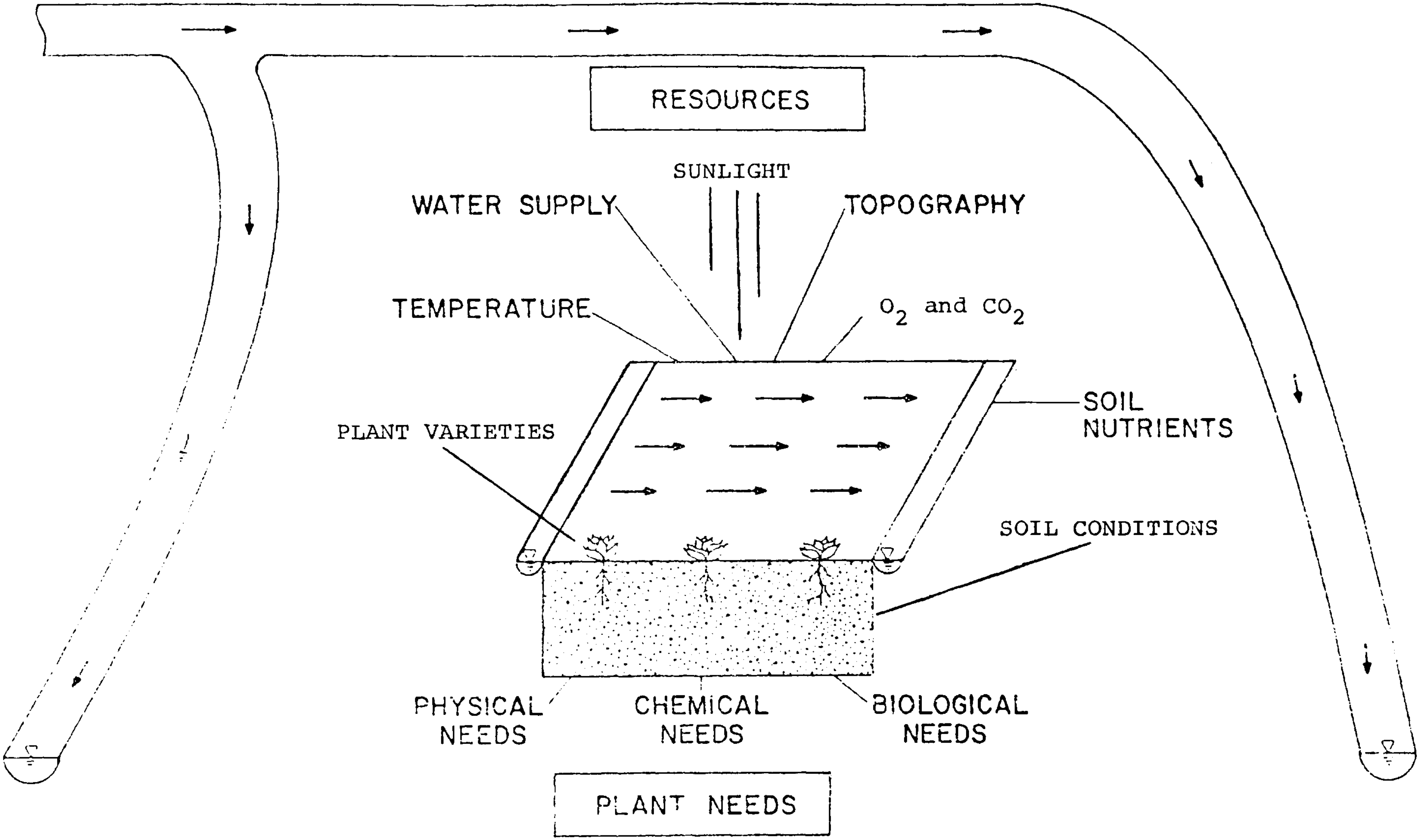


Figure 2.14. Major components of the agronomic subsystem.

The plant and its environment are the focus of our understanding of the plant-soil subsystem. The plant dictates what is needed from the environment and when it is needed. The natural resource base determines what practices are needed to provide this optimum environment for the crop plants. Agronomic practices which have been developed over time by farmers' experience and pragmatic agricultural research provide realistic practices for an area. Scientific activities can develop solutions to problems which the farmers have been unable to solve. Both the farmers and researcher require information about the plant and its immediate environment to determine which conditions are most suited for a particular crop. Agronomic practices then are a means to modify the natural environment so as to best serve the needs of the plant and to make the best use of the area's natural resources. Economic, physical, or social restraints may make it impossible to provide optimum conditions or to manage plants effectively. The needs of the plant, however, still determine the "ideal" conditions, and the constraints determine how close we can get to that ideal. The result is the "practical" set of practices for an area given the local situation.

You must understand what constitutes optimum plant growth conditions. The process is to ask, "What is the production potential for this area?" Also, "What are the modifications to the natural conditions that are needed for the plants to produce at the maximum potential?"

Natural Resources

The agricultural areas of any country are limited areas which have specific environmental conditions allowing crop plant production at some agreed upon level of optimum yield. Crop production usually requires some modification of natural resource conditions. For example, the modification might be how fertilizer is applied. Other modifications include irrigation water application or control or removal of the natural vegetation. In other cases, modification is made to the crop plant itself through plant breeding (or selection) to develop a plant type that is either better adapted to the existing conditions or that will produce at higher levels under new improved conditions.

Each agricultural area has specific conditions that will indicate different sets of management activities and crops. Areas that have some similarities of conditions and requirements are often grouped together into agricultural zones on the basis of climate, soils, or water resources. Using climate as the criteria for the types of agriculture, we often use such terms as Lowland, Humid Tropics, the Arid Tropics, the Humid Temperate regions, and the Arid Temperate regions. These are some of the major agricultural areas of the world, but they also suggest that the main differences are in water supply and temperature.

An expansion of agricultural activities into locations that are considered marginal, from a natural resource perspective, is made possible by practices that either modify the natural conditions or modify the plant to better fit the environment.

These modifications include irrigation to supply the water needs of crop plants; drainage to bring new areas under production; insect and disease control to make areas inhabitable by man and animals; land leveling to allow for surface irrigation methods; soil conservation techniques to provide for long term agricultural operations and salt control and land reclamation to remove excess salts and toxic substances from the soil.

In summary, the management and modification of natural resources is the basis of the agricultural system. The success of these methods in making areas suitable for crop production largely limits the areas that will be inhabited in the world. Most people live in active agricultural areas where crops are produced or can be traded for other products.

The modifications that will be required are not only a result of natural conditions, but they are also influenced by the needs of the crop plants that can then be produced in the area. The natural state must be modified to approach the ideal.

The practicality of making these modifications is determined by the natural conditions, the feasibility of making the changes, the cost of the changes, and the benefits obtained. This will be followed by a consideration of ways to modify the resources to improve plant production. Resources can be divided into physical and biological. The physical resources are climate and land.

Physical Resources

A. Climate

Temperature is the primary factor in determining which areas can best be used for various crops. Large areas of the world are currently unsuitable for crop production because of low temperatures. Short growing seasons also limit crop productivity. Some crops require total freedom from frost which limits their distribution, while others can stand frost during certain growth stages.

Temperature is not easily controlled or managed. Instead, crop selection and timing of planting dates are developed to match prevailing climatic conditions. Temperature modification is usually too expensive except for high value crops which can be grown under glass, or for short periods of time such as the control of brief frosts in citrus and early flowering deciduous or time fruits.

Day length or photoperiod is another important climatic factor and, like temperature, the major management approach is to modify agronomic practices which suit the prevailing conditions. Plant breeding has been quite successful in providing new varieties of crop plants that can be grown under varying photoperiod conditions.

Water supply is perhaps the most important climatic resource in agricultural operations. Irrigation provides a means for crop production in areas where no crops could be grown. It can be used to expand production in areas of marginal natural water supply.

Major water supply problems usually include conditions of excessive or insufficient water for good crop production. In cases of excess water, adequate drainage systems can lead to the development of productive lands, as in Egypt. In cases of a water deficit, irrigation is used to supply water for improved plant growth. In a given area, often both drainage and irrigation are needed for improved crop production. Irrigation systems supply water for plant growth, while drainage systems control the water levels and residual salts which are usually a major problem of irrigated areas.

Dryland farming, or alternate year cropping, as practiced in parts of Colorado, is basically a water resource management technique. In such areas, the water supply from two seasons is needed to produce small grain crops. This technique, however, is mostly adapted to small grain production on deep soils having a high water storage capacity. Under climates in which the stored moisture, supplemented by rain, is sufficient to produce a crop.

The water needs of plants, much like temperature, are not constant but change in relationship to the growth stage of the plant, and with the changes in the climatic factors. With the exception of some dryland areas, most soils have sufficient storage capacity to hold enough water for plants throughout the growing season. Where natural precipitation is limited during a given growing season, supplemental irrigation is needed for good crop production. Where natural precipitation is lacking altogether, irrigation becomes an absolute requirement because it is the sole source of water for plant growth.

Temperature, photoperiod, length of growing season, and water supply largely determine the areas where cultivated agriculture can be practiced. Temperature and photoperiod are largely uncontrollable but fortunately there are many areas having good conditions for plant growth with respect to these factors. The expansion of agricultural operations into these areas often requires that the water supply be controlled or supplemented. Therefore, irrigation is the primary management technique that allows these areas to be used for agricultural pruposes.

B. Land Resource

The other physical natural resource is land. In a consideration of the land resources we are primarily interested in topography, soil formation, and the nutrient supply of soils.

Many areas are too steep to allow cultivation without excessive soil erosion. In such cases, cultivation is not practiced unless the area is greatly modified by the building of terraces. This is most practical in climatic areas that allow intensive cropping practices, or in areas that have limited alternative areas for crop production.

At the other extreme are those areas of nearly level or gently rolling topography. These areas have few insolvable problems limiting cultivation and therefore constitute the major world agricultural area. Water supply is usually a limiting factor so irrigation is usually required in these areas. To irrigate the area, some land leveling is often required for better control of surface irrigation.

Topography and soil formation are intimately linked. Steep areas are subject to natural erosion preventing formation of a deep soil. More level areas often have deep soils. The reverse may be more applicable in flood plain areas where the deposition of soil material by water over time has resulted in an almost level topography.

Other important soil characteristics include water holding capacity, nutrient supply, freedom from plant toxic substances, and the soil's physical conditions. Some of these characteristics can be modified, such as salt removal, while others like texture, are essentially fixed. For example, water holding capacity of a soil can only be slightly increased without a high investment. Also soil temperature can only be slightly modified at low cost. You must delineate those modifications which can be made within the given economic limits for increased crop production.

The Components of the Subsystem

The overall purpose of the plant-soil dimension is to produce a crop with economic or social value to man. An examination of this dimension then, must begin by listing the specific needs of crop plants as shown in Figure 2.15. Crop plants vary in the amounts of particular inputs required for optimum growth and production. Within limits, basic requirements for crop growth are similar. Figure 2.15 suggests that the plant, its physical, biological, and chemical environment are all interrelated.

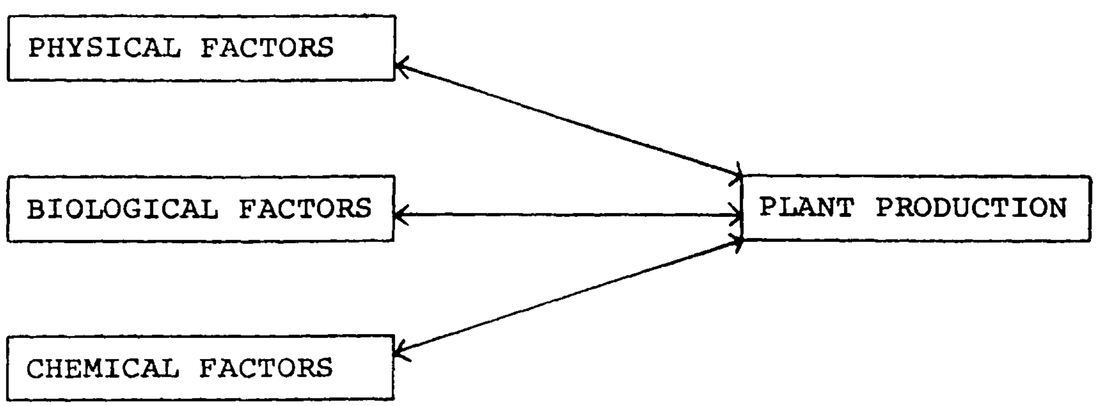


Figure 2.15 Physical, Biological and Chemical Factors Important for Plant Growth.

Basic plants needs can be subdivided for convenience into physical, chemical, and biological components. Physical needs include solar energy, temperature, mechanical support, and space. Chemical needs include water, oxygen, carbon dioxide, major and minor mineral nutrients, soil pH, and freedom from yield-decreasing toxic elements or compounds. Biological needs protection or freedom from pathogens, destructive insects and rodents, competition plants, and animals. Other biological needs include beneficial insects which are necessary for fertility, insect control, and pollination of some plants.

There are no areas in the world where all of these needs are met naturally for particular types of crops. Those few areas which approach ideal conditions will usually have populations of many plants which may not be of current interest or of use to humans. Some modification of the natural conditions is required to utilize the natural resources for plants that are of primary interest to man.

To gain a better understanding of the functions of the plant-soil dimension, the major plant needs are examined in detail. Examples are given of specific management practices that are used to direct these inputs to the crop plant for use.

A. Physical

1. Sunlight

The input of light energy drives the photosynthetic mechanism of plants. For plants to use light, it must be absorbed by the chlorophyll and photoactive pigments in the plant leaves. The intensity of the light must be high enough to provide energy at or within the ideal range for a particular type of plant. In addition to the intensity, the quality of light is also as important as is the duration or day length.

Sunlight intensity and duration varies throughout the year. Control is limited to selecting the growing season for a crop that will best match the needs of the plant with the natural conditions. Breeding and selection work can sometimes result in improved varieties that better match the natural conditions or can be grown in different periods of the year.

2. Temperature

The temperature of a plant is primarily controlled by the environment. Plants can stay slightly cooler than the air temperature, but cannot maintain an internal temperature much above the environment. Temperature changes the rate at which reactions occur within the plant, thus placing limits upon the growth and photosynthetic rates. If the temperature is above freezing, this rate of reaction is the primary effect. If the temperature goes below freezing, the plant can be damaged or killed. Many plant processes, such as flowering and seed development, are directly linked to temperature with the companion effect of day length.

As with sunlight, which is the provider of the environmental temperature, the major control is the timing of the growth period to match the needs of the plant with the environmental supply. In addition to air temperature, soil temperature is also important. This can be varied to a limited degree by cultural activities such as mulch, irrigation, and drainage.

3. Support

Plants require soil deep enough to develop a root system that is strong enough to support the plant. Soil depth and the ability of the roots to penetrate the soil profile are important. This penetration is a factor of the physical characteristics of the soil and how well the plant roots can grow as well as the temperature and aeration of the soil.

Control methods are both physical and biological. The soil can be mechanically disturbed so that root development is not hindered by impenetrable layers and the structure of the soil can be improved to increase aeration. High water tables can be lowered by drainage so that the plants can develop deeper root systems. Toxic substances can be removed so that the roots can penetrate new areas. Irrigation can provide a water supply so that the plants can grow roots into deeper layers that were dry. If the soil is too shallow, additional material can be moved to the area, but this is expensive and is only justified with high value crops.

4. Space

Plants need room to grow. Crowding has a depressing effect upon the yield and quality. Also affected are leaves. Their access to sunlight is another problem caused by too much competition among plants which causes a decrease in the plant's nutrient and water supply.

Proper plant spacing and plant populations are of prime importance. Spacing varies among crops, growing seasons, and the quality that is desired. You can control this by spacing the rows and the plant intervals along the row, by controlling the seeding or transplanting rate, and by thinning the crop at an early stage of growth.

C. Chemical

1. Soil pH

The pH of the soil solution influences the availability of mineral nutrients to the plant not only by the direct effect upon the solubility and form of the nutrient, but also by the effect of pH on the symbiotic organisms in the soil. Many pathogenes are likewise affected by soil pH and some plants, such as potatoes, are grown at a pH which is not optimum for their growth, but provides control of the soil pathogens.

Soil pH can be changed by adding ground limestone or by the addition of acidic materials, or by the removal of excess salts. Before making such changes, the crop rotation pattern should be determined as the pH requirements can vary among crops.

2. Major Mineral Nutrients

Mineral nutrients are divided into major and minor groups based primarily upon the amounts of each that are needed by plants. The range in amount is quite extreme, going from hundreds of kilograms per hectare in the case of nitrogen, to a few grams per hectare in the case of molybdenum. The major plant nutrients are N, P, and K with Ca, Mg, and S sometimes included as secondary major elements. Plants require these elements in the correct amounts, the correct form (available) and in the correct proportions. Also, due to the supply and cost of nutrients, economic considerations are important in making decisions about modifications to the natural supply of these materials.

The major control methods consist of the addition of the nutrients to the soil in mineral form or as animal manures or green manure crops. Crop rotations that include the use of a legume to supply nitrogen to following crops are also widely used. Modifications must carefully consider the balance that must be maintained among the levels of each nutrient, the form that is used to supply the nutrient, the needs or limitations of crops that will follow in the rotation, and the method and time of application. When additions are required, it will probably be necessary to supply these elements on a regular basis. The intervals will vary every two to four years with Ca and Mg, to as short a time period as providing nitrogen at two to three times during a given crop season. Soil tests and tissue tests coupled with plant observations are useful guides.

3. Minor Mineral Nutrients

The minor elements are required by plants in much lower amounts than are the major elements. This in no way changes their importance; however, because most of these elements are involved in the control of plant growth, development, or reproduction, a deficiency of any one can severely limit the growth of plants even though all other mineral needs are met.

The minor elements, like the major elements, can be added to the soil. In addition, foliar application may be the best method because the element may be in a nonavailable form in the soil. Great care must be used in modifying the supply of the elements because they can also be toxic to plants at higher levels. The gap between optimum levels and toxic levels can be quite narrow. With the exception of application by foliar methods which can occur more than once in a crop season, these elements are usually applied once and will last for a number of years.

4. Freedom from Toxic Elements or Compounds

The minor elements can be toxic at levels above that needed for good growth. Boron is a prime example of this effect. Na, Cl, Fe, and Al can also produce toxic effects. Bicarbonate ions can also exhibit detrimental effects, but these ions are usually associated with the irrigation water. Selenium and some of the heavy metals can be toxic to plants, although the levels of these elements are most often below plant toxic levels but will accumulate in the plant tissues and produce toxic effects on the animals or people that eat the plants.

Usually removing toxic elements involves leaching with irrigation water. The specific leaching methods vary from simple leaching in the case of Cl to cases which will require the removal of the soil material by inversion plowing or the abandoning of the field.

5. Carbon Dioxide

The supply of carbon dioxide to the leaf tissues involves the uptake of the CO_2 from the atmosphere through the stomates of the plant and the transfer to the cells that are active in PSN. This uptake through the stomates involves the loss of water to the atmosphere. The supply of CO_2 to the plant is one of the major growth rate limiting factors. It is the plant activity that requires the greatest amounts of water. In most crop plants, 80-90% of the plant's water use is used in CO_2 uptake. Low water supply to the plant has a direct effect upon growth rates by causing the stomates to close, thus cutting off the CO_2 supply and stopping PSN activity.

With the exception of greenhouse or other controlled atmosphere environments, the only way to control CO_2 uptake is to ensure that the plant has an adequate supply of water so stomates can remain open and provide a steady supply of CO_2 to the cells involved with PSN. Adding the organic matter to the soil may be beneficial in increasing the supply of CO_2 because it will be released during the decomposition of the organic matter in the soil. This effect is difficult to determine and probably will be negated by even a slight wind.

6. Oxygen

Plants release O_2 into the atmosphere through the stomates as oxygen is a by product of PSN. Plants need oxygen to metabolize sugars in the growth process. The need for O_2 is usually most critical in the root system since most plants cannot transfer O_2 from the leaves to the roots (rice being the major exception) and thus the roots are dependent upon the soil air for the O_2 supply.

Control is limited to maintaining the structure of the soil in a loose condition so that the atmospheric oxygen can diffuse to the root system. Of equal importance is keeping the water in the soil at levels less than saturation by controlling irrigation applications and/or providing for the drainage of excess water.

7. Water

A continual supply of water to the plant is crucial so that the photosynthesis (PSN) rate can proceed at the maximum possible speed consistent with the limits imposed by the other inputs. Water is only important as a medium of reaction in the plant, but also takes part in many of the reactions of growth and development. Except for soil, water is the largest single input to agriculture. Water quality is also important with consideration given to temperature, nutrient levels, toxic elements and compound, and general salt contractions. These factors are important because of their effects upon both the soil and the plant.

Plant water control methods vary widely. Agricultural operations are sometimes classified on the basis of water supply regimes or methods. Thus, rainfed agriculture, irrigated agriculture, and dryland agriculture, are commonly used as terms which divide agricultural methods on the basis of the water supply to the plants. The degree of control varies from none in humid area agriculture where all plant water is provided by precipitation, to total control in the case of irrigated operations in the arid regions that do not receive precipitation during the growing season. Specific operations vary from alternative cropping methods, to crop selection, planting times, plat populations, mulching, soil fertility control, and irrigation as either a supplement to natural precipitation or as the total supply of water. The plant's needs for water is continual and changes throughout its life cycle. The supply of water, therefore, is not only a factor of amounts, but also of distribution. In addition, the application of the water must be done in ways and at times that are not detrimental to the other needs of the plant.

D. Biological

1. Protection from Pathogens

The plants growth rate and the development of the yield can be adversely effected by the parasitic actions of various pathogens. The specific effects of these organisms is both direct and indirect. It is direct in that part of the plant's carbohydrate production or part of its tissue is consumed by the pathogen, it is indirect in that products of the pathogen's metabolism are detrimental to the plant by inhibiting the plant's metabolism even to the point of killing it.

Control methods vary depending upon the crop and the type of pathogen. The most usual methods are to prevent the plant infection by controlling insects that spread the pathogens, by using seeds that are free from infection, by using plant varieties that are resistant to the pathogens, by removing the pathogens from the environment as in soil sterilization, and by using the plant's natural defense mechanisms to ensure the plant growth at its best level and not being weakened by deficiencies of minerals, water supply, toxic substances, or physical damage.

2. Protection from Destructive Insects

Insects feed upon plant tissues or upon the fluids in the plant. This decreases the plant growth rate by the tissue loss and carbohydrates, but many insects can facilitate the infection by plant pathogens by providing entry into the plant through the destroyed tissue or by using a carrier of the pathogen and infecting the plant during feeding. The action of insects shows the plant growth rate and decreases the yield by eating the reproductive organs. Only in extreme cases do insects destroy the crop.

As with pathogens, control methods vary with the types of insects and the plants involved. In addition, the growth stage of the plant and the insect are important. Specific methods include killing the insects by chemical or biological means, preventing the growth of the insect by chemicals or by destroying the eggs or larval stages. Rotating crops decreases the build up of insect populations by growing plants that are not food sources to specific insects, by planting border or buffer crops that inhibit the movement of the insects are more attractive to the insect thus protecting the crop plant, and by using varieties that are resistant to the insects.

3. Supply of Beneficial Insects

Many insects have beneficial effects upon crop growth. Fertilization of the flowers by insects is a necessity in some areas. In addition, many insects are parasitic upon other insects and can thus provide protection to the plants.

Control involves the movement of beneficial insects into the field during the flowering period as in the case of bees and wasps, and using and selecting chemical control methods in order to effect only the target insects and not harm the beneficial species. Crop rotation and planting border plants that attract beneficial insects is also used.

4. Freedom from Competition by Other Plants

The water supply, sunlight, nutrients and other plant needs are usually limited. To ensure that the crop plant makes maximum use of these factors requires that other plants be controlled and not competing with the crop plant.

Land preparation is primarily performed to destroy the natural vegetation. The cultural activities that follow planting of the crop are also involved with the removal of competing plants. In addition to mechanical control of the plants, chemical and biological control can be used. Crop rotations are also used to decrease the seed supply of the unwanted plants. Irrigation or drainage can also be controlled to prevent or inhibit the growth of these plants and their production.

5. Protection from Grazing Animals

Pasture crops are raised for the direct use of animals. But even in this case, the crops need periodic protection so they can continue to produce and reseed. Other crops are intended for later use by animals.

The control methods recommended are controlling the times and duration during which the animals can feed on the crop, or by preventing the animals from having access to the crop. The specific control method will depend upon the animals involved. In the case of wild animals it may involve their destruction to prevent damage.

The plant-soil dimension's primary function is to provide an environment which will allow crop plants to produce acceptable yields. The yields must not only be at levels of production that are economic, but of the quality that is required by producers and consumers.

THE INSTITUTIONAL ENVIRONMENT:
RESOURCE - ALLOCATION DIMENSION

As shown in Figure 2.16 the Resource-Allocation Dimension is part of the Institutional Environment and focus in this section is on resource allocation.

The economic dimension at the farm level deals with the resource allocating process as traditional farmers and their families seek to survive, or commercial farmers attempt to maximize returns from production efforts. The decision makers must go beyond mere technical efficiency (attempting to maximize production) decisions. Farmers are influenced and constrained by social and institutional factors off the farm and by many physical and monetary constraints of resources on the farm. In order to effectively assist farmers in their resource allocation decisions, an understanding of the linkages between (1) macroeconomic objectives and policies, and microeconomic considerations and principles; and (2) the various farming activities and decisions is essential.

Economic decisions in farming are greatly influenced by the various macroeconomic objectives and policies. The macro development objective of policy and infrastructure building would require an increase in government revenue collection which in turn affects the individual farmer's resource allocation decisions when various revenue collection techniques are devised and set in motion. Government policy and programs to assist farmers would likewise enter the farmer's decision-making process.

The discipline of economics deals with optimal resource allocation. This underlying criterion requires that all the resource-utilizing and revenue-generating activities of the farming unit be assessed. If greater income can be generated by making improvements in the irrigation aspect of production activity than in some phase of marketing activity for the investments considered, then the resources need to be allocated in that direction. Other than resource allocation there are essential and direct linkages between various farming activities and operations. For an increase in effective water supply to make the desired maximum contribution to farmers' well-being, marketing constraints may need to be removed. For an economist to determine the optional resource allocation of a particular farming unit and assess the possible contributions that various undertakings could make to the individual farmer, information from other relevant disciplines such as agronomy, engineering, and sociology needs to be acquired.

In this section we will:

1. Define the role of the discipline of economics in farming and explore its relationship to the other farm-related disciplines.
2. Briefly explore the various farm management activities.
3. Illustrate the utilization of some of the economic principles in decision making in various farming activities. (Detailed illustration of the use of economic principles and analytical techniques is presented in the "How to do it" section of the training manual.

ECONOMICS, ROLE IN AGRICULTURE, INTERACTION WITH OTHER DISCIPLINES, -- AN INTRODUCTION

ECONOMICS AND FARMING

The principles of economics applied in decision making at the farm level are classified under microeconomics. The concern at this level is to maximize the return to the farm or individual farmer by an efficient allocation of natural resources such as land and water, man-made resources such as irrigation canals and machinery, and human resources of physical labor and know-how. This is to be accomplished in an environment of physical and human resource constraints, social and governmental regulations, and changing market conditions (see Figure 2.16).

The above characteristics of the function of the discipline of economics applied to farming illustrated the diversified information that it requires and the complexities to consider in a particular study. In investigating a particular farm problem several types of information are needed including:

1. The on-farm and off-farm resources such as land, labor, water, fertilizer, credit, and others that can be made available for farming.
2. The technical information from various relevant disciplines of irrigation engineering, agronomy, and animal science regarding improved farming practices such as in irrigation, planting, weeding, and animal breeding.

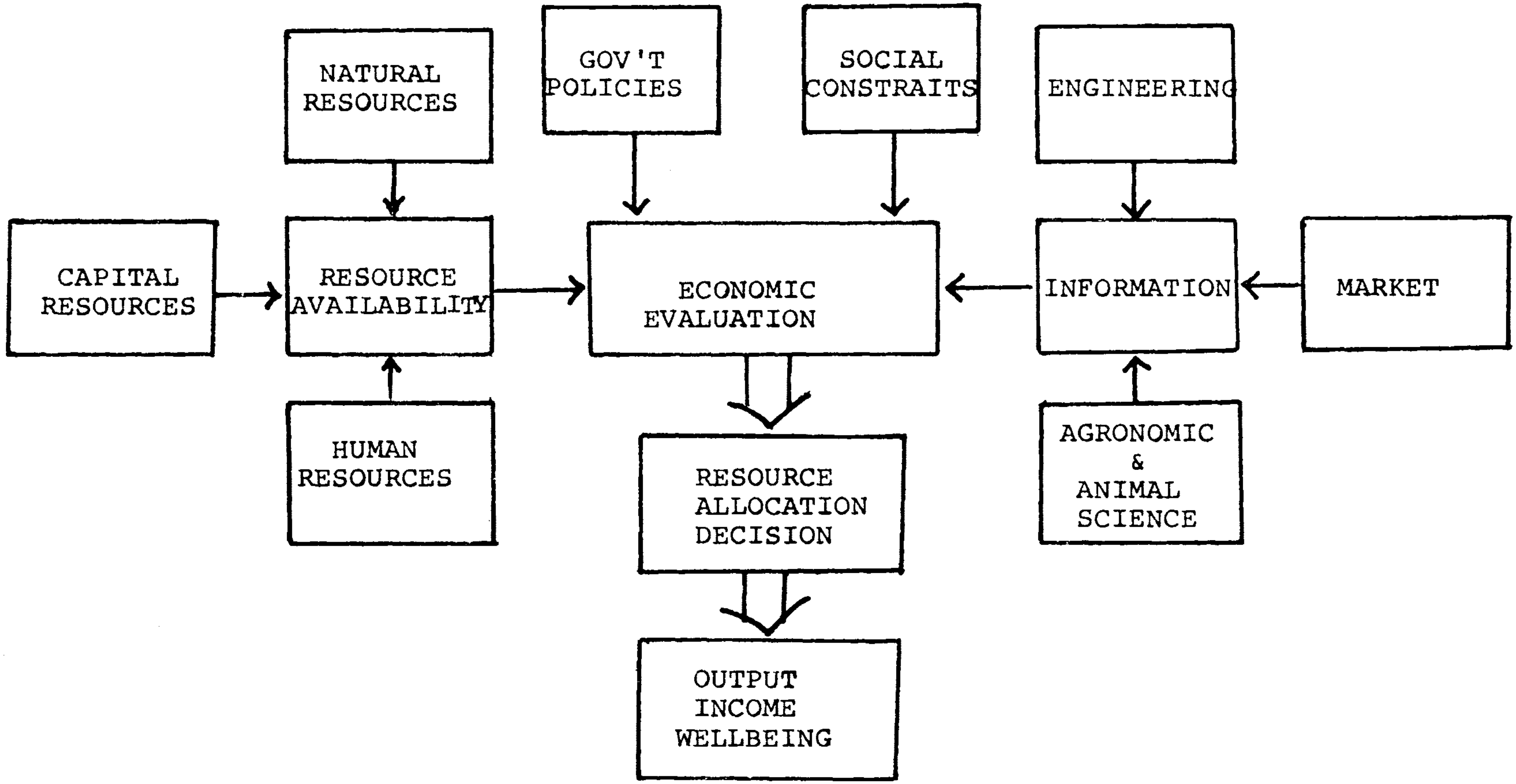


Figure 2.16. Inputs and constraints considered in a farm resource allocation evaluation.

3. Market price information.
4. The governmental and socio-cultural constraints such as an upper or lower limit in production of a particular crop, none price allocation of inputs such as water and fertilizer, farmer's attitudes and behavior toward adoption or non-adoption of new inputs, changes in cropping patterns, and farming practices.

It would be upon such a comprehensive and complete assessment that an economically efficient and viable solution to farming can be found and successfully implemented.

ECONOMICS AND THE OTHER FARM RELATED DISCIPLINES

Given the market condition and governmental policies, significant interaction between the various disciplines of engineering, agronomy, economics, and sociology are required for the identification of various problems in agriculture and the search for feasible solutions and their implementation. The nature of the interaction and the stage of investigation at which the discipline of economics participates depends on the problem under investigation. In the case of an irrigation problem, the engineers may suggest a number of alternative solutions which can resolve or reduce the magnitude of a problem, but evaluation by economists would be needed to identify the resource efficient solution before implementation. The decision to undertake a particular project or to choose among alternative projects is ultimately based on economic considerations rather than engineering efficiency criterion. In these instances the discipline of economics takes the investigation a step further toward the implementation phase.

The role of economics in agriculture and its relation to other disciplines involved can be further highlighted by exploring the concept of efficiency, the difference between economic efficiency and physical efficiency and by the reason for proceeding beyond physical efficiency in determining resource utilization.

Physical efficiency can be defined as achieving the maximum level of output from the given amount of input or conversely achieving a certain level of output with the least possible input utilization. Output can be a physical good or a service, and the input can be a physical input or knowledge. Economic efficiency consists of technical and allocation efficiency. Technical efficiency measures the differences in output that can arise from:

1. Full utilization of resources versus over or under utilization.
2. Different methods of production.

Allocative efficiency deals with optimal use of input combinations.

An objective of the irrigation engineering applied to a farm is to improve the physical efficiency of the irrigation system for improved crop production. More specifically, it deals with such elements as achieving minimum water loss in delivery and application, uniformity of application, and minimum erosion from irrigation. The discipline of agronomy concerns itself with various factors which affect production of crops with the ultimate objective of yield maximization on a sustained basis. (See the engineering and agronomic sections.)

Would achieving the optimal physical efficiency condition in an irrigation system or maximum yield per acre provide the desired and sufficient conditions that can lead to the achievement of ultimate goal of the enhancement of the farmers' welfare? A positive answer can only be given if the resources are free. The inputs and practices that achieve maximum physical efficiency such as maximum output per unit of land may turn out to be undesirable or inefficient from the economic point of view.

The difference between physical optimization and economic optimization is illustrated by the following example. In the production of a particular crop a number of inputs such as land, water, labor, capital, and management, are utilized. In this case we consider all other inputs as fixed or given and focus on the application of water in order to achieve maximum output per unit of water input of maximum yield (see Figure 2.17).

The total output curve describes the response of yield or output of cotton to water application. At zero supplemental or irrigation water an output level W is achieved from application of other inputs and water from the rain. Water application

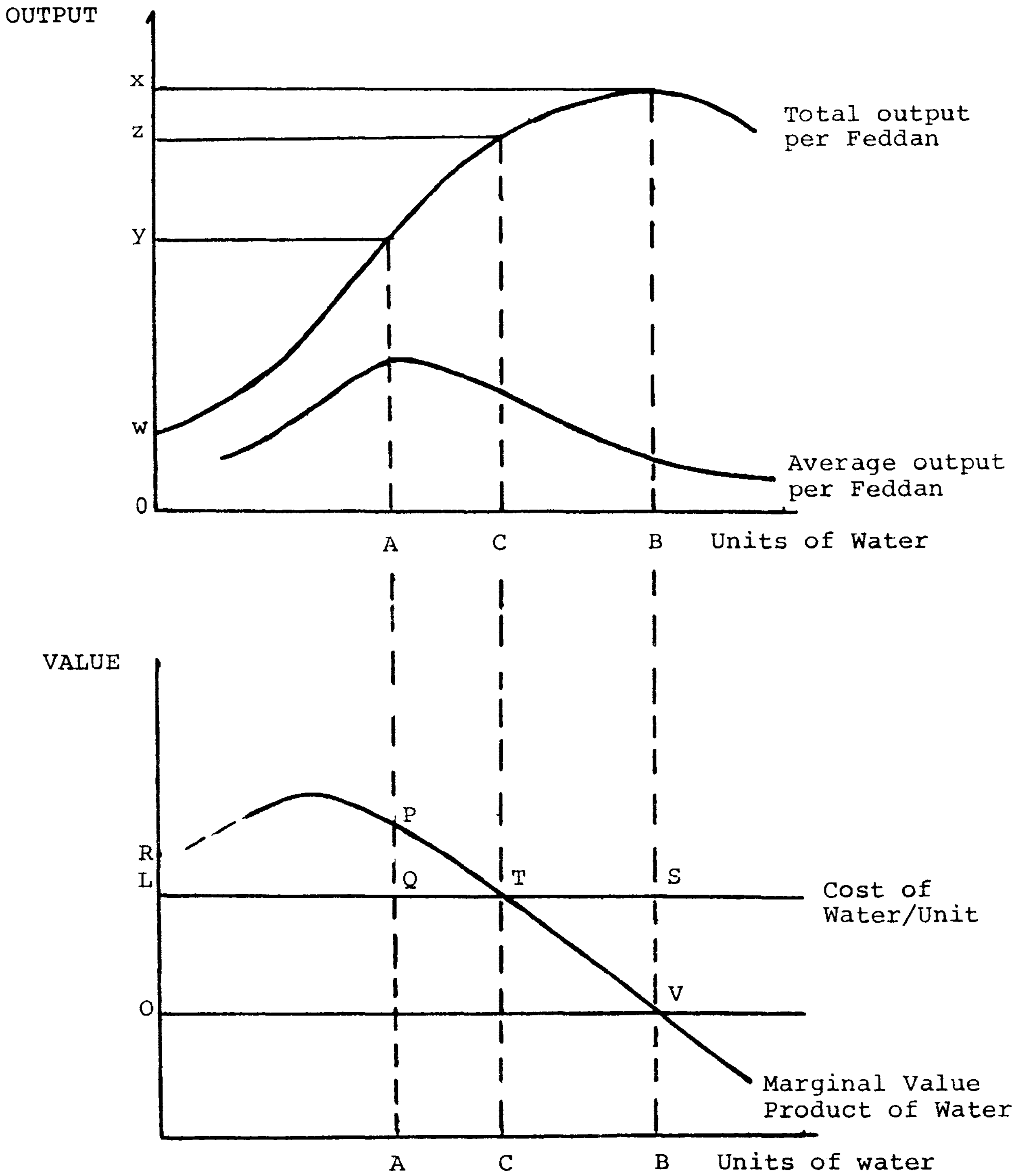


Figure 2.17. Physical versus economic optimization conditions.

level A leads to output level Y at which the average physical output per unit of water is at its maximum. Application level B leads to maximum achievable output. Water application beyond point B leads to over irrigation and possible waterlog, thereby lowering yield and output.

Without consideration of the cost of the water and price of the output produced or under the condition of a zero cost for water, the rational choice would be to apply water level B and achieve maximum output level X. But water is generally not free though in Egypt often it is assumed to be a free good. There is cost associated with its provision due to costs of storage, lifting, delivery, and application. If water is priced on the basis of supply and demand conditions, then the cost of water would include its scarcity value as well. Suppose the price of water is fixed at L Egyptian pounds per unit as shown by horizontal line LS. Since the increase in yield from each additional unit of water continues to decline as more and more units of water are applied (law of diminishing returns), then so does the value or return from each additional unit of water applied decline. This relationship is shown by the downward sloping marginal value product curve.

At the point of maximum output per unit of water input, (application level A) the per unit value return to water applied is P and cost of water is L. An increase in application of water from level A toward level C continuously adds more to the return than to the cost of the water. This is shown by segment

PT of the marginal value product curve which lies above segment QT of the water price curve. This demonstrates that increasing water application from level A toward level C increases the net benefit to the farmer.

THe cost of water per unit and return from consecutive units of water used are equal at point T. This equality represents the economic optimum and suggests that the farmer should apply level C rather than A or B. At the economic optimum, the total gross return ot the farmer is equal to the area ORTC and cost of water equal to area OLTC and the return to the other input factors and farmer's effort is equal to LRT.

Application of water beyond point C adds more to cost than to return from water applied and consequently lowers the net return on the farmer compared to application level C. Application of water at physical optimum of B would add area CBST to the water cost of the farmer and the smaller area CBVT to the farmer's return. The net loss to the farmer is area TVS from the application of additional water units of CB.

The difference in focus and efficiency criteria between physical sciences applied to farming and economics as illustrated in this section, highlights the indispensable role of an interdisciplinary investigation of a farming system. In the following section the economic aspect of farm management activities which is a component of the overall farm management decision making process (illustrated in Chapter I) could be explored.

FARM MANAGEMENT ACTIVITIES

Farm management in general includes five broad categories of production activities, capital building activities, commercial activities, financing activities, and accounting activities.

General Farm Management Activities

Production activities:	input level and combination
	enterprise choice and combination
	tillage practices
	irrigation practices
Capital building activities:	purchase of machinery
	lining ditches
	building drainage
	leveling land
Commercial activities:	marketing outputs
	purchase of inputs
Financing activities:	acquiring fund
	using fund
	forecasting future needs
Accounting activities:	production records
	transaction records
	tax records

These activities require a series or large number of decisions that are to be made by the farm manager.

It is mainly in the production and capital building farming activities where various farm related disciplines of engineering, agronomy, economics, and sociology are brought together to assist farmers in their decision making. Farm production activities involve making decisions on resource allocation, adoption of new inputs such as chemical fertilizer and high yielding varieties, and changes in farming practices.

Capital building activities refer to accumulation of fixed inputs. These activities include investment in fixed cost inputs such as sakias, and investment in farm improvement such as irrigation and drainage systems. Improvement could also be made in human capital such as in know-how of farmers. Capital building activities generally require large investments and the benefits from these inputs and improvments would occur over an extended period of time.

Commercial activities involve decisions on marketing agricultural commodities and purchase of farm inputs. Financing activities are concerned with obtainment and utilization of funds or financial capital. Commercial and financial activities fall primarily in the realm of the discipline of economics. These activities and relevant decisions are influenced by institutional and socio-cultural factors.

Accounting activities are undertaken in order to assist farm managers in their decision making in the technical, commercial, and financing activities. Certain types of records are kept and accounting statements prepared in order to meet the requirements of government agencies and various other institutions.

PRODUCTION AND CAPITAL BUILDING ACTIVITIES

In view of the focus of the EWUP project and its inter-disciplinary feature, the following discussion of the economic section in this training manual will be primarily devoted to the description of the role of the discipline of economics in technical farm management activities of production and capital building. More specifically, a number of decisions that are needed to be made by the farmers in this area along with the appropriate economic analytical techniques and relevant principles of economics will be explored.

Decisions on various farm management technical activities of production and capital building which may be undertaken by farmers can be classified as being made with respect to:

a. Variable or short-run production activities.

b. Fixed or long-range investments and commitments.

c. Farming practice for both short- and long-range activities.

In any particular year the decisions on what to produce and how much to produce are further based on the decisions on the combination of inputs, levels of input application and the allocation of these inputs among various enterprises. Costs and returns associated with short-range production decisions generally occur within that particular production season.

Decisions on long-range investments (such as undertaking major improvements, introduction or greater utilization of farm machinery, and extension of the size of the operation by purchase and long-term lease of land) entail long-range and greater impacts on the profitability and well-being of the farmer due to their high cost and changes in the structure of farming.

The farming practice or method of production is included both in short and long-range nature farm operations. A change in the method of irrigation or application of fertilizer without a major change in the structure of the irrigation system and investment in machinery illustrate a variable change. A shift toward utilization of machinery and major improvements would most likely entail a change in farming practices. The introduction of machinery or major improvements and changes in use of such variable factors as chemical fertilizer are recognized as intensive farming practice. Expanding the land area by renting or buying is recognized as an extensive farming practice (see Figure 2.18.

Farm management economics has devised and applied different analytical tools which utilize various principles of economics in order to assist the farmers in their decision making. The tool of the analysis itself is a format within which information can be brought together and the relevant principles of economics

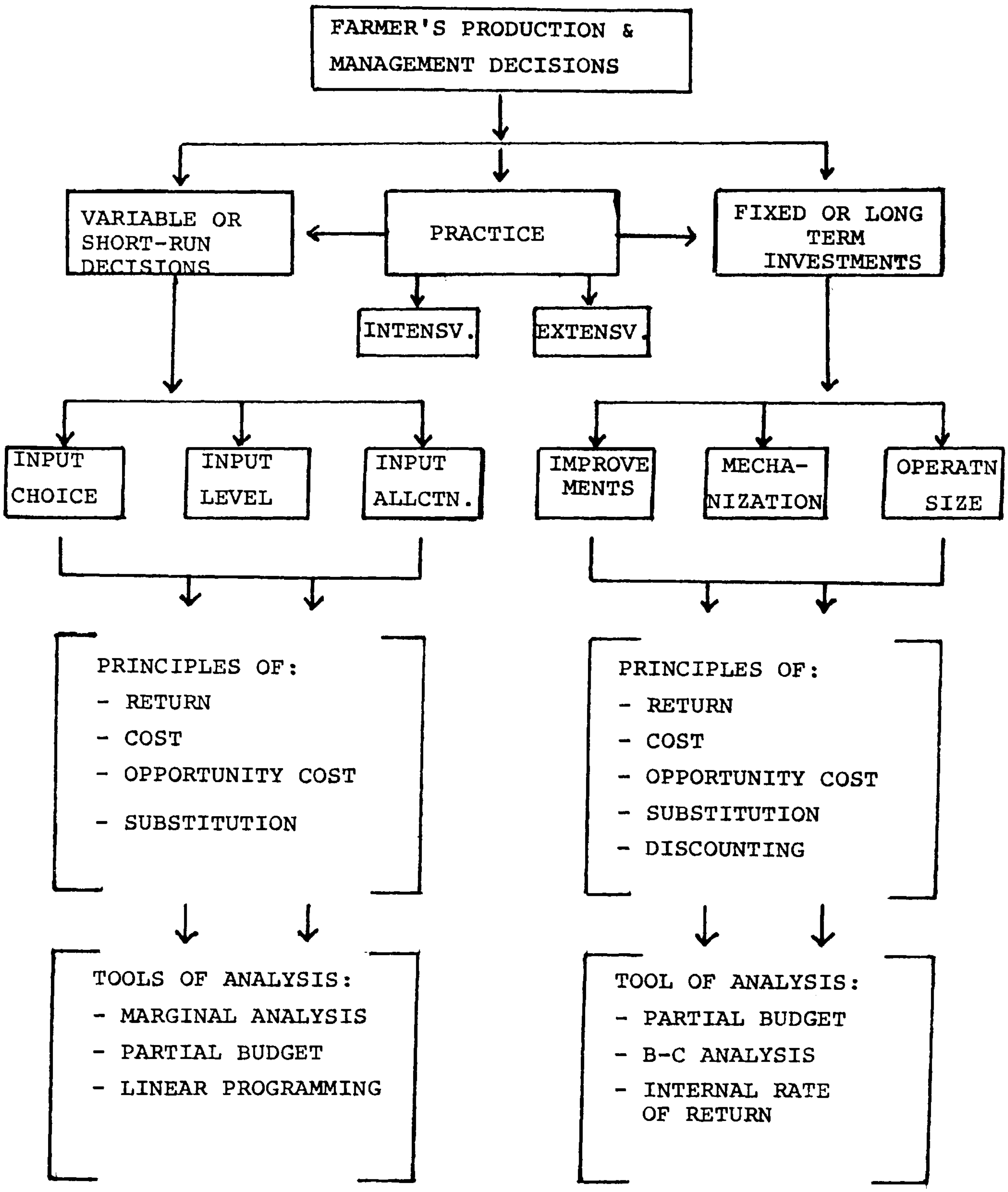


Figure 2.18. Application of principles and tools of economic analysis in farm management.

applied. The principles of economics serve as guides toward optimal decision making as it explains the why of profitable farm management. All economic decisions such as allocation of a particular input among various uses, choice of product combinations, investments in machinery and improvements should be made in terms of economic principles.

Some of the principles of economics and analytical techniques applied in the production aspect of farming will be illustrated in section III. The role of financing, marketing, and farm record keeping, on farm income and profitability are briefly explored in the following pages.

FINANCING ACTIVITIES

As farmers in developing countries evolve out of the low productivity subsistence farming and enter the stage of diversified or mixed agriculture, farm financing activities become important. The amount of funds at the farmer's disposal could be viewed as another factor of production which can affect the farmer's production decisions. Funds are required for the purchase of various traditional and non-traditional inputs that are essential for production and profitability of the farming operation. Such funds can be acquired by production of cash crops such as cotton, off-farm employment, and borrowing from various governmental and private lending institutions.

The use of high payoff non-traditional inputs, such as chemical fertilizer, fuel, pumps and others, have particularly necessitated the use of economically sound financial decisions. The decisions involved may include borrowing, saving attitude, production of cash crops, and off-farm employment. In view of this, a farmer needs to identify his various sources and uses of cash fund and engage in cash flow analysis of his farming operation. Shortage of funds to purchase fertilizer in critical periods of the growing season may prove detrimental to the profitability of his operation. (See the "how to do" section for cash flow analysis.)

COMMERCIAL ACTIVITIES -- MARKETING DECISIONS

Farmers are engaged in a series of after-harvest activities which are classified under marketing. These activities include some on-farm processing, storage, and transportation. These activities involve cost and in the meantime add to the value of the farm commodities. Increasing the efficiency of these activities may increase the supply of agricultural commodities available for sale as much as an increase in production.

Proper storage may reduce the physical loss from storage, and storage for the optimal length of time as can be determined by change in market price of the products stored compared to the cost of storage. Reducing the loss due to on-farm processing of certain crops which may be accomplished by switching from traditional methods to some modern method, such as rice milling, can add to effective supply available for marketing.

Large seasonal price fluctuations are observed in low income countries. The farmers' need for cash to pay debts or make cash purchases have forced them to sell their crops soon after harvest when the influx of commodities forces the post harvest price to a very low level. Good financial planning by farmers can remove this pressure and consequently allows an efficient marketing practice to be undertaken.

When faced by monopoly buyers of agricultural commodities, information about prices in other farming regions of the country and urban centers improve the farmer's bargaining position. Likewise, information of agricultural cooperatives can provide farmers with collective and stronger bargaining positions in the sale of their products. Knowledge of market conditions and farm cooperatives can also assist farmers in the purchase of inputs such as fertilizer, seeds, and others.

ACCOUNTING ACTIVITIES

Farm records serve as an essential source of information which can be utilized by farmers in the improvement of their farming operations. Such information could be analyzed by the farmers themselves and by the researchers and various government agencies involved in assisting the farmers.

Farm records on the yield of various crops, levels of various inputs used in the production of various crops, costs of purchased inputs used and family labor allocated to farm operations serve as a base for comparison with operations of other farms and improvement of a particular farm over time. Where there are differences in the profitability of farms of similar natural endowment in similar regions of a country, an evaluation of farm records would assist in identifying the factors responsible for such profitability differences.

Quantification of the differences in operation between progressive and traditional farmers as made possible by farm records is essential. Quantitative evidence can make a strong case to the traditional farmers for the need for change to a more profitable type of farming operation.

Progressive farmers who are in closer contact with research institutions and government extension agencies are more responsive to adoption of new techniques and utilization of new inputs that can improve their farm output and income. Farm records maintained by these farmers would then make it possible for them to evaluate the contributions to their farm profitability made by the use of new inputs such as chemical fertilizer and adoption of new farming practices such as in timing of irrigation, level and method of water application.

Experienced researchers and extension workers who are familiar with a particular farming region can utilize the farm production record to identify the possible sources of problems which could then be further evaluated by an interdisciplinary team for farm experts. Such an evaluation could then be used to find, evaluate, and recommend solutions to existing farm problems.

Overall, the farm records are used for the following reasons:

1. To establish factual basis for comparison with performance of other comparable operations, past years performance, and goals set.
2. To aid in planning for the future by providing data that can serve as a base in estimating the effect of operational changes on productivity and income of the farm.
3. To aid in obtaining credit.
4. To meet the tax reporting requirement and to assist in tax planning and management.

APPLICATION OF PRINCIPLES OF ECONOMICS IN FARMING

OPPORTUNITY COST PRINCIPLES APPLIED TO LABOR UTILIZATION

In the traditional farming sector labor is one of the major inputs. The farm family contributes a large number of man days or man hours to farming and it is essential for a farmer to recognize and estimate the contribution of this labor input to the total farm output and income. The members of a farm family may be able to obtain a job working on another farm or work in the industrial or service sectors and receive an income from such employment. The money that could be earned in alternative employment is given up if family members work in their own farm. The income from other employment foregone is an opportunity cost to the family farm and must be considered in decision making. The farm family labor should be divided so that the total family income from both the family farm and other employment is at a maximum. The economics optimization principle applied to this situation is the equalization of the marginal value product of a unit of labor to the opportunity cost of a unit of labor. The opportunity cost is estimated on the basis of unit labor wage that the farm family member can obtain from outside employment, and the marginal value product is estimated on the basis of contribution that the labor could make to farm output if he worked on the farm. The farm family labor is optimally allocated between the family farm and other employment when the earning per unit of labor from the last unit of such labor employed in outside employment is equal to the marginal value product of that last unit of labor when utilized on the farm. However, in real world situations, the sociocultural factors such as high value placed on staying in close proximity of one's family would lead to an allocation of labor which may not be justified on economic grounds.

PRINCIPLE OF RETURN--EQUAL MARGINAL RETURN--APPLIED TO ON-FARM WATER UTILIZATION AND ALLOCATION

Where there is a cost associated with water input or a limit is placed on the quantity of water available for each farm, the return to a farmer would be affected by the farmer's water allocation decision among his various fields or crops. If water is unlimited and free, each field or crop could be given water so that the yield from each crop or field would be at a physical maximum. In this evaluation the physical maximum would be equal to the economic optimum. However, in the real world this is not the case. Even when unlimited water is provided at no direct charge to farmers, there are costs associated with its application such as pumping and irrigation labor time. In the instances where these costs are also very low, the potential for over utilization and waste exists.

Under the economic allocation principle of marginal return, water as a scarce resource would need to be allocated between various crops such that its contribution to the value of output (MVP) of a particular crop is equal to that of each other crop. For example, if a farmer has a limit of 20 units of water at zero cost per unit and is producing the three crops of wheat, cotton, and berseem, then the optimal resource allocation condition would require that:

MVP W = MCP C = MVP B

$MVP_i = MPP_i \times P_i$

MPP_i = marginal physical product or increase in physical output of a particular crop (i) from application of one additional unit of input (water).

P_i = price of the unit of output (i) produced.

This equality would have to occur at the positive range of values as shown in the following table (Table 2.2) the optimum allocation of the 20 units of available water occurs when 5 units is applied in wheat production, 7 units in cotton production, and 8 units in berseem production. The value of total farm production has reached a maximum of 215 pounds under this pattern of water allocation. If water is allocated such that the marginal value product of wheat is greater than the marginal value product of cotton and berseem then the farmer's income can be increased by changing the farmer's irrigation practice where more water is applied to wheat and less to cotton and berseem until the marginal value product of the three crops is equal.

Where there is a cost per unit of water made available, then the marginal value product of water applied to each crop could need to cover the cost (LE 10) of the water.

TABLE 2.2

COST, ALLOTMENT, RETURN, AND
THE LEVEL OF WATER APPLICATION

Input Water	Cost Per Unit	Wheat		Cotton		Berseem	
		TVP	MVP	TVP	MVP	TVP	MVP
1	L.E.10	15	15	16	16	15	15
2	L.E.10	27	12	30	14	29	14
3	L.E.10	37	10	42	12	42	13
4	L.E.10	45	8	52	10	54	12
5	L.E.10	51	6	61	9	65	11
6	L.E.10	54	3	69	8	75	10
7	L.E.10	54	0	75	6	83	8
8	L.E.10	50	-4	79	4	89	6
9	L.E.10	45	-5	81	2	93	4
10	L.E.10	39	-6	81	0	95	2
11	L.E.10	32	-7	78	-3	95	0
12	L.E.10	24	-8	73	-5	93	-2

MVP W = MVP C = MVP B = per unit cost of water (MC)

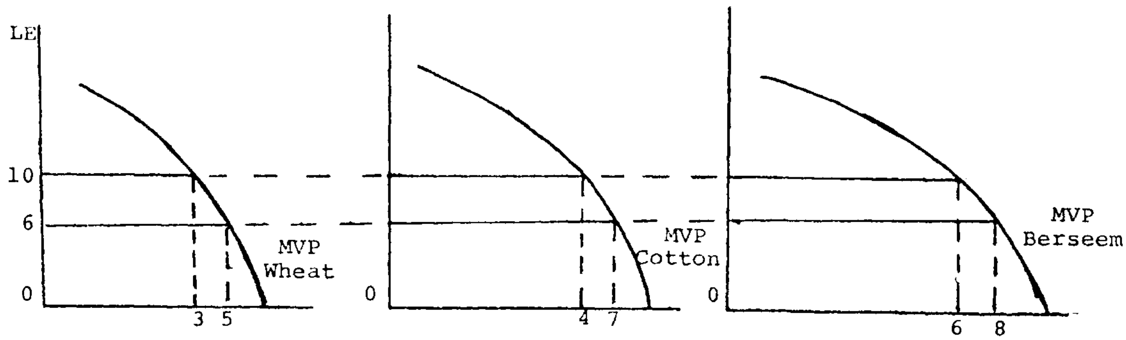


Figure 2.19. Return, cost, and the level of water utilization.

In this hypothetical situation the water is distributed between various crops with total utilization of 13 units (3 units for wheat, 4 units for cotton, and 6 units for berseem production) which is less than the maximum available water. Farmers attempt to use more than the 13 units would lead to an increase in cost of water which is greater than the return from the additional units of water.

This pattern and level of water application results in a maximum farm production value of 164 pounds. Given no change in level of other inputs, input costs, and crop values, the purchase and application of additional water to any of these farm enterprises would lead to a decrease in the net farm income (see Table 2.2).

If water was provided free of charge and in an unlimited amount, then the criteria for optimal level of water application would be to maximize the value of each crop based on water application. This would occur when seven units is applied in the production of wheat, nine units in the production of cotton, and ten units in the production of berseem. The value of total farm production has reached a maximum of 230 pounds with this higher level of water application. It needs to be acknowledged that in the real world situation the water is neither free nor unlimited.

PRINCIPLE OF SUBSTITUTION APPLIED TO CHOICE OF FARM ENTERPRISE

In resource allocation analysis we viewed the various crops produced as given and searched for optimal allocation of inputs between them. Conversely, a farmer needs to assess the various inputs such as land, labor, machinery, water, as well as the market value of various crops in order to make the selection of an optimum combination of farm enterprises. In addition, the farmer needs to consider the social constraints and government policies in making this decision. This is an extremely important economic decision that needs to be made by farmers before each planting season once or twice a year.

Economic optimality condition requires that the combination of farm enterprises and consequent allocation of resources should be carried out where the return to the farmer's efforts is maximized. The maximum profit is achieved when the expansion of size of one farm enterprise (such as cotton production) and the consequent reduction in size of other enterprises from associated resource reallocations on the farm, cannot lead to a further increase in farmer's income.

In the simple case of one input and two outputs the economic optimality condition requires that the marginal rate of product substitution between the two products such as wheat and cotton should be equal to the inverse of the price ratio of these two products (for detail see "how to do it" manual).

$$\text{MRPS of Wheat for Cotton} = -\frac{PW}{PC} \text{ or } \frac{\Delta C}{\Delta W} = -\frac{PW}{PC}$$

MRPS = rate at which one product substitutes for another in utilization of resources

PW = price of wheat per unit

PC = price of cotton per unit

ΔC = change in cotton production

ΔW = change in wheat production

When cross multiplied the equality between marginal value product of wheat and cotton becomes apparent. This represents the optimal allocation of inputs between the two enterprises or optimal choice of farm enterprises.

However, in a real farm situation a large number of inputs and outputs enter the decision making process. Linear programming is often used as the analytical technique in determining the optimal choice of farm enterprises. (See the "how to do" marginal analysis and linear programming sections for methodology and analytical detail.)

FIXED INVESTMENT DECISIONS

The discipline of economics applied to on-farm decision making goes beyond short-term resource allocation in the production aspect of farming. Long-range investments in and improvements of the farm such as land leveling, and construction of lined ditches and drainage systems, or the introduction of machinery such as irrigation pumps and tractors would also need to be evaluated on the basis of their economic merits. Such on-farm investments have both national or macro and farm level or micro implications. Investments in farm machinery which replaces labor may directly increase the benefit of a number of individual farmers but may add to the national unemployment problem and to demands for more of the nation's scarce resources of skilled labor, capital and foreign exchange.

An individual farmer makes his investment decisions on the basis of costs and benefits directed at his operation rather than the economy and society as a whole. Changes in national valuation and macro policy would be reflected in cost and price structure which in turn affects the farmer's investment decisions.

For example, consider the case where an improvement in the irrigation system in the application stage could be made by land leveling. Land leveling would require a large investment in terms of equipment and labor when undertaken, while the benefits from it may continue over an indefinite period of time. The benefits that may arise from yield increase, reduction in water waste, and other increases in benefits and reductions in cost from a more efficient water application needs to be evaluated over the future years. The cost of leveling may include the actual leveling cost plus an interest which reflects the cost for the funds borrowed or the opportunity cost of farmers savings used for the improvement. The discounted value of the returns can then be compared against the costs of leveling. If the benefits are greater than the costs, then land leveling may be considered beneficial from the economic point of view. However, land leveling would need to be compared to other alternatives available to the farmer to determine if it should be undertaken.

Suppose another area of improvement as suggested by the team of farm researchers is a reorganization and improvement of the on-farm water delivery system. Still a third alternative where a major investment could be made is to engage in a joint venture with a neighboring farmer in poultry production.

The above mentioned three areas of investment are not technically mutually exclusive. However, the large investments required by each one of these investment opportunities and the financial resource constraint of the farmer necessitate that a choice be made by the farmer. The three alternatives considered have somewhat different initial investment requirements considered have somewhat different initial investment requirements which are assumed to fall within the farmer's resource constraint.

The farmer's decision on the choice of alternative investments open to him depend on a number of variables which affect their profitability and implementation. A number of these variables are as follows:

1. Initial investment required.
2. Productive life of the investment.
3. The discount rate.
4. Annual operation and maintenance cost.
5. Amounts and schedule of receipts.
6. The nature of complementarity and competitiveness with other operations of the farm.
7. Socio-cultural factors.
8. Government policies.

Assuming that each one of the three alternatives were implemented and equally desirable from the social and government points of view, then the choice would be based on the net increase in the farmer's income which these investments could bring about. Such an economic analysis and comparison can be made by means of estimation of the internal rate of return or simple partial budget analysis.

The investment alternative which makes the maximum contribution to the enhancement of the farmer's income and consequently his well-being would be chosen. To allocate resources in the disposal of farmers such that the income and well-being of the farmers are maximized is the role attributed to economics as applied in farm management.

THE INSTITUTIONAL ENVIRONMENT: STRUCTURAL-CULTURAL DIMENSION

The structural-cultural dimension or social organization and the major focus of effort will involve around the irrigation behavior of water users. The principle assumption is that within an existing irrigation system, the farmers' irrigation behavior as well as other activities is goal oriented and depends upon the farmer's situation. We assume that this behavior is rational and purposeful based upon all the circumstances in which they are placed. Any evaluation of the farmer's activities must consider the factors which influence his behavior. The purpose of this section is to discuss the individual and group factors which can influence farmers' irrigation behavior. When the time comes for evaluating irrigation practices, then the researchers can understand the reasons for such practices both from the farmer's reasoning, the researchers' observations, and measurements.

One method for describing the farmers' irrigation is to place the influencing behavior factors into a particular sociological format. This format is set-up so that the field sociologist can organize important variables around a specific activity. This format is only a framework to help explain specific types of irrigation behavior. Such a framework will be discussed by (1) presenting the general sociological categories, (2) describing the units within each of the categories, and (3) examining the specific dimensions which measure the farmers' situation.

GENERAL SOCIOLOGICAL CATEGORIES

The general sociological categories are shown in Figure 2.20. These categories organize the variables in a type of map which help explain farmer behavior.

SITUATION			ACTION	
SETTING	CULTURE	STRUCTURE	PROCESS	RESULT
1. Physical Setting	1. Activities	1. Nominal Parameters	1. Individual Level	
2. Institutional	2. Normative	2. Graduated Parameters	2. Organization Level	
3. Technological Setting	3. Values/ Beliefs/ Perceptions	3. Capacity of Position		

Figure 2.20. Format of major sociological categories affecting an individual's behavior.

To begin with, any study of farmer behavior must start from a particular action or set of sections. From that action one examines the situation which affects a particular behavior in order to understand why the action occurred. Therefore, the point of origin in any study of behavior will be the result one wants to explain. Such a result will be either examined at the individual level or at the organizational level which is the process of concern for the researchers. In other words, if a particular action involves a single person or a small group of people, then the analysis will look at situational variables which affect only the individual or the group of concern. If the action involved groups of people and formal/informal organizations, then an additional set of variables is needed and the situation analysis will follow a different path. Regardless of the level of the analysis the important factors to be studied will come from the situation.

The situation includes three major categories: the setting, the culture, and the structure. These categories are then subdivided into a number of minor categories which serve as guides for developing specific variables which measure and thus evaluate the situation (Figure 2.20).

The Setting

The setting refers to the environment in which the social system is placed. There are many types of environments but the physical, institutional, and technological settings are important for our work. These are described as:

Physical Setting - This arena comprises the physical environment and the general demographic characteristics of the population living within a particular geographic area.

Institutional Setting - This environment comprises the different formal and informal organizations which affect an individual farmer or a group of farmers.

Technological Setting - This environment describes the degree of the farmer's ability to control natural and social factors which operate as either incentives or disincentives as he attempts to reach his goals in farming.

Culture

Culture describes the patterned ways of thinking, feeling, and behaving in the social setting. Three general categories for examining culture are:

Activities - Those deeds and actions performed by the farmer.

Normative Condition - The rules governing relationships and socially acceptable as well as unacceptable activities are defined as:

Values/Beliefs/Perceptions - Those aspects of the culture which the farmers view as good or bad, as true or false, as to what exists and what does not exist.

Structure

Structure is that aspect of a social system which describes its form and sets boundaries for the interaction of its component parts. The structural dimensions are:

Unranked Parameters - Unranked or nominal units within the social system which occupy specific positions in relation to each other that are of comparable rank.

Ranked Parameters - Units within the social system which occupy specific positions in relation to each other that are of different ranks.

Capacity of Position - The degree of power, prestige, and wealth associated with a unit in a social system.

SOCIOLOGICAL BOUNDARIES DESCRIBING THE SITUTATION

Included in the different categories which describe the situation are many parameters which serve as a means for explaining a further specific type of behavior. Figure 2.21 displays the parameters which must be considered in any analysis of behavior. Such parameters serve as reference points which help explain the positions and relationships of the categories. Using these parameters, then, helps to explain why a farmer or a group of farmers act as they do.

In the general category of setting, the parameters defining the physical setting are: the demographic characteristics of the area, the size of the area, the location of units within the area of study, the time frame involved, and the resource base of the community under study. These reference points describe the surrounding physical and demographic influences which will affect the individual's behavior. The institutional reference points include four types of linkages or ties: (1) enabling linkages, which provide authority and resources to the farmer actor; (2) functional linkages, which supply physical inputs and services to the actor; (3) normative linkages, which include aspects of a social system which share similar norms and values with the

S I T U A T I O N			A C T I O N	
SETTING	CULTURE	STRUCTURE	PROCESS	RESULT
1. PHYSICAL SETTING - Demographic - Size - Location - Time - Resource Base	1. ACTIVITIES - Subunit - Unit - Between Unit/Subunit - Between Unit/Institutional Linkages	1. NOMINAL PARAMETERS - Position of Unit Manager - Linkages with Unit Manager	1. INDIVIDUAL LEVEL (Decision Making, etc.)	
2. INSTITUTIONAL SETTING (Type of Linkage) - Enabling - Functional - Normative - Diffuse	2. NORMATIVE CONDITION - Subunit - Unit - Between Unit/Subunit - Between Unit/Institutional Linkages	2. GRADUATED PARAMETERS - Position of Unit Manager - Linkages with Unit Manager	2. ORGANIZATION LEVEL (Formal and Informal)	
3. TECHNOLOGICAL SETTING	3. VALUES/BELIEFS/PERCEPTIONS - Subunit - Unit - Institutional Infrastructure	3. CAPACITY OF POSITION - Unit Manager - Likages with Unit Manager		

Figure 2.21. Format of sociological parameters affecting behavior.

actor; and, (4) diffuse linkages, which are informal linkages not included with the other types of linkages. A technological setting includes all the facilities a social system has which increases the members control of the environment. Therefore, the parameters describing the setting of the farmer place that farmer in a certain physical and institutional environment. The activities and relationships of the farmer are contained within that environment.

The dimensions of those activities and relationships are further defined under the culture and structure categories. Within each sub-category under culture (activities; normative condition; and values, beliefs, and perceptions) the major points of reference involve the unit, or the focus of study, and the unit's relationship with the institutional parameters affecting the unit. Another reference point would be the unit's relationship with other factors of the environment which are controlled by the unit. We will call these units subunits. For instance, if the focus of the study would be on a particular farm, the farm would be considered the unit with the individual fields in the farm as the subunits and organizations such as a bank or a COOP as the institutional linkage. If one wants to examine the exact relationship of the farmer (the unit manager) to all the existing institutional linkages (graduated and nominal), then the structural category of the farmers situation must be analyzed.

An analysis of an irrigation system will thus begin with a look at the overall setting of the situation. This focus will then center on the two specific areas of analysis: the cultural and the structural aspects of the situation. One may focus on a particular unit and look at the social activities, beliefs, and rules influencing the manager of that unit; or the focus may center on the linkages between the manager and his community. Such analyses will look at both the cultural and the structural components of the situation and place them within the overall environment. The action of a unit be it a farmer or a group of farmers, may be understood and explained (Figure 2.22).

DIMENSIONS OF THE SITUATION

What has been presented thus far is a social mapping which may be used by a field sociologist to conduct a sociological evaluation of an irrigation system. This social mapping technique divides the analysis process into specific categories and what follows is a partial list of concepts which can be used to measure and describe each category:

<u>Setting</u>

1. Physical Setting

   1.1 Demographic Patterns

   Births/Deaths

   Migration

   Population Size

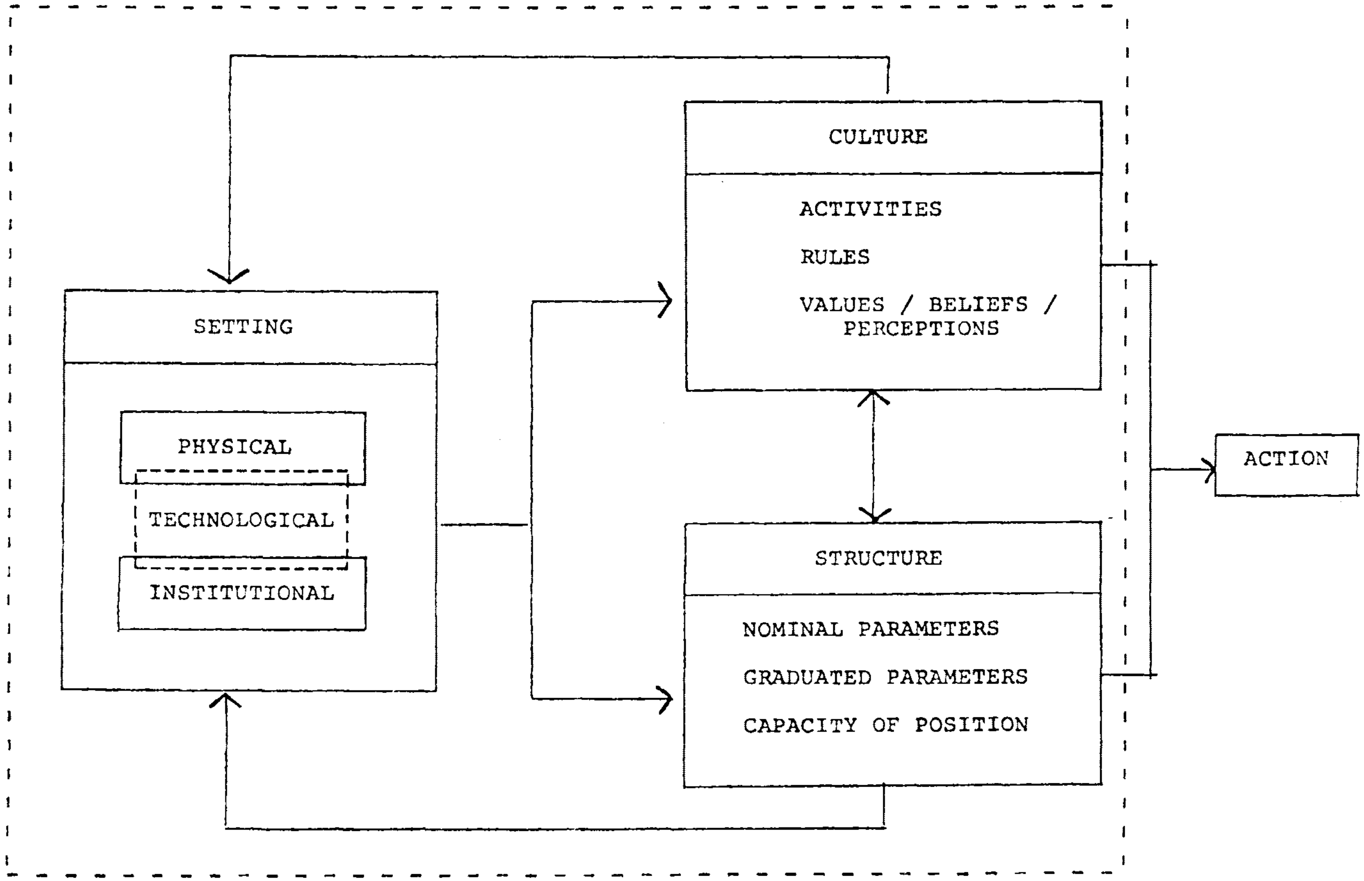


Figure 2.22. The approach for examining a particular form of behavior.

Growth Rate

Population Density

Age/Sex Composition/Marital Status

Occupation

Education

Ethnic Origin

Household/Families

Income

Mobility

Urban/Rural

1.2 Size of Area

1.3 Location

Fragmentation

Arrangement of Fields in a Command Area

Arrangement of Village to Farmers and Fields

Arrangement of Family Groups to Each Other

Arrangement of Farmers to Each Other

Arrangement Along a Canal, Watercourse, etc.

Arrangement of Infrastructure

Urban/Rural Arrangement

1.4 Time

Within cropping season (crop management, i.e. cutting, weeding, irrigating, harvesting, etc.)

Cropping Seasons

Multicropping

1.5 Resource Base

2. Institutional Setting (Types of Linkages)

   Enabling - Organizations and groups which control the allocation of resources needed by the institution (for example, the Ministry of Irrigation).

   Functional - Organizations performing functions and services which supply the inputs and which use the outputs of the institution (for example, Fertilizer Agencies).

   Normative - Institutions which have norms and values (positive and negative) which are relevant to the program of the institution (for example, the Groundwater Research Institute).

   Diffuse - Elements of society which can be clearly identified with membership in formal organizations (for example, the local government officials such as the ONDA).

3. Technological Setting

   Physical Technology

   Development and Use of Ideas

   Adoption-Diffusion Situation

Culture

1. Activities

   (Look at specific activities performed by the unit being analyzed).

2. Normative Condition

   Absolute/Relative Standards

   Dejure/Defacto Laws/Policy Statement
   (Formal/Observed Laws)

Folkways

Mores

Norm Conflict

Sanctions

Integration/Coordination

Isolation

Competition

Conflict

Accommodation

Cooperation

Communication

3. Values/Perceptions/Beliefs

Self

Values

Frame of Reference

Rationalism

Definition of the Situation

Traditionalism

Affect/Sentiments

Morale

Tension

<u>Structure</u>

1. Nominal Parameters

Role

Associations

Communication Networks/Patterns

Division of Labor

Reference Group

Special Interest Groups

Boundary Maintenance

Systematic Linkage

Degree of Homogeneity

Complexity

2. Graduated Parameters

Authoritarian Structure

Caste

Communication Networks/Patterns

Access to Services

Division of Labor

Influence

Power/Control

Rank

Social Distance

Status

Leadership

Centralization/Decentralization

The above list of concepts should only serve as a general guide for studying the sociological categories. The particular circumstances surrounding the analysis which determine what is to be examined.

UTILIZATION OF THE FORMAT IN EVALUATION STUDIES

The purpose of the format as presented in Figure 2.23 is to serve as a guideline for an irrigation system evaluation study. Because of the large number of concepts which may be used in each of the categories a tremendous amount of data can easily be compiled. It is extremely important that only relevant data be collected. Therefore, the researcher must be very careful in how the information is gathered and used. One useful method for gathering the information is to convert the format into a matrix (Figure 2.24).

The purpose of the matrix is to determine which critical questions should be asked. For instance, the various factors making up the different categories along the horizontal side will be matched with those same categories situated along the vertical axis. As a result of the combination, different questions will arise reflecting the influence of one factor upon another factor. Figure 2.24 provides an example of this procedure.

Along the horizontal axis lies the categories of setting, culture, and structure. One characteristic of the setting will be placed on the vertical side. Taking the size of a farm as the setting characteristic, one can construct a number of questions concerning irrigation behavior.

Does the size of the farm affect the way the farmer irrigates?

		SITUATION				ACTION
		SETTING	CULTURE	STRUCTURE		
SITUATION	SETTING	- Physical Setting - Institutional Setting - Technological Setting				
	CULTURE		- Activities - Normative Conditions - Values/Beliefs/ Perceptions			
	STRUCTURE			- Nominal Parameters - Graduates Parameters - Capacity of Postn		
ACTION						- Individual Level - Organizational Level

Figure 2.23. Matrix of sociological components.

Does the size of the farm play a part in conflicts that arise in the area?

Does the size of the farm correlate with knowledge of proper fertilizer use?

Does the size of farms influence communications patterns in the area?

Does the size of the farm lead to the establishment of special groups?

Does the size of the farm constitute the only indicator of prestige?

The researcher must remember that the questions to be asked will be the result of the interdisciplinary mix of the research team. This matrix format is a guide for the researcher in his work but the initial director of work will originate from the sociologist's interaction with other members of the research team.*

In conclusion, what has been presented in this section is a framework which a field sociologist can use to evaluate an irrigation system. The framework contains a number of categories which describe the setting of the social systems and the specific positions and relationships present in that

---

*A problem of all disciplines is usually that of collecting too much rather than enough data. Useful data does not include that which is simply of interest for the researcher but that which will likely be useful in helping farmers improve their present crop production possibilities.

	SITUATION		
	SETTING	CULTURE	STRUCTURE
SETTING	Physical Setting - Size of Farm	Size--Irrigation Activity Size--Conflict Size--Knowledge of Fertilizer	Size--Community Network Size--Boundary Maintenance Size--Prestige

Figure 2.24. Example of a matrix relationship of sociological components affecting a specific behavior.

system. From the interdisciplinary definition of the problem the sociologist must be able to examine a social system with measurable variables in a systematic manner in order to answer critical questions emerging from the interdisciplinary definition of specific problems. The framework allows for that systematic research to occur by providing a structure for examining in an effective manner what possible questions may arise.

CHAPTER III

MANAGEMENT DECISION MAKING IN THE CONTEXT OF A DYNAMIC FARM IRRIGATION SYSTEM

Summary of Chapter

This chapter will provide the following information:

1. The Nature of the System.
2. Integration of Farm System Components
   - Major Functions of Farm System Components
   - Interaction of Farm System Components
3. Illustration of a Farmer Decision Maker

CHAPTER III

MANAGEMENT DECISION MAKING IN THE CONTEXT OF A DYNAMIC FARM IRRIGATION SYSTEM

The purpose of this chapter is to integrate the four major dimensions discussed in Chapter II and demonstrate how a farmer combines the different aspects of these dimensions in order to farm the land that he has (Figure 3.1). What will be presented is (1) a discussion of the nature of a system, (2) the integration of the farm system components as described in Chpater II, and (3) how a farmer utilizes the various components through management decisions to farm his land.

THE NATURE OF A SYSTEM

A system is an orderly collection of interrelated parts whose organization exhibits some goal or purpose. This organization is a result of the component parts interacting with each other in a specified manner. How the system operates is also dependent on the environment with which it is a part. We will now look at a farm irrigation system in order to describe how specific component parts make up a system and how that system interacts with its environment.

Figure 3.2 provides an idealized sketch of the physical boundaries and components of a farm irrigation system as described in Chapter II. The first major boundary is the canal

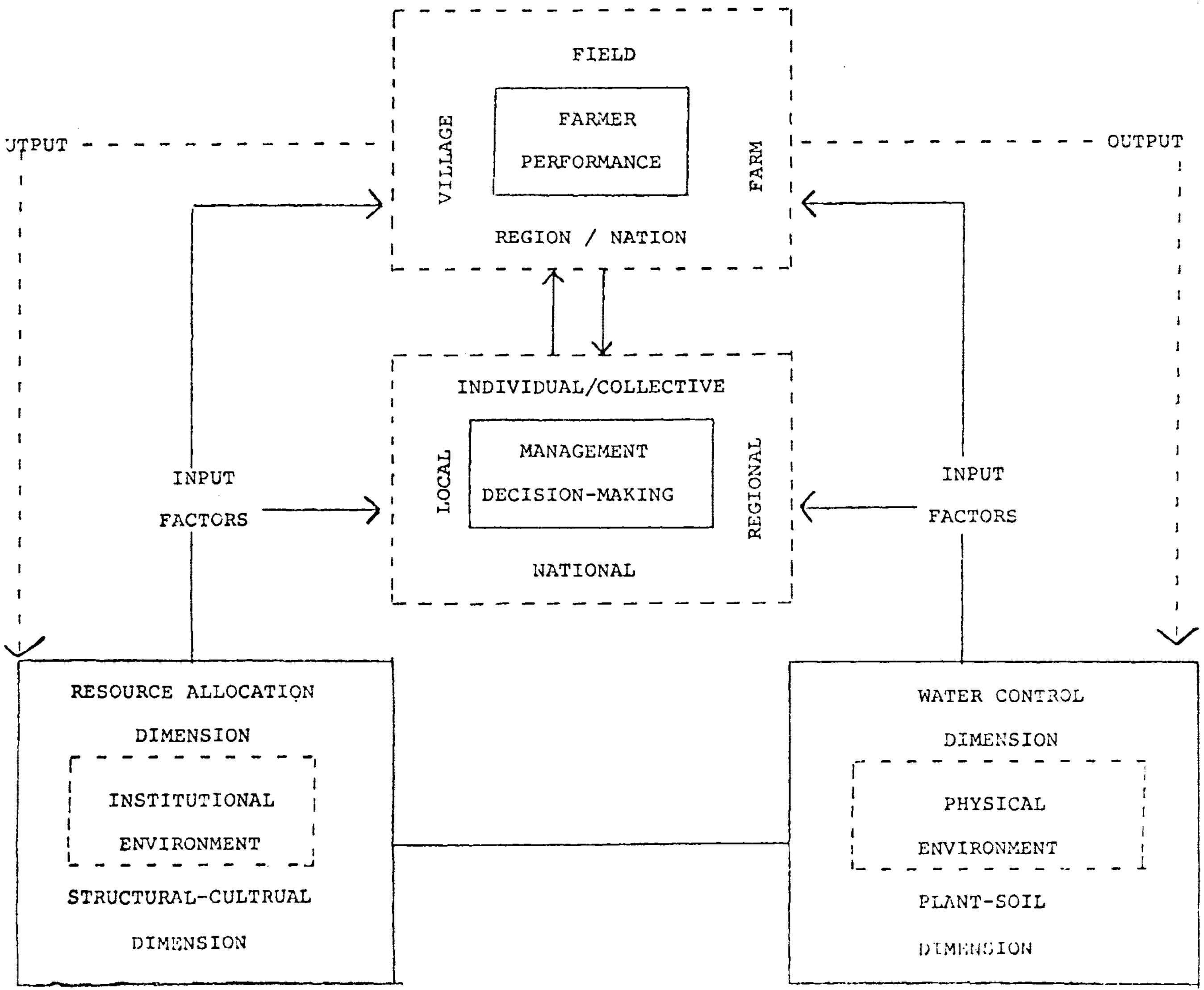


Figure 3.1. Management decision-making framework.

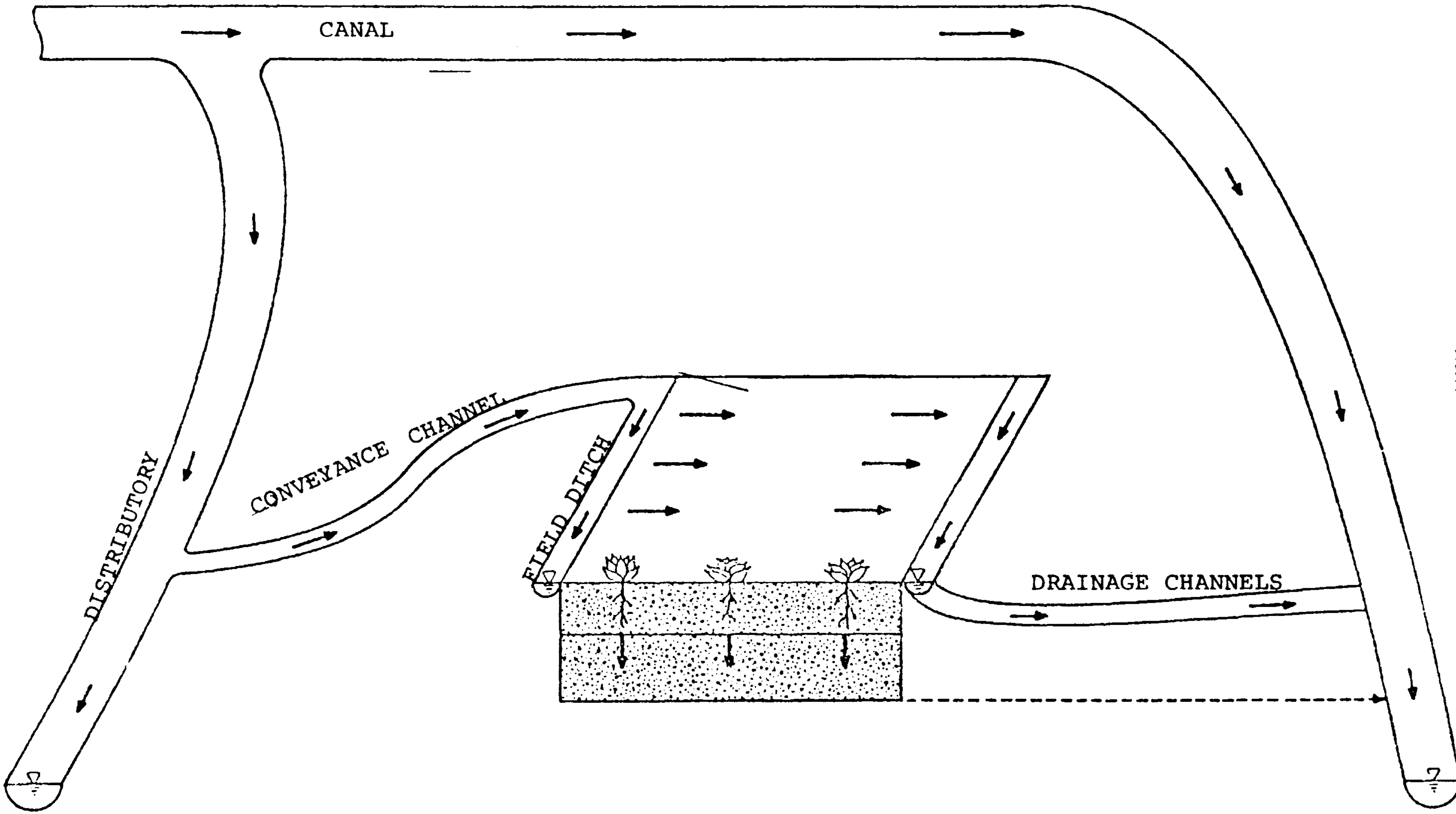


Figure 3.2. Idealized sketch of a farm irrigation system.

itself which is linked with the total irrigation system including the river system and storage reservoirs. The drainage system is also a physical boundary which delimits the farm system in space. Within the farm system there are physical boundaries such as conveyance channels for water delivery. Field channels which supply water to specific farms of the system are also physical boundaries. Each farm is separate from other farms and minor drainage channels are linked to the major drainage system. Within the geographic area of the farm system there exists many physical components pertaining to the plants and soils which make up that farm system (Figure 3.3). Also added to the physical dimension of the farm irrigation system is a cultural and an institutional framework which encompasses an individual farmer and influences how that farmer thinks, feels, and behaves (Figure 3.5).

The major point which is to be made is that a farm system is composed of many physical and institutional components which are organized in a particular manner which ultimately influences how a farmer makes decisions on what to plant, how to irrigate, and so on (Figure 3.1). What will now be discussed is how these many components interact with each other in order to create a meaningful farm system which in turn results in determining many of the farmer decisions.

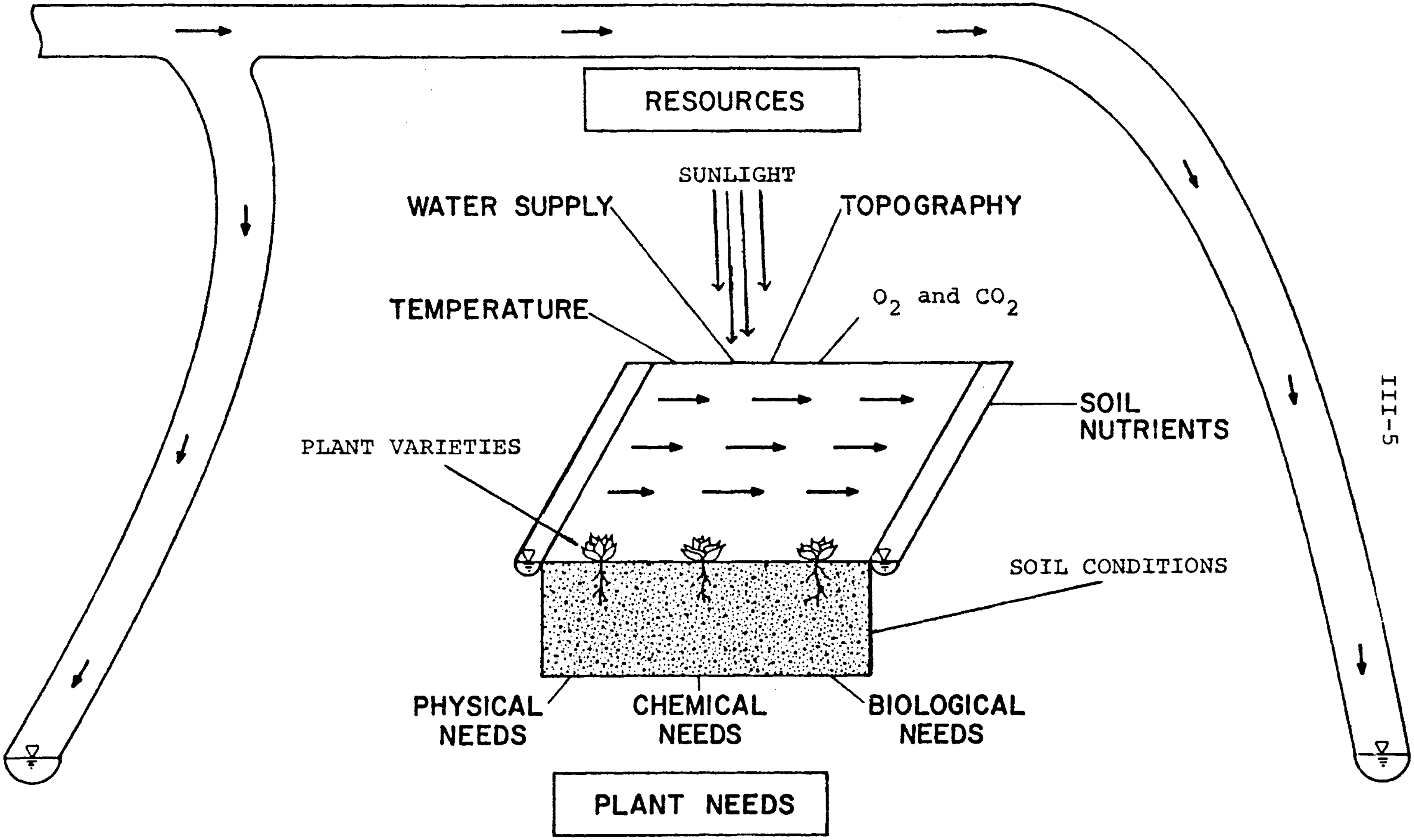


Figure 3.3. Idealized sketch of plant-soil components in a farm irrigation system.

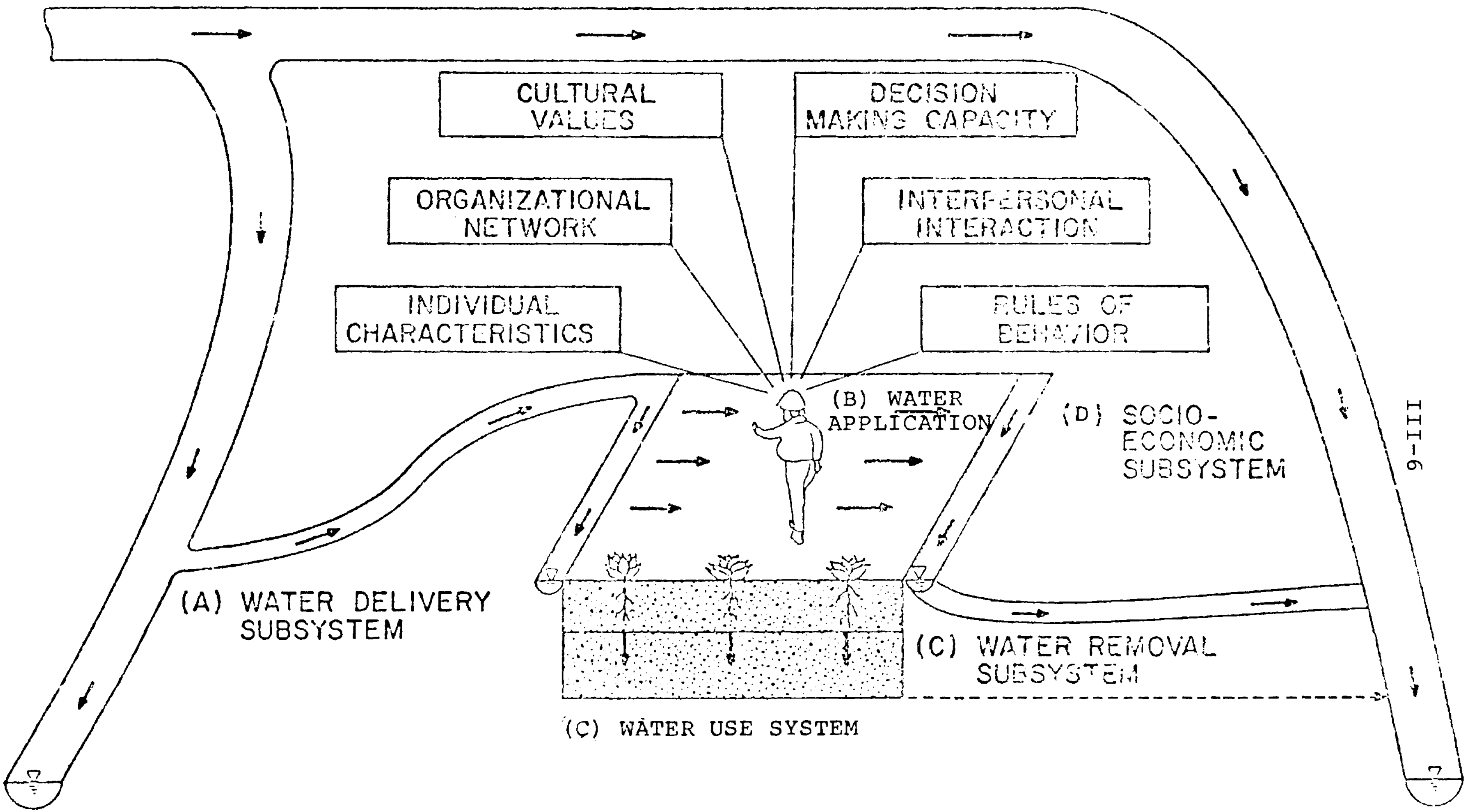


Figure 3.5. Idealized sketch of a farm irrigation system.

INTEGRATION OF FARM SYSTEM COMPONENTS

The purpose of a farm irrigation system is to provide an adequate physical (water control and plant-soil) and institutional environment for the production of crops. This production of crops would meet basic human needs and provide a surplus for the betterment of the social and economic lives of individuals and the goals of their communities. Such a purpose defined the goal of the farm irrigation system. In order to achieve this goal, the specific subsystems described in Chapter II and referred to in the previous section of this chapter are integrated in a specific organized manner. What this integration is will be the topic of the following section.

In accomplishing the goal of a farm irrigation system many functions must be performed. Figure 3.6 described those functions and shows which elements previously discussed perform what functions. What is of interest here is that in order for a crop to be adequately produced, a farmer must take into consideration a number of factors pertaining to the delivery, application, use, and removal of water. In addition, that same farmer must be concerned with the climatic and soil environments into which the crop will be grown. If that was not enough, the farmer is also constrained in his actions by the institutional environment surrounding him. The farmer must be concerned with these functions because only when all of these functions are achieved will the crop adequately develop. What is even more

SUBSYSTEM	MAJOR FUNCTIONS	MAJOR ELEMENTS
1. Water Control		
a. Water Delivery	Delivery sufficient quantity and quality of water to the field.	Canal, main ditch, field ditches, slope, size and shape of channels.
b. Water Application	Application of desired amount of water at the proper time in a uniform manner to meet crop tolerances for production desired while satisfying leaching and erosion control standards.	Water supply rate, field geometry, field topography, soil infiltration rate, irrigation method.
c. Water Use	Supply water requirements for crop growth, maintain acceptable levels of salinity, maintain appropriate environment (soil-air) temperature, insure adequate nutrients, provide appropriate soil conditions.	Water quantity and quality, soil type, nutrient availability, evapo-transpiration.
d. Water Removal	Provide necessary surface drainage, maintain given salinity levels, provide root aeration, improve workability of land.	Leaching requirement, evapo-transpiration rate, drainage facilities, soil type/subsoil type.
2. Agronomic	Management of physical and biological resources to produce food, fiber, and specialy crops; ensure long term productivity of crops.	Plants, climate, temperature, water topography soil physical, biological, chemical aspects, nutrient supply insect control, management practices.

Figure 3.6. Major functions and elements of farm irrigation subsystem.

SUBSYSTEM	MAJOR FUNCTIONS	MAJOR ELEMENTS
3. Social	To provide the social and organizational supports needed for successful manipulation of farm irrigation systems to achieve individual and social goals in both the short and long run.	Facilities (institutional services), activities (collective etc.), rules (norms, laws, etc.), communication (extension, etc.), linkages (institutions), beliefs, knowledge.
4. Economic	Appropriate resource allocation, maximization of production optimize decision making process.	Land, labor, capital, markets, risk/uncertainty, cost/benefits, consumption.

Figure 3.6 (continued).

critical is that such functions do not operate alone but interact with each other and thus the farmer must work with these functions together as a "whole" system in order for him to become successful.

To illustrate these interrelationships, Figure 3.7 provides a diagram showing selected parts of the water control system and how they affect each other. The particular components were chosen as an example though other components could have been chosen to illustrate specific relationships.

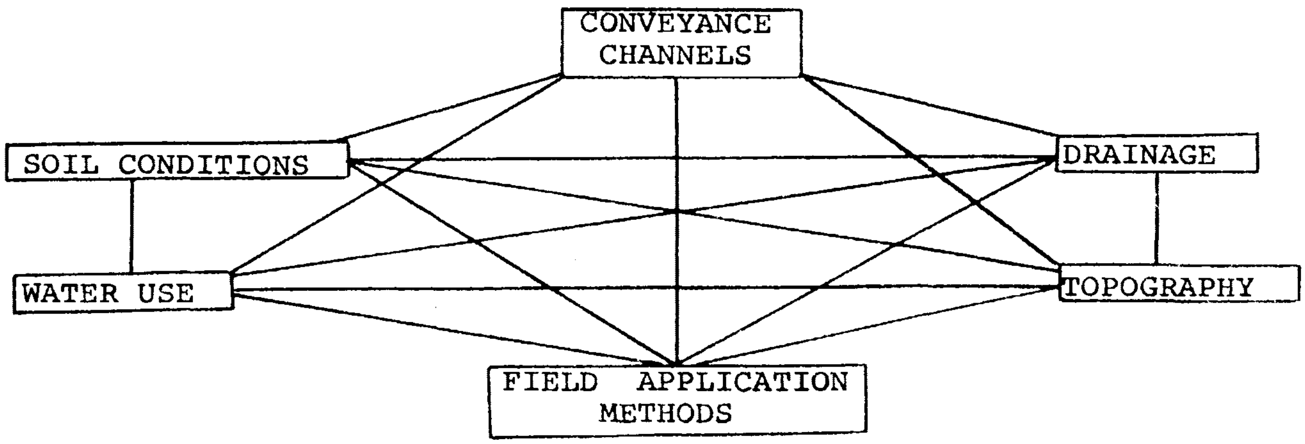


Figure 3.7. System interrelationships.

Figure 3.7 can be viewed in several ways. First, each of the components listed is related to all the other components. No component is viewed as major or minor. All components tend to act and react on each other. A full explanation of all possible relationships is not yet possible because the science of irrigation itself is still developing. However, we can explain many of the relationships based on present knowledge. For example, the particular soil conditions on a given farm relate to channel losses through seepage. Soils with high infiltration rates result in seepage to groundwater which can create drainage problems. Soil conditions also affect conveyance, application and water use efficiencies because the volume of water delivered depends on conveyance efficiencies and in turn the water delivered influences how efficiently water is supplied to the fields and used by crops. Also the particular topography of the command area and farmers fields influences all the other factors both directly and indirectly.

A second concept of system interactions is that a change in one of the components influences changes in all other components in various degrees. For example, if the topography of command areas and farmers' fields is made more level both positive and negative results would occur. Level fields could increase field application efficiencies, water use efficiencies by plants, and improve soil conditions through more uniform distribution of water. However, dead level fields could result in drainage problems.

This leads to another concept that is of vital importance to improving the farm system. A change in one component alone is probably not sufficient to improve the system significantly. For example, an improvement of conveyance channels alone will not ensure improved irrigation efficiency. More water may be applied to fields but with less efficiency and too much water as well as too little can be detrimental to soils and plants and create substantial drainage problems. Also, soil conditions may be improved with the addition of organic matter or new methods of cultivation. This, however, may not improve the overall functioning of the total system.

Combine the complexities of this one subsystem with the equally intricate, if not more so, interactions of the other subsystems and we can have some sensitivity as to the complicated situation which faced the farmer. The critical point is that the subsystem described in Chapter III have particular functions in the production of various crops. Within each of these subsystems are many component parts (elements) which must be managed or taken into consideration by the farmer. All of these subsystems must then be examined and managed together or in other words, they all must be integrated as a whole farm irrigation system. What will not be presented is an example of how a farmer integrates these subsystems into a decision making framework.

ILLUSTRATION OF A FARMER DECISION-MAKER

Let us assume that there is a small farm in Egypt owned and operated by farmer Abdul Mootizim. Mootizim is an Arabic noun which means organizer. Mootizim comes from an Arabic verbal root meaning to organize. This word is used because Abdul Mootizim, the manager, is the single most important building block of the farm irrigation system. He not only makes daily and often hourly management decisions that affect his crop yields, but also he is under a set of constraints which often dramatically limit his decision making capabilities.

Figure 3.5 and a verbal description will provide an idealized picture of farmer Mootzim's farm level situation. The farm is located on a perennial canal which provides water on an 8 day off 4 day on rotational system. There is an ample supply of water throughout the year. The water is supplied through earthen convyeance channels to the farm of five feddans located about midway of the command area. The fields on the average are about 5 meters by 10 meters and brought to a level based on Abdul's judgement and experience. The drainage water from his fields flows to the main drain. The crops grown are wheat, berseem, and year round vegetables for both home consumption and the market.

Abdul is middle age, hard working, educated to the 6th standard, and supports a wife and five children. As an owner operator he makes rational decisions and earns his income only from the operation.

Abdul is linked with a number of organizations which greatly affect his decisions making. These organizations include the total irrigation bureaucracy which establishes policies, enforces water laws and codes, provides services and regulates the supply of water to the canals and to the command area.

For example, the irrigation engineers of the district and the local gatekeepers control the water distribution schedules by maintaining specified water levels in the main canals. These local authorities have control over closing and opening sluice gates to allow water to flow to the command area servicing Abdul's farm of 5 feddans and about 150 feddans belonging to 70 other farmers. To most farmers the gatekeeper represents the main authority with which farmers have regular contact. At times Abdul and other farmers find it necessary to circumvent the local authorities by installing illegal pipe intakes and pumping directly from the canal to increase irrigation supplies.

Usually Abdul has little control over policies, laws, services, and decisions about water supplies, canal closures, maintenance and operation of canals above the outlet which serves his area. Included in organizations are also service organizations including suppliers of fertilizer, seed, insecticides, credit, and extension services. The inputs are usually supplied through the local government cooperative established to serve farmers. Abdul as an individual farmer, however, has little control over decision making in the cooperative but must depend on services provided. Often supplies are limited and extension services are not available in the quantity and quality he needs for best decision making. Abdul is also linked with the revenue department by those who make collection. He is also tied to the local village administration by the local civil officials including police and the <u>sherf</u> who represents the government. As a resident of the village he is also linked to other organizations providing health, education, and religious services.

Abdul is a part of the village social system and therefore, his decision making is influenced by the cultural values, beliefs, status roles, and power relationships which are generally well established. Several expamples of factors which may influence his irrigation behavior include: mutual cooperation in cleaning and maintenance of the farm conveyance system, fairness in sharing water, water as common property of the community, his status role versus that of other farmers, and the power and influence of large farmers and local authorities.

Abdul as an individual is involved in a network of relationships and interactions with other farmers, local leaders, and local authorities which influence his decision making capacity. For example, if other farmers do not cooperate in cleaning and maintaining the main conveyance channel or the private ditch, or if they do not cooperate in maintaining the cooperative <u>sakia</u> for lifting water then his supplies are restricted. He must maintain good relationships with local leaders who have influence over some of the crops he grows and the inputs allotted to him, Interactions are important with the gatekeeper to obtain extra amounts of water when needed. One way to obtain extra water is to install extra legal pipe intakes to private ditches which at the first reaches may double the supply rate. At the end reaches these intakes are often a necessity to get enough water to supply a sakia.* Interactions with canal authorities may be very widespread. For example, on one farm system it was found that "illegal pipe intakes to private ditches constitute one of the most important factors causing unequal shares of water to farmers. While this practice contradicts the basic Islamic principles of equity in water distribution for all, local irrigation authorities must find it beneficial for farmers and themselves to allow the widespread practice to continue."

There are many norms or rules that also regulate Abdul's irrigation and farm behavior. For example, there is a norm that water is common property and should be shared equally. When this norm is broken Abdul can expect some disapproval or other sanction by other farmers and perhaps the irrigation authorities. There is also an established rule that the maintenance, cleaning, and weed control in the private ditches are responsibilities of Abdul and other farmers. When this responsibility is not met by the farmers, the Irrigation Department can clean these ditches and charge the farmers for the expense. Likewise, the Irrigation Department has the right to install field drains at farmers' expense and to regulate the price farmers can charge other farmers for lifting water for various types of pumps. All of these rules and other rules and norms have an influence on the decisions Abdul makes at the farm level.

---

* Sakia is a water lift provided by animals.

Let us assume that Abdul Mootizim is aware that his crop yields are not adequate. He is aware that crop stands and growth of plants in some fields are often much less than optimum. He contacts the local extension worker who brings an agronomist to investigate his problem. After examining the crops there is an indication from visible inspection that nitrogen levels may be low. Analysis of both plant tissue and soil samples indicate that only about half the nitrogen recommended is available to the plants. Abdul is surprised and insists that he applied the correct amount and the coop officials who issued the fertilizer agree Abdul is still worried and somewhat upset that the extension worker and agronomist may not believe that he is telling the truth. On another occasion an engineer was making a tour and Abdul, by chance, met him and asked if he would visit his farm and offer advice about his problem. The engineer also asked about nitrogen rates but from observation he noted that the drainage system was chocked with weeds and not functioning adequately. He therefore, gained permission to make measurements of the water supplied to the farm, to each field, and groundwater levels. He found over time that roughly the proper volume of water was supplied to the fields but groundwater levels were within 1 meter of the ground surface. He recommended that the farmer clean the drains which was done but with little change in the basic problem of poor plant population and growth of crops. When this did not solve the problem, field drains were recommended and Abdul took a long term loan to be repaid over twenty years to install an expensive tile drainage system. After a year Abdul still found little improvement in his crop production levels and observed that there were still areas of poor crop stands and visible signs of nitrogen deficiency in plants. Abdul began to place pressure on the worker, threatening to report his costly case to a high level official in the directorate who was related to a friend of his wife's father. Therefore, the extension worker, with help from a sociologist and an economist, came to the farm. They documented the case of Abdul and confirmed from information that Abdul used the recommended seed rates, type of seed, fertilizer, insecticides, and other inputs that whould have produced higher yields. It was evident that Abdul was not only losing money but was quickly getting into a bad debt situation. In interviews with Abdul it was found that his knowledge levels of soil-plant-water relationships was limited. As a result, they recommended that the extension worker get more information from subject matter specialists related to irrigation methods. Even after using a furrow system for row crops instead of a border system there was little improvement. Even closer borders did not remedy his problem situation much. By now Abdul, known for his great <u>suber</u> (patience), was almost ready to give up and go to Cairo to seek work on a construction crew.

By chance a team of researchers from a new EWUP arrived about this time and included Abdul's farm in a study they termed Problem Identification. Though at first the members of the team could not agree as to the causes of the problem of Abdul and other farmers on the farm system, they collected data over a period of two months which at many points confirmed previous data. Working together they checked out many combinations of factors and found that while the proper volume of water was applied, roughly a third of the nitrogen applied was leached to the groundwater. It was also found that during the summer season, the groundwater levels caused problems of salinity due to capillary action. These groundwater levels also caused danger to root systems especially of some fodder crops. Studies of field application methods, including water advance time, patterns across fields, and a topographical survey of fields, provided data that suggested critical problems had been overlooked previously. The level of the basins was off in places ranging from 4 cm to 10 cm over the field. High spots in the basins resulted in plants in a constant drought situation and salinity levels inhibited seed germination and plant growth. In low spots plants were receiving an excess of water which not only leached costly nitrates but added to the already dangerous water levels for much of the year. Interviews indicated that while Abdul thought his fields are about dead level, he did not have the equipment or the technical knowledge to do a better job of leveling his irrigation basins.

To make a long story short, Abdul Mootizim and the team of water management researchers finally arrived at a set of improvements. By one cropping season these improvements had resulted in higher yields and an improved level of living for Abdul's family.

In summary, as researchers focus on irrigation problems on farms, they learn to view farm level problems from the perspective of Abdul Mootizim or the manager who can never afford to focus on a single set of problems. To focus on only one set of problems is not only costly but is contrary to the nature and structure of a complex system. Single problems are relatively easy for an expert to identify, but the real problems and their interdependencies with other problems require a systems approach and interdisciplinary team work.

Figure 3.9 provides a view of some of the factors or problem areas on Abdul's farm which depressed crop yields.

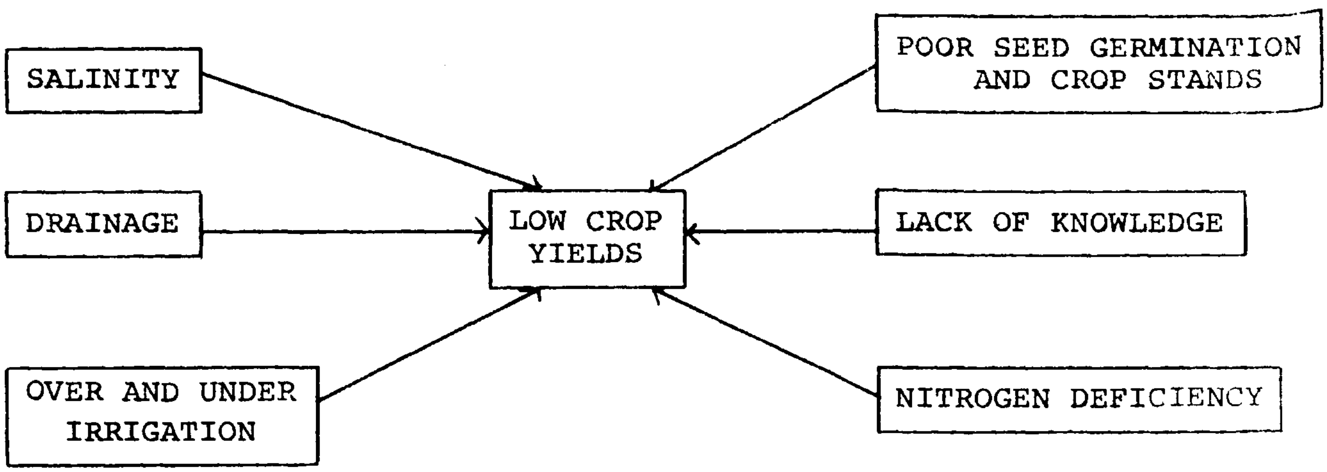


Figure 3.9

There is no attempt to show the complex interdependencies because these have to be identified on each farm through Problem Identification. Problem Identification at the farm level is important because there are no universal or general recommendations that will fit all farms even on a single farm irrigation system. The point is that a management orientation is essential to identify problems and find their solutions. To assist the millions of farmers in Egypt, improvement to increase the efficiency of the total farm system requires a focus on all factors.

In summary, a definition of farm water management for improved agricultural production is:

> ... the process by which water is manipulated and used in the production of food and fiber. Management utilizes water, soils, solar energy, infrastructure, legal codes, and institutions to provide water and other inputs for plant growth.

There are many reasons why there are few definitions of farm water management. The management concept is difficult for many to understand due to the lack of farm field experience, lack of opportunities to work with and understand the perspectives of other disciplines, and the biases we all have learned in our professional work and strictly disciplinary training. In the training program you will be exposed to the management concept in research, much farm level field experience, an opportunity to learn from and appreciate other disciplines, and an opportunity to get to know a team of trainers who have experience in interdisciplinary team operations.

Let us keep in mind throughout this training program that we all must continue to overcome certain professional and disciplinary biases of which those coming from our previous professional and disciplinary experiences and training are probably the most powerful. Chambers* reminds us of a major reason why the management concept has not been given sufficient attention in the past. He states

> Hydrologists concern themselves with the water cycle and the movement of water from one farm or location to another. Engineers concentrate on the design and construction of works, using their mathematical skills to calculate stresses, capacities, flows and the like. Soil scientists may try to measure percolation rates in different soils with different water applications. Agronomists investigate the crop water requirements. .Sociologists study the micro-level village community, the allocation and appropriation of water, the origins and resolution of conflicts. Economists try to calculate the costs and benefits of alternative ways of obtaining or using water and argue about price policies. Each profession and each discipline is pointed towards certain aspects of irrigation such as these and is programmed with relevant research skills. Moreover professional prestige and advancement are achieved through work which is highly regarded by fellow professionals. Research tends to use conventional methods and be designed to refine existing paradigms. Is it not often true that research priorities are generated lacking the situation of rural people rather than by the presupositions of professionals?

If we are to help Abdul Mootizim, we must take the knowledge and experience of each discipline and utilize it in an interdisciplinary team approach to on-farm system problems. In so doing we improve Abdul's management of the system

---

* Chambers, 1978

to better achieve his goals of increased crop production. Let us review some disciplinary views of the system and integrate them.

ANNEX I

PROBLEM IDENTIFICATION CASE STUDY:

MANSOURIA DISTRICT

A case study is presented to introduce you to the problem identification field study that was completed by EWUP staff in Egypt. The purpose is to show how the present training course is relevant to what you will be doing in your own country. You are requested to study this case study and use it as a reference in the training as we attempt to refine our methods throughout the training program. After the presentation of the case study, we attempt to identify ways and means the approaches can be improved. The evaluation of the case study is that arrived at from the EWUP staff members themselves and CSU staff members who assisted on temporary assignments in Egypt. The purpose is not to criticize those involved but to derive lessons learned for improvements. All those involved are fully aware of the short comings of this first P.I. attempt in Egypt. You are here to discover with the trainers how we can refine our approaches and methodologies.

To emphasize, each trainee is requested to do the following:

1) Careful study of the Mansouria case.
2) Identify the ways P.I. can be improved.
3) Indicate areas where you need additional expertise.

The philosophy which we all should internalize from the outset of the training is that we are all involved in a learning experience. We are more interested in your ability to ask the right questions than your ability to give "bookish" answers before you know the questions.

The case study is presented in the following format:

1. Overview of Mansouria District
2. Objectives for the P.I. studies
3. Team preparation
4. Reconnaissance and site selection
5. Formal problem identification and team activities
6. Major findings in Mansouria District
7. Evaluation of the Mansouria case study

1 Overview of Mansouria District

The Mansouria District, chosen as the area for the first P.I. studies, is located within the Giza Governate which is in close proximity to Cairo including much of Cairo's sister city of Giza. The District contains approximately 24,745 feddans and is unique from many other districts in that it is primarily a vegatable feddan producing area which is influenced by the demands of Cairo city. Unlike most other districts it is exempt from many of the government crop allocation policies. Year round cropping is done because the climate is adequate year round for good crops. Common winter crops include berseem, clover, flax and vegetables and summer crops are dominated by maize and vegetables. Orchard crops include citrus, mangos and dates. Given the constraint of small holdings intercropping is common.

The irrigation and drainage system is similar to other parts of the country and water is made available to farmers on a 4 day on and 8 days off rotation schedule. Most of the water delivered by the irrigation system to the farm must be lifted by Sakia, Tambour and modern pumps powered by diesel fuel or electricity.

Farmers typically live in compact villages ranging in size from several hundred individuals for sub-villages to several thousand for larger villages. Government services provided include cooperative, village banks, schools, health services, transportation facilities and local law enforcement.

2 Objectives

The objectives for P.I. are related to the major purposes of the EWUP. These are stated in the official project documents as:

a) "To develop and demonstrate repeatable improved water management and associative practices that increase agricultural production and improve the social and economic conditions of the small farmer."

b) "To increase the institutional capacity to develop and sustain an improved on-farm water management program for the betterment of economic and social levels of living of small farmers."

Note that as in most projects the initial purposes give direction as to the focus. Water Management and associated practices point to the areas for which attention is to be directed. Agricultural production increases are a target along with sustained institutional capacity. Social and economic improvement for small farmers suggest areas of concern and the target is to be small farmers. The two purposes also delimit the area for P.I. which is the farm irrigation system. The purposes further imply the need for engineering, economic, agronomic, legal and sociological analyses needed for the P.I. studies. The specific purpose of P.I. stated earlier is to gain an understanding of the farm system and to identify the major or priority problems which require more intensive research and solutions.

3 Team Preparation

The initial preparation for P.I. did not include all the personnel actually involved in the first field studies. Only some of the senior researchers of the EWUP were selected and sent to CSU in the fall of 1977 where they took specialized classes and participated in meetings with CSU project personnel. All Egyptian personnel took part in an interdisciplinary course related to the Research Development Process. This course only dealt with the framework to be used for P.I. studies and did not provide much focus on how to do it. At that time no training course had been designed for field implementation procedures for P.I. It was not possible for the project director and the technical project director as well as two senior CSU staff members to take part in this course. Therefore, the concept was new to them as well as for many of the EWUP field staff who did not come to CSU. As a part of the first training program at CSU weekly meetings were held along with private sessions with CSU staff to discuss the procedures to use for the first P.I. studies. A special two day session was also conducted by a private consulting firm and CSU staff related to team building. Again it was unfortunate that all project personnel could not participate. Prior to departure for Egypt the American staff members received some general orientation to work in Egypt. Again all the project members could not participate due to various constraints.

In Egypt as field personnel were being selected and logistics were being developed, meetings were held by team members to plan the initial P.I. studies. As is usually the case the first months of setting up a project take considerable time because in the real world there are substantial constraints and problems that must be resolved. For example, facilities for personnel itself is a major problem and new staff require a period of time for adjustment. Ideally, it would have been useful to have had a separate farm water management research and development center where all disciplines would feel at home and be able to develop loyalties to, however, the only facilities available were those provided by the Irrigation Research Center. Also as research and experience has shown it would have been more ideal to have members of several disciplines housed together but this was not possible in the beginning. Therefore, as expected, much time was needed for members of the various disciplines involved to get to know each other and to learn how to work together. An interdisciplinary team does not just come into being, it has to be developed gradually over time.

The first major formal document to give direction to P.I. was the development of a project work plan in January of 1978 which was revised and approved in April 1978. This document, designed as a guide for the EWUP staff, includes information on the following topics:

Project organization

Procedures for P.I. studies

Procedures for field trail activities

Team coordination, cooperation and training procedures

Procedures for project evaluation

Reporting procedures

This document, which was developed by senior staff, should be carefully studied by each trainee who participates in the summer 1979 training program. It is made available to each trainee in English or Arabic and is required reading. Each trainee will be evaluated on his understanding of this work plan. This work plan and continued efforts at regular staff meetings for information and planning indicate that substantial preparation has taken place. Unfortunately all EWUP personnel were not involved and field staff especially were often not aware of the content of the work plans on the results of informational meetings. This was due primarily to the long period of time required to select and train personnel and organize an action oriented project.

Training of field personnel for the first P.I. field studies also was faced by considerable constraints that are understandable. Location of good staff is always a problem because participation in new projects involves personnel who are willing to leave secure positions for a new job which always is a risk. Though some individual training of field personnel did take place, P.I., it was not formalized until the summer of 1978. This was not ideal as all agree but given large constraints quite a lot of preparation for the first P.I. studies in Mansouria did take place. It should be realized that the level of preparation was greater than that of many similar projects.

4 Reconnaissance and Site Selection

Reconnaissance is for the purpose of doing an overview of the farm system and sensitivity to large problem areas. Reconnaissance began early at CSU in an attempt to identify previous relevant research. This search for information was continued both at CSU and in Egypt in early 1978. Senior researchers and project directors held meetings with government organizations and international development agencies in Egypt to ascertain what previous research data were available. Attempts were made to learn from government officials their views of the farm level problems and areas of needed investigation.

Team members also took part in the preliminary field reconnaissance to gain an overview of farm system problems. Though there was a lack of objectives established prior to field visits senior and junior researchers visited farm sites in Mansouria District and talked with farmers and personnel working directly with farmers about their perceptions of farm level problems. Without a detailed plan and a division of responsibilities there was the tendency for large groups of project members to go together on these visits. Though it is not possible to judge the impact upon farmers by such large groups there is always the damage of overwhelming farmers in such a way that they will not provide reliable information. Such visits can also establish an image that the government has come to intervene in a large way thereby reducing incentives for farmers to participate. After these initial visits there was not sufficient time to evaluate what was learned. Ideally prior to such farm visits team members should decide <u>what</u> information is needed and <u>who</u> should conduct the key informant interviews <u>with whom</u>. This would necessitate a division of labor which would probably result in more efficient work.

Senior researchers have reported on the problems involved in sample site selection and the size of the sampling units. Usually this is one of the initial problems of team research because the sampling methods and size of sample is related to the particular measurements to be made. These differ for each discipline because the sampling methods and size of sample is related to the particular measurements to be made. These differ for each discipline because methodologies differ. The first real test for the team is to decide on criteria for site selection. In the Mansouria District it was not sufficiently clear as to what the criteria were except as the work plans of April 1978 state "The research areas will be chosen on the basis of irrigation districts which have different soils, cropping and irrigation problems." Three irrigation districts including Mansouria, Kafr El Sheikh and El Minya were selected as research sites. Within each district as for example, Mansouria hydrological units such as Kafret Nasar, Beni Magdoul and El Hammami were chosen. Within the hydrological units sample farm units were chosen in order that hydrological, agronomic, sociological and economic data could be correlated. Project reports indicate that instead of clear initial concensus on criteria for sample farm selection each discipline developed their own criteria. After long deliberation some agreement was established and the following specific farm sites were selected by team members as shown in Figure 1.

Figure 1 Farm Site Selection Criteria For Beni Magdoul and El Hammami

Discipline and Place	Number of sites and criteria
Agronomy	
Beni Magdoul	7 sites because work had begun by engineers and to the degree possible representative crop and soil conditions
El Hammami	7 sites with representative crop and soil conditions
Economics	
Beni Magdoul	7 sites above and 11 farm family units
El Hammami	7 sites above with 12 farm families with variation in farm size
Engineering	
Beni Magdoul	3 or 7 sites above at different water course locations
El Hammami	4 or 7 sites above at different water course locations
Sociology	
Beni Magdoul	sites and farm families used by economists
El Hammami	sites and farm families used by economists to show differences in farm size

In addition to these sample sites comprehensive soil testing and soil land classification surveys were conducted in the Beni Magdoul and El Hammami areas. In the farmers 5 sites in 4 villages were selected about 4 feddans each and 448 soil samples were taken. Likewise in El Hammami ten sites per village of about 10 fedans were selected and 280 samples were taken. The soil land classification survey covered 800 feddans in the Beni Magdoul area and 2000 feddans in the El Hammami area.

With the exception of the soil testing and soil land classification surveys, tough decisions and substantial compromises were made in selection of farm sites for the PI studies. Under the circumstances, especially the constraint of time, the sites selected have yielded much data but a major question can be raised about the adequacy of sample size for both the economists and the sociologists who by nature of their research methods and the variables they measure require larger samples. Also data is needed from those fields and farms outside the sample site which sample farmers have because farming decisions by the farmers are made often consideration of their total operation. Data is also needed at the village level which was collected by use of key informants and by observation. It must be realized, however, that especially in working with small farmers and for purposes of PI that traditional research methods and ideal sample surveys can not be used often because they are time consuming and expensive. The collection of adequate data for understanding the system and identification of major problems is the goal of PI.

5 Formal Problem Identification And Team Activities

After the reconnaissance which resulted in an overview of the farm problems and the selection of sample farms, the information gained was used for the preparation of the formal PI field investigations. Variables were identified, measurement procedures were developed, field workers were trained, and logistics were planned. These activities were planned primarily by each of the disciplines separately with a minimum of close collaboration. Time was a major constraint and without an overall frame work or design the tendency is for each discipline to work out its own plans. Without a framework and close collaboration it was not possible to implement joint plans for data management. This, however, did not hamper data collection and with more experience more team planning can be done at future research sites. It should be mentioned that the senior sociologists involved documented their training procedures, developed their own work plan, established validity and reliability checks and instructions to field staff, maintained notes on field problems, documented all field visits and activities, pretested interview schedules Such records are invaluable in reviewing all activities for future PI studies.

One activity which can be used to develop improved cooperation and collaboration between disciplines early in PI studies is the development of maps needed by all researchers. Existing maps in Egypt are often out of date, therefore the following maps of total water courses are useful in PI studies: topographic, general features showing all conveyance channels, drains, location of water lifts, roads, buildings, bunded units and basins and cuts made for irrigation, ownership and farm size, crops. Such maps can be used for baseline studies and if updated during the life of the project they can show changes over time. Of equal importance, mapping will necessitate close team work because good quality maps are needed by all researchers. A special section of the training program will be devoted to mapping techniques.

While each discipline group prepared detailed checklists of variables to measure and measurement methods, the major areas delienated by the EWUMP for PI investigation were set forth in several objectives. These are provided to indicate the areas of investigation decided upon after the reconnaissance of the Mansouria District. These were as follows:

Problem Identification Field Survey

a) The objective is to identify and characterize the basic physical chemical properties of the system under study.

1) Ground water conditions
2) Surface water delivery
3) Drainage conditions
4) Site water budgets
5) District water budgets
6) Water quality and quantity
7) Soil classification and capability survey
8) Soil fertility surveys
9) Soil moisture relationships
10) Climatic factors

b) To evaluate present on-farm irrigation practices in relationship to crop yields.

1) Irrigation efficiencies
2) Conveyance efficiencies
3) Field application efficiencies
4) Consumptive use
5) Macro and micro field topography
6) Field size and geometry
7) Irrigation methods and practices
8) Water distribution methods, (rotation systems and non rotation systems.)
9) Farm delivery structures
10) Farmer irrigation behaviors and perceptions

a) Decision making processes

b) Perception of constraints

c) Knowledge of soil - water - plant relationships

c) To catalogue and evaluate farmer's agronomic practices as possible constraints to increasing crop production.

1) Cropping patterns

2) Irrigation methods

3) Seedbed preparation

4) Seed quality and methods of seeding

5) Fertilizer utilization and practices

6) Pest control, weed control, and plant disease control

7) Harvest and storage methods

8) Farm mechanization

9) Soil - water - plant relations

d) To identify major macro and micro institutional constraints to increasing production and farmer's responses to present constraints:

1) Price policy measures

2) Credit availability and utilization

3) Essential input availability and utilization

4) Farm size and tenure arrangements

5) Formal and informal cooperation

6) Local Government services (agricultural irrigation, extension, health, education, local government, etc.)

7) Markets and transportation

8) Information sources and channels (availabity and use)

9) Production quotas and regulations

10) Macro and micro water regulations (charges, pumping distribution, rotation, de jare and de facto.)

The work plan of April 1978 provides the detailed lists of factors to be investigated by each discipline group. Without time spent in reviewing farmer research, discussions with officials, and the farm level reconnaissance the team members would not have been able to develop their PI study adequately.

6 Major Findings of the Mansouria PI Study

In roughly six months of field investigations with several interruptions the following major findings were obtained. These findings point to some areas that require more intensive research at the search for solutions stage and some areas that suggest government intervention for solutions. The major findings are given by discipline as they were reported in the December 1978 summary report.

Engineering Constraints

- Irrigation water is not distributed equitably to all reaches of the farm system
- Lack of a scheduling of irrigation turns and many illegal intakes
- Water table rising sharply after each irrigation
- Undetermined seepage from canals and ditches
- Loss of water over canal tail escapes probably due to reduced night irrigation
- In some areas need to add large leaching factor which adds to watertable problems
- Water in drains have high sodium content and requires special management when served for irrigation
- Over irrigation at planting common but other irrigations undetermined
- Basins are not as level as expected and D produces problems of water distribution on fields

Lack of adequate maintenance of government canals and private ditches as well as drains

Agronomic Constraints

- Poor crop stands and low plant populations which are from 51 to 75 percent of optimum for corn
- Possible problems with micro nutrients
- Salinity can be a problem on 25 percent of Beni Magdoul land and 17 percent of El Hammami land. Potential problems of soil sodicity on 9 and 23 percent of Beni Magdoul and El Hammami land.

Socio-Economic Constraints

- Excessive slack time in crop rotations or 58 days per agricultural year.
- Excessive costs of lifting water estimated costs savings of LE 30 per feddan
- Lack of voluntary farmer organizations especially related to scheduling of irrigation, clearing and maintenance of canals and drains, sharing implements and labor
- Lack of communication between farmers and government officials
- Possible problems of illiteracy in farmers use of new technology
- Weakened local leadership overtime and differences between "official leaders" and "real leaders."
- Low level of understanding and respect between farmers and officials
- Weak incentive system for farmers due to attempts of government to regulate agriculture
- Ineffective quantity and quality of extension services and weak local cooperatives which are primarily for inspection and control rather than for services

- Lack of an integrated rural development concept by government
- Fragmentation of holdings

The data for this first P.I. study in Egypt is available. The purpose here is only to present the major findings and attempt to draw lessons from the case study that will provide insights of how we can improve our approaches to P.I. studies. The next section attempts to evaluate the case study utilizing the views of project personnel who were involved in the field studies. Also we will utilize insights from CSU TDY staff who were involved in the P.I. studies on a short term basis.

2. Evaluation of the Mansouria P.I. Case Study

A general summary of problems from the perspective of the EWUP staff is given and secondly, a more specific analysis is made of selected aspects that were missing in the first P.I. efforts are presented. Figure 2 is a summary of problems perceived by project personnel.

Figure 2 Summary of Problems Reported By Senior Researches of EWUMP

Problem Area	Nature of Problem
Understanding of PI Concept	- Lack of understanding by senior and junior project personnel - Some skepticism about PI and interdisciplinary approach - Need for a framework for PI
Interdisciplinary Concept	- Project organization in practice focuses more on disciplinary focus - Lack of interdependence between disciplines - Lack of team collaboration - Project is more multidisciplinary than interdisciplinary
Coordination	- Lack of knowledge of what is expected by team members - Lack of initiative from team leaders - Lack of clarification of authority roles - Better implementation of work plan - Lack of direction
Communication	- Lack of communication of activities of disciplines - Lack of sharing data - Need more social as well as professional interaction - More opportunities for feedback - Need to learn how to accept criticism - Need more positive communications and less hidden agendas
Facilities	- Members of disciplines have offices set-up similar to an academic institution - Need a facility which has own identity rather than that of a single ministry - Work schedule needs more flexibility - Need to strive to remove some inequities in benefits
Logistics	- Transportation problems need better supervision and scheduling - Need better supervision of field staff

	- Equipment problems - Better selection methods and orientation of new personnel
Linkages With Other Organizations	- Need to continue to build up and maintain linkages by design - Need to develop more credit-ability with local organizations - Need to keep all interested organizations better informed
Decision Making & Planning	- Need more flexibility and need to play larger role in some areas of decision making - Too much emphasis on getting into field before we know exactly what we need to do
Data Management	- Need to develop a system so we can correlate all data

After the presentation of the ways project personnel perceive PI can be improved a more detailed evaluation is presented from the case study of ways PI can be improved. Focus is given to Planning and Implementing Reconnaissance, improved team communication and collaboration, sample selection, mapping of farm systems, data management, and ranking of problems from research findings.

1. Planning and Implementing Reconnaissance

The initial reconnaissance by the EWUMP team supplies must of the information that will be useful for the remaining research sites thereby saving much time. As discussed earlier reconnaissance efforts should provide the following: First hand understanding of form system; input for design of formal PI studies, building an interdisciplinary team, over-view of relevant prior research efforts. and creditability with all organizations interested and involved in the project. To accomplish these objectives reconnaissance can not be left to random activities but must be planned. The initial efforts of reconnaissance required much more time than following efforts due to lack of planning. Efforts were piece meal and due to lack of planning large numbers of researchers visited farm sites together. Such large groups with several vehicles not only confuse farmers but can lead to much rumor in the village as to "what is the government up to now?" Instead of developing creditability with farmers such approaches can lead to much speculation. Another problem observed was the fact that no one was designated to ask questions of farmer clients, all the visitors often ask questions. It was also observed that inadequate note keeping was done and few attempts were made to discuss observations after field visits. Check lists of questions to be asked by a designated individual team member has been found to be more efficient. Also another problem observed was the tendency to take windshield tours of sites without taking the necessary time required for useful information. Such brief ill organized tours indiciate frustration "to do something even if it is not productive" rather than team planning. As discussed earlier there was a tendency to get to the field before careful plans were made as to who should be involved and what was to be accomplished.

In visiting government offices and the offices of international organizations there was also lack of planning. Usually a decision was made by one discipline or individual without consultation with team members. After such visits often there was no reporting in the farm of memos to communicate information to the team. Sometimes each discipline group visited the same organizations separately.

This evaluation suggests the need for more planning for future reconnaissance efforts. It should be mentioned that many of these problems were expected in the first efforts due to lack of experience by team members as they were getting adjusted to each other and to the new research approach.

2. Improved Team Communications and Collaboration

Probably the major problem perceived by the team was the lack of good communication and collaboration. Communication is one of the most important components of successful team work. Good communication never just happens, it must be designed. Research on team building suggests that the location of project personnel is related to communication. The conventional approach is to segregate disciplines in special rooms, however, this does not enhance team work. Project leaders need to carefully design situtations such as meetings for increased communication. Such meetings have been established in the project but often they have not provided sufficient feedback from all personnel. Team leaders also must provide opportunities for communication. A method to ensure improved communication is the use of memos which contain information of activities. For example, the senior sociologists have documented most of their activities including training methods, visits to agencies, field work problems and preliminary reports of findings.

Team collaboration requires that all members understand project goals and their specific job assignments. Job specifications are needed even before personnel are selected. Also good team collaboration requires that there is a clear understanding of authority roles and responsibilities. It is one thing to develop an organizational chart and another to implement the same. Team leaders often have not exhibited the leadership expected. Figure 3 provides some of the requisites for both effective communication and collaboration. Time taken in planning for team collaboration is not wasted. There is a notion by some that interdisciplinary research requires too much time in planning and communication, however, this can also be viewed as time saved if team work results in accomplishment of project objectives.

3. Sample Selection

Sample selection required much time for the team because there was lack of concensus on criteria for both site selection and the selection of sample farms. Again this requires team leadership and collaboratiion by all disciplines involved. There will always be a need to compromise because the "scientific ideal" is not always what is either possible or needed for PI field studies. First, decisions must be made about the criteria which must be specified by all disciplines. Secondly, the sampling units must be the same for all disciplines if there is to be a correlation of physical, economic and social factors. Thirdly, it must be realized that some disciplines such as economics and sociology require additional sampling units which will need to include the village as a unit of analysis. While the sample farmer is interviewed for data about his operation key informants can be used effectively for village level data. When chosing the sample farms considerations should be made as to his total holdings on the study water course and other water courses which influence his farm decision making.

4. Mapping of the Farm System

A major oversight in the initial PI studies was the development of maps for use by project personnel. As suggested earlier there is a need for maps which show general features, topographical problems, size of basins, fields and farms, ownership patterns, all conveyance and drainage channels, all field inlets and pumping stations. Mapping in Egypt is important because available maps are often out of date. Mapping not only provides much base line data, they provide a means of understanding the system, and also can be used later to document changes over time. Maps are also an excellent means of presenting some types of data. Since the number of sample farms is quite small at both sites, maps provide information about the total command area. Maps also are useful in sample selection. It is hoped that appropriate maps will be developed for future research sites.

5. Data Management

As team members realized there is a need for a plan for data management. Without such a plan each discipline will analyze their own data and there is not adequate means for correlation of data from all disciplines to rank priority problems. Several attempts have been made to develop such a system but none has yet been implemented. This is why the first PI data did not produce a definite ranking of priority problems. Statistical evidence is needed to supplement judgements as to what the priority problems

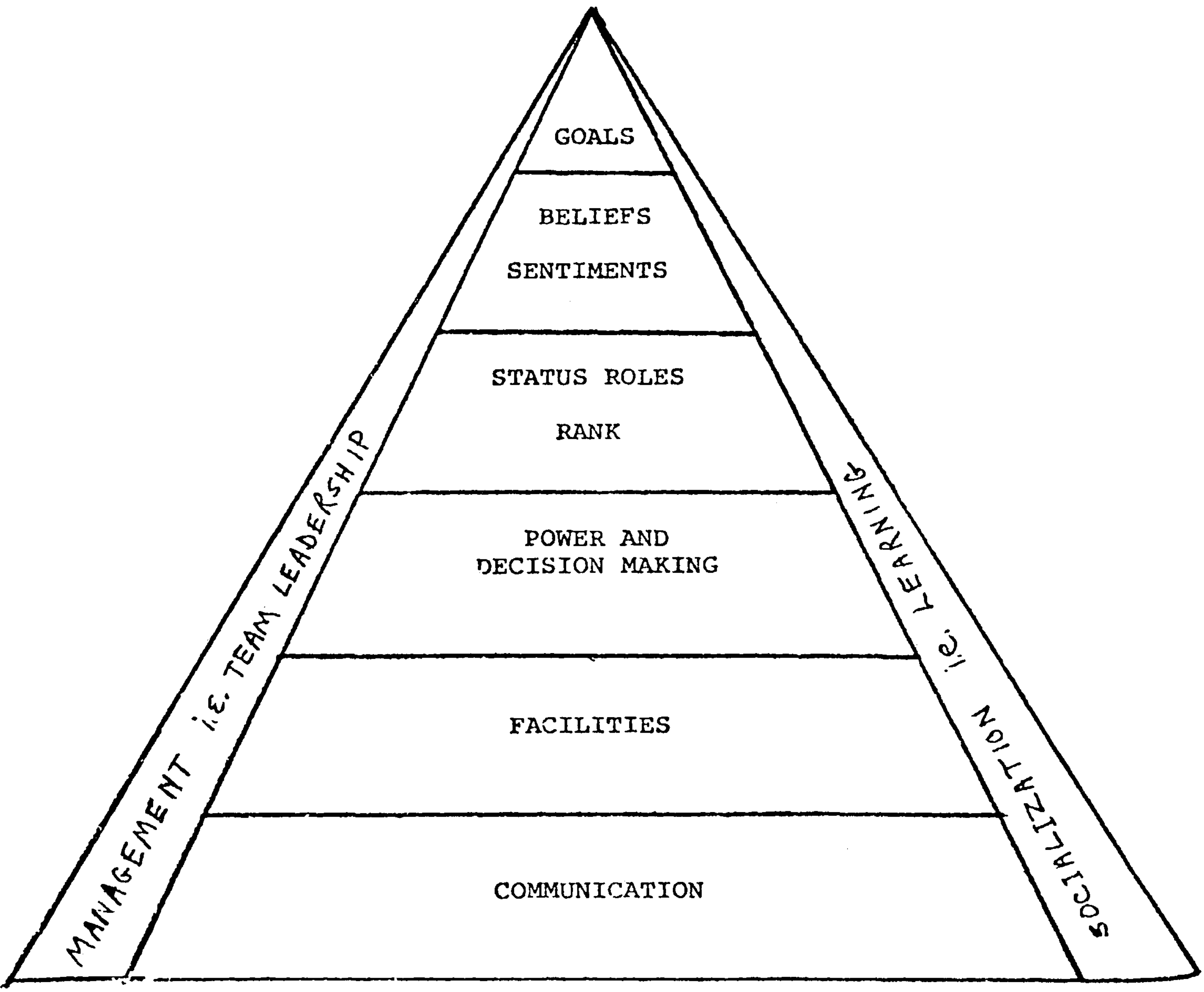


Figure 3. Key elements in interdisciplinary team research systems.

are. It is hoped that a special consultant will be made available to help design and implement an adequate Data Management scheme in the near future.

6. Ranking of Priority Problems From PI

While the team has collected much data there is no indication of what the ranking of the major problems is. The purpose of the PI is to provide such a priority ranking in order to identify those problems which require research to discover solutions. Needless to say all the problems identified can not be researched in depth,therefore some means short of objective analysis must be developed to sort out those problems which require immediate attention. One approach is to combine as much data as possible from the disciplines to identify those factors which influence yields. Criteria can also be developed for selecting out those problems which are primary and those which are of secondary importance. Also those problems that require policy changes can be delineated and separated from those that require project intervention. The team can establish valuation criteria to be used to separate out those problems with which the project must give its primary attention.

In conclusion of the case study, the major question is what you as a trainee intend to do to improve Problem Identification studies. You will be given an opportunity during the training to analize this case study as a team and also the challenge of helping to design and implement a PI study on selected farms in Colorado.

Questions for Trainees

The purpose of the following questions is to stimulate your thinking. These are some of the questions similar to those we will be facing throughout this training program. There are no easy answers.

1. List the major physical and socio-economic factors which were not examined in the Mansouria case study.
2. Which of the findings of the Mansouria study are most significant constraints to crop production? How did you make this decision?
3. What were the major problems faced in the Mansouria case studies that inhibited the work of researchers?
4. What factors would you look for in a reconnaissance to determine why a farmer operates as he does?
5. Would you suggest how to arrive at criteria for site selection?
6. What do you think reconnaissance means?
7. What do you think is meant by team building?
8. What is problem identification as you understand it at the beginning of the training course?
9. What is interdisciplinary field work as compared with single discipline field work?

ANNEX II

RESPONSIBILITIES OF THE RESEARCH TEAM

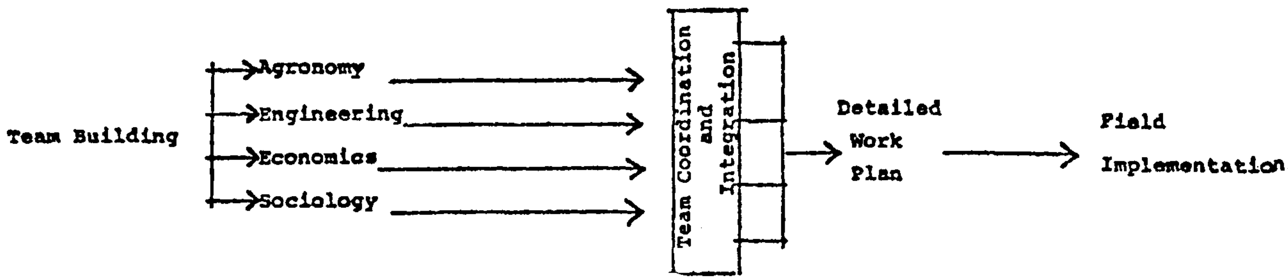
This annex will discuss the responsibilities of the team with focus on mutual data need, data collections, work plan development, fields trials, and analysis and reporting data.

Given the nature of the farm irrigation system the approach to problem identification and other phased activities of the EWUP must be interdisciplinary. While team members representing various disciplines will have their specific tasks to perform, many responsibilities will overlap. It will be the purpose of this section to 1) discuss the interrelationship between the performance of disciplinary tasks that demand the cooperative effort of more than one discipline, and 2) discuss how this interdisciplinary effort is organized to collect data.

Disciplinary vs. Interdisciplinary Study:

The key concern related to what activities are performed by whom is that the data collected bv one team member will often be of immediate use by another team member. For example, on given farm systems all team members need data on crop yields, crop stands, cropping patterns and cropping intensities. Also, the work done by one team member is often essential to other team members for their collection of data. For example, maps will be used by all team members for the collection and recording of data. If the engineers develop or obtain a base map of sites to be studied, this map can be copied and made available for crop surveys, soil surveys, topographical surveys, cross section slope and length of convergence system, location of outlet structures, field ditches, lifts, drainage system, ground water fluctuations, farm yield size, irrigation basin size, ownership patterns, tenure patterns, fragmentation, etc. These examples are to illustrate the interdependence of activities and the joint efforts of team members. Figure 1 shows the importance of team coordination in the planning of activities. Note that there must be close coordination of team members in major tasks.

Figure 1 - Diagram to show Team Coordination



*This process demands constant communication among the team members for reviewing, evaluating, and revising the work plan. The responsibility for this communication lies with the team leader who must call the team meetings necessary for facilitating this communication. The team leader has a crucial job regarding this team building process.

Each discipline has the necessary expertise to perform specific tasks that are needed. For example, in referring to the Technical How-To-Do-It Series in Annex II, one can see specific tasks such as the installation of flumes, the measurement of water entering those flumes, installation of observation wells, and other activities which only engineers can perform. Likewise, agronomists will take soil samples, measure crop yields, examine plant diseases and pests, determine consumptive use and be involved with other investigations related to their expertise. As for the social sciences, their expertise lie in analysis of economic conditions of the area (economists), organizational and interpersonal relationships (sociologists), and other socio-economic considerations. Each discipline legitimately has specific areas which they concentrate on, but again these specific studies must be placed into the context of "team" research efforts.

In the process of team consultations the questions must be answered as to what types of data collected by one discipline is required by other disciplines. The team must decide who will be responsible for the collection of data related to these factors and how these data will be made available quickly and efficiently for other team members. In the foregoing, Engineer is denoted by Eg, Agronomy by Ag, Economics by E, and Sociology by S.

Figure 2 Illustration of Types of Data Collected by One Discipline and Used by Other Disciplines

Eg ← S 1. Farmers perceptions about

- -night and day irrigation
- -major problems inhibiting increased yields
- -solutions to major problems

Eg ← S + E 2. Farmer decision making processes related to

- -crop decision making
- -when to irrigate a given crop
- -when to stop on irrigation
- -water lift methods
- -who applies water at given irrigation

Eg ← S + E 3. Farmers estimation of

- -depth of infiltrations of water
- -depth of crop root system penetration
- -crop water requirements
- -critical water demand periods and stages growth
- -sources of major losses
- -magnitudes of losses
- -water logging

Eg ← S 4. Propensity of farmers to cooperate

- -in water lifting
- -trading of irrigation turns
- -farms implements - machinery sharing
- -sharing of work
- -patterns of both formal and non-formal cooperation

Eg ← E + Ag 5. Farm management practices

- cropping patterns and intensities
- seedbed preparation
- levels of farm technologies
- seed rates, quality, and seeding methods
- fertilizer inputs, timing, amount and placement methods
- plant protection measures
- harvest methods
- storage methods

Ag ← S + E 6. Adoption-diffusion of improved technologies

- rate of adoption
- time required for adoption
- later rejection of adopted technology
- channels and courses of information used at each stage in the process
- characteristics of the innovation
- farmer creditability with information source

Ag + Eg ← E 7. Economic returns and costs

- lifting water (alternative methods)
- various crop mixes
- storage systems
- transportation
- marketing

E + Ag + Eg S 8. Legal and organizational factors

- -delivery of water to command area
- -distribution of water
- -pricing of water
- -settlement of disputes formally and informally
- -farmer interaction with river irrigation officials
- -dejure vs. defacto
- -sanctions
- -incentives

Eg, Ag, E S 9. Information for farm decision making

- -marketing
- -irrigation schedules, closures, etc.
- -extension - agronomic
- -quality and quantity of information

From this partial list of activities, it can be seen that much of the data gathered will be used by more than one discipline. It is therefore the responsibility of the research team to delineate the specific approaches to be taken that will coordinate the efforts needed to gather the data. One such coordinated effort is described in the next subsection.

Responsibilities for Data Collection:

The team members from the various disciplines must also establish a strategy for obtaining data. The following is an example of a work plan for the gathering of socio-economic data.

1. Review of Literature and Preliminary Field Surveys

Literature and available data in English and Arabic must be reviewed and summarized. Such data may be obtained from research institutes, FAO, Ford Foundation, and other organizations in Egypt. The literature search should include the sources of university researchers and others. When available, information retrieval systems may be utilized such as the ones at CSU. Senior researchers are responsible for this initial search activity and should provide summaries or abstracts for each team member of all previous research that is relevant to the project goals. This activity should take place at the beginning of the project and not left until much later.

Preliminary field surveys are then to be completed to provide information for the development of the formal problem identification surveys. Several farms can be chosen for socio-economic case studies in particular irrigation districts. The sources of data will be key informants from the area including cooperative extension and irrigation personnel plus the decision makers of selected farms. These farms should be chosen to represent differences that are expected such as farm size, soil type, water quantity, etc. Senior researchers should conduct these surveys to gain experience for designing the formal survey methodologies.

2. Tentative Work Plan for Problem Identification Field Surveys

2.1 Major factors to investigated
2.2 Major sources of field data
2.3 Methods of data collection
(a) Published and un-published data available

(b) Structural interviews with key informants including farmers, cooperative personnel, and local government officials.
(c) Structured interviews with a random sample of farm families.
(d) Field observations of activities

2.4 Recording of field data
(a) Maps
(b) Precoded questionnaires
(c) Field dairy of data collection personnel

2.5 Field supervision of data collection

The field work is the direct responsibility of the advisers and the site team. At each site a junior research officer will be responsible for all daily supervision.

2.6 Data management plans

All field data should be recorded on precoded data forms. Intensive field supervision to assure good quality data should take place throughout the survey to check for validity/reliability, and objectivity of data. Data should be carefully checked by a specific individual for recording errors and then punched directly on computer cards. The data management master plan must be developed jointly by all teams.

2.7 Training requirements

Training should be given to all field data collectors by the research advisers after the preliminary survey and development of data collection instruments. Training should include interview techniques, sampling procedures, recording of data, use of field diaries, internal checks for quality of data and mapping techniques. This training will require about one week and should be done under field conditions. Training should include the pretesting instruments and interview techniques. Field data collectors should be given orientation about irrigation agronomic practices by the advisers for agronomy and irrigation.

3. Sampling Procedures

Stratified random samples can be selected within each grid of the hydrological unit. Available data can be examined to decide if a stratified random sample should be selected on the basis of farm size or other variables. It is important that the sample farms selected be used by all teams. Otherwise the data cannot be correlated in the form of regression analysis.

4. Time Frame for Completion of Problem Identification Field Survey

5. Methods for Validity and Reliability of Data

- 5.1 Pretesting questionnaires
- 5.2 Checks from outside sources
- 5.3 Internal check questions
- 5.4 Test, re-test methods
- 5.5 Data recordings reliability
- 5.6 All schedules will be in simple Arabic

The checks for validity and reliability will be the direct responsibility of the supervisors and the senior researchers.

6. Applied and Evaluative Field Trials

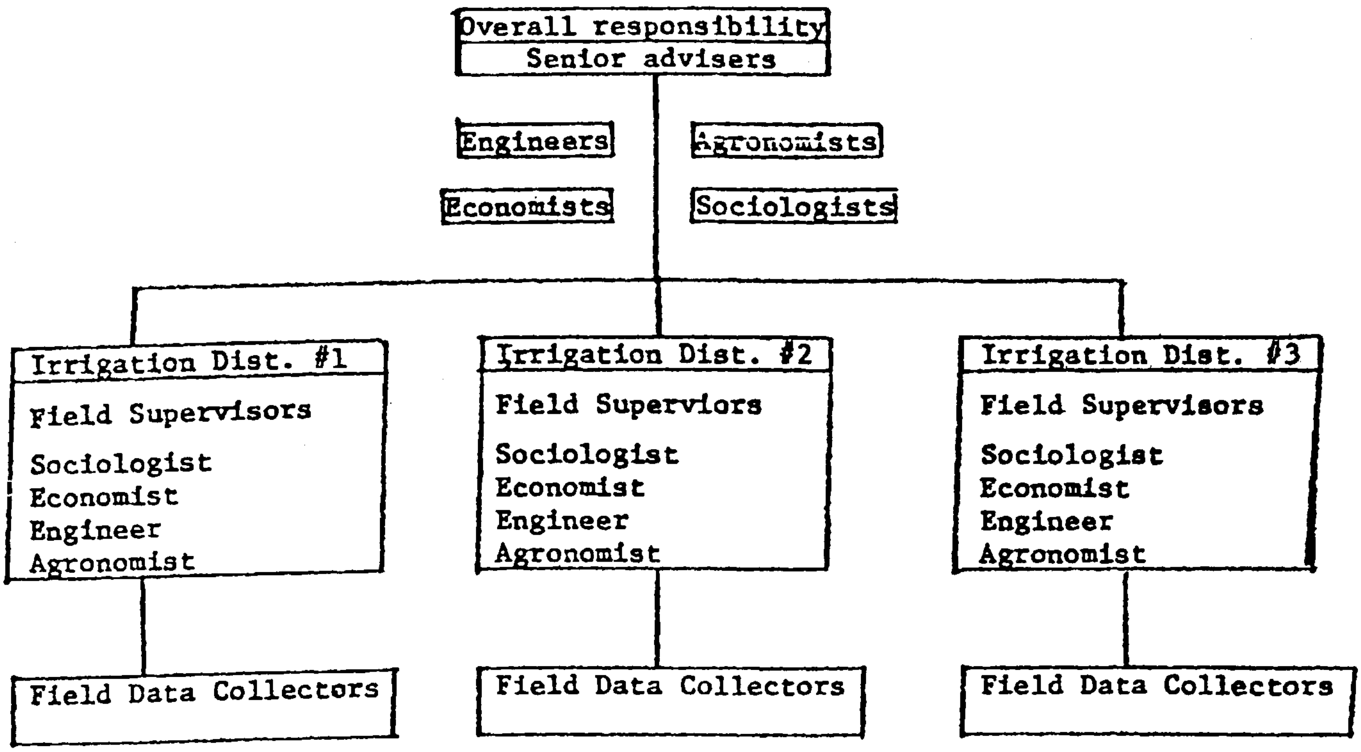
Where technologies are tested such as conveyence systems improvements, land leveling agronomic improvements, etc., "before" and "after" studies can be conducted by the socio-economic team. The data collected in the problem identification survey provides the "before" data. Data later can be collected to ascertain farmer acceptability, cost-benefit environmental and social impact of the improvements. These data also provide insights and guidelines for developing programs for transfer of findings to other farmers. It is suggested that senior researchers be responsible for the collection and analysis of these data after improvements have been made.

7. Analysis and Reporting Data

Given the large volume of data to be generated by the socio-economic and other teams it is suggested that the problem identification data be analyzed by computers. This requires joint data management and a uniform coding system. Several standard programs are available for such analysis. One that has been widely used by the social and physical sciences is SPSS system available from North Western University, USA. Decisions should be made about the program that will best serve the purposes of the project and the types of analyses needed. Farm management data can be analyzed by small hand calculators and these should be utilized whenever possible. Data obtained from applied and evaluative research can also be evaluated, coded, and analyzed in the main office by trained staff.

Reporting of field investigations should be of several types. Preliminary reports are needed even during the field data collection period for decision makers as a part of the progress reports. Brief reports should appear often for non-technical audiences in language they can understand. More comprehensive reporting can be done as specific activities are completed. It should be stressed that reports should be designed for specific audiences in order that findings can be used.

8. <u>Responsibilities for Data Collection</u>**



**This format is for the collection of data from three major hydrological areas in Egypt.

ANNEX III

EQUIPMENT NEEDS

In pursuing a proper and adequate problem identification program, it is necessary to utilize various pieces of equipment which are integrally involved in the numerous measuring practices. The following list of equipment needs evolved from the different aspects of problem identification with regard to water management. Developing an equipment list and procuring the same is a task of management. And far to often this is left until the last moment.

(1) Water Delivery Measurement:

(1.1) Mogha Delivery

-Flumes

-Staff Gauges

-Levels

-Field Notebook

-Flow Meters

(1.2) Tubewell Delivery

-Carpenter's Square

-Folding Rule

-Field Notebook

-Flow Meters

-Flumes

(2) On-Farm Measurements:

(2.1) Mapping: Topographic

-Farm Level and/or Alidade

-Steel Tape

-Stakes and Range Poles

-Field Notebook

(2.2) Mapping: Field and Watercourse Orientation

(2.2.1) Plane Table

-Tripod

-Map Paper (plain, grided, transparent)

-Drawing Board (18 x 31" or 46 x 79 cm)

(2.2.2) Alidade equipped with peep-sight alignment hairs

(2.2.3) Other Equipment

-Rod

-Measuring Tape

-Scale

-Compass

-Small Spirit Level

-Field Notebook

(2.3) Surveying

-Level

-Staff Rod

-Stakes or Chaining Pins

-Pucca Turning Point

-Field Notebook

(2.4) Soil Moisture Sampling

-King-tube Sampler (or other type)

-Plastic Bags (15 x 15")

-Scales

-Hammer

-Straight Edge

-Touch-Feel Chart

-Field Notebook

-Oven

-Plastic Sheets (2-6 ml thick, 24 in^2)

(2.5) Soil Fertility/Salinity Sampling

-Shovel or Spade

-Soil Sampling Augers

-Tubes and Buckets (Stainless Steel or Plastic)

-Field Notebook

(2.6) Observation Well Installation

-Pipe

-Threaded Cap for Pipe

-Auger

-Coarse Sand

-Concrete

-Plastic Tube (3 mm diameter)

-Plug

-Measure

-Field Notebook

(2.7) Socio-Economic Observations

-Field Notebook

-Check Lists

-Calculator

-Computer Cards and Keypunching Facilities

(3) Miscellaneous Equipment

- Data Management Facilities to store records and data
- Writing Materials
- First Aid Kits
- Snake Bite Kits
- Medicines
- Red Cross Manual

ANNEX IV

DATA SUMMARY FORMS

A. Irrigation Data Forms

Irrigation Data Summary Sheet
Soil Moisture & Irrigation Data Summary Sheet
Change in Soil Moisture Between Irrigations: Data Summary Sheet
On Farm Flume Data Sheet
Semi-Log Chart For Grading Curves
Hydrometer Analysis
Sieve Analysis
Soil Moisture Sampling Report
Table of Linear Dimensions
Suggested Tabulation Form
Flow Depth and Top Width Data
Flow Rate Data
Water Advance/Recession Data
Cylinder Filtrometer
Bulk Density Data
Soil Moisture Content Data
Irrigation Evaluation Summary Sheet
Summary Sheet For Flooded Rice Irrigation Evaluation
Dead Storage In Watercourse
Record of Wastage of Full or Part of Mogha Discharge
Soil Moisture Status vs. Water Applied--Summary Sheet
Water Application Summary Sheet
Cylinder Ineiltrometer Data Sheet
Furrow Infiltration Data Sheet

B. Irrigation Data Forms in Arabic

Observation Well and Piezometer Data Sheet
Daily Sounding in Wells
Soil Moisture Sample Data Sheet
Daily Gauge Record for Canals & Drains/Hydraulic Unit No. 3
Weekly Job Planning and Record Sheet
Data Record Sheet-Technicians
Water Application & Runoff Summary Sheet
Water Budget Summary Sheet
On Farm Irrigation Runoff, Conveyance Loss Summary Sheet

C. Farm Management

Estimation of Receipts from Crop Sales
Estimation of Cash Farm Receipts: Crop and Other Income
Estimation of Cash Farm Receipts: Livestock Products and Livestock Sales
Family Living Expenses
Scheduled Debt Payments
Estimation of Cash Farm Expenses: Labor and Feed and Livestock Purchase
Estimation of Cash Farm Expenses: Machinery

IRRIGATION DATA SUMMARY SHEET

Crop____________ Site____________ Season____________ Previous Crop____________

Area____________ Distance to Sakia____________

Crop Operation	Date Performed	Canal Rotation	Time Begun	Interval (days)	Water App. (cm)	Time of Irr. (mm)	Acc. App. (cm)	Recommended Acc. App. (cm)	Est. Acc. E.T. (cm)

SOIL MOISTURE & IRRIGATION DATA SUMMARY SHEET

Page ______

Hydrauli Unit ______________ Season ______________ Area (feddan) ______________

Study Site ______________ Crop ______________

OPERATION	DATES & DIRR	INTERVAL (days)	SOIL LAYER (cm)	BEFORE SMS (cm)	AFTER SMS (cm)	FC (cm)	ΔSMS[1] (cm)	SMD[2] (cm)	Ea[3] (%)	Er[4] (%)	WT[5] (cm) BEFORE	AFTER
			0-30								MA	
			30-60								MI	
			60-90								DR	
			Σ									
			0-30								MA	
			30-60								MI	
			60-90								DR	
			Σ									
			0-30								MA	
			30-60								MI	
			60-90								DR	
			Σ									

1 (AFSMS - BFSMS)

2 (FC - BFSMS)

3 SMD/DIRR

4 ΔSMS/~~DIRR~~ SMD

5 cm from ground surface

CHANGE IN SOIL MOISTURE BETWEEN IRRIGATIONS: DATA SUMMARY SHEET

Study Site ______________ Season ______________ Crop ______________ Area (feddan) ______________

IRR NO & DATE	SOIL LAYER (cm)	Date SMS AFTER IRR-1 (cm)	Data SMS BEFORE IRR (cm)	ΔSMS (AF-BF) (cm)	SMS INTERVAL (days)	IRR INTERVAL (days)	ΔSM[1] (cm)	DIRR (cm)

[1] ΔSM = ΔSMS (IRR INT/SMS INT)

ON FARM FLUME DATA SHEET — بيانات جداول وعبارات المواقع

Hydraulic Unit ______________________ وحدات القياس الهيدروليكية

Site No. ______________________ رقم الموقع

Field No. ______________________ رقم الحقل

Operator ______________________ اسم الفلاح

Season ______________________ الموسم

Crop ______________________ اسم المحصول

Operation : IRR ______________ DRAIN ______________ العملية ـ ري ـ صرف

Flume Site ______________________ حجم العبارة

Observer ______________________ الملاحظ

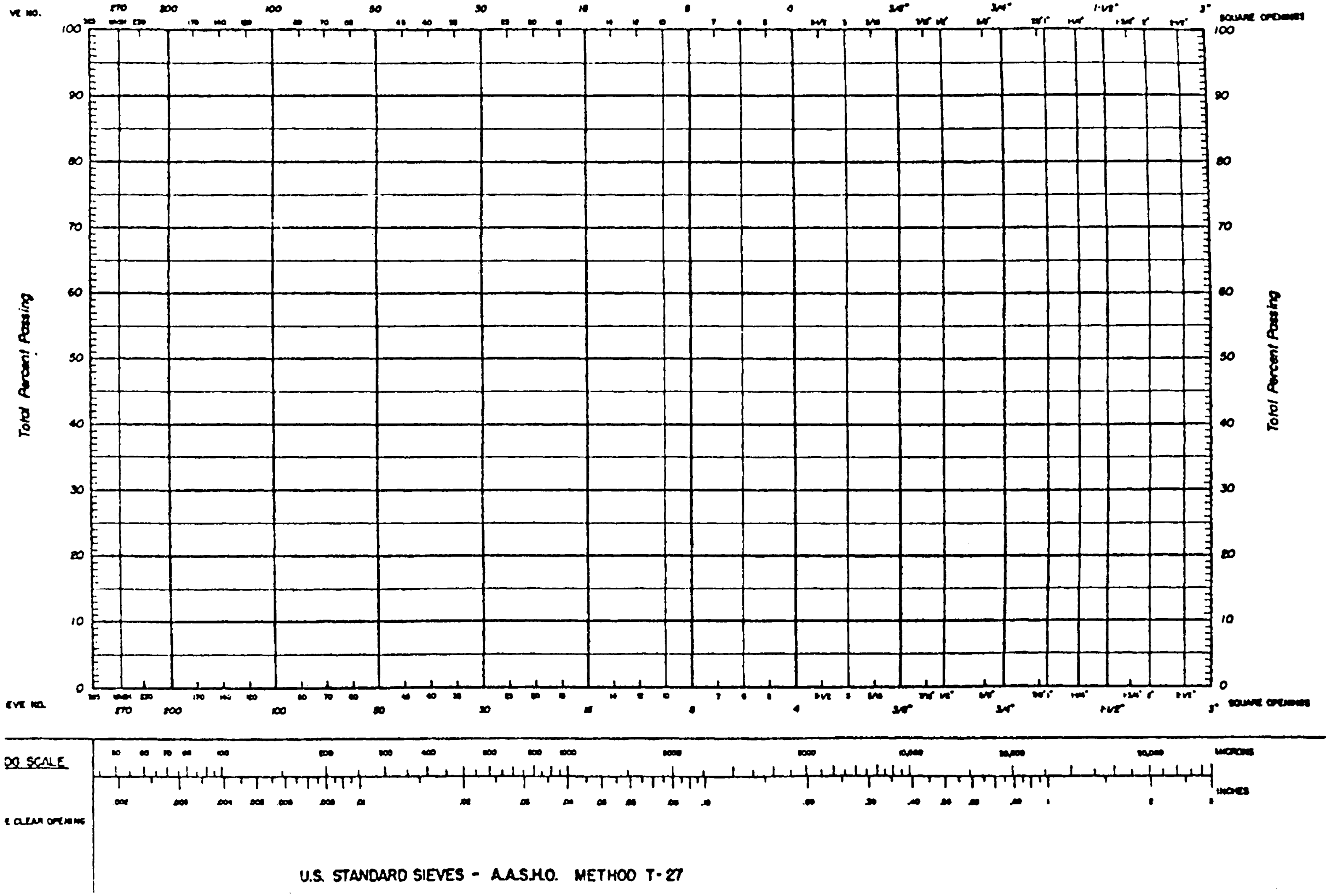
Date ______________________ التاريخ

Time اليوم	U.S.L. cm(h_a) قراءة الامام	D.S.L. cm(h_b) قراءة الخلف	H_a H_b الأمام الخلف	Submergance نسبة العمق	Q(discharge) lit/sec التصرف باللتر ثانية	REV Sakia عدد لفات الساقية	LIFT Sakia مقدار الري	REMARKS ملاحظات

aterials Laboratory

SEMI-LOG CHART FOR GRADING CURVES

Project ______
Location ______
Station ______
Material ______
Sample No. ______



U.S. STANDARD SIEVES - A.A.S.H.O. METHOD T-27

HYDROMETER ANALYSIS

Sample description ______________________________ Date ____________

______________________ Specific Gravity ____________ Tested by ____________

Location ______________________ Hydrometer Correction ______________________

Hydrometer Sample ______ % Finer than ______ sieve. Mass dry soil W = ______ g

Time	Elapsed Time t - min	Temp °C	Hydrometer Reading		% Finer P	L (Table 2) cm	K (Table 3)	D $K\sqrt{L/t}$ mm	% Finer in Total Sample
			Original	Corrected					

Table 3: Values of "K" For Computing Particle Diameter In Hydrometer Analysis

Temp °C	Specific Gravity - G			
	2.6	2.65	2.7	2.79
16	0.0146	0.0144	0.0141	0.0139
18	0.0142	0.0140	0.0138	0.0136
20	0.0139	0.0136	0.0134	0.0132
22	0.0135	0.0133	0.0131	0.0129
24	0.0132	0.0130	0.0128	0.0126
26	0.0129	0.0127	0.0125	0.0124
28	0.0126	0.0124	0.0122	0.0121
30	0.0124	0.0122	0.0120	0.0118

SIEVE ANALYSIS

Dry mass of sample after washing on 0.075mm (No. 200) sieve __________ g

Size Opening mm	Sieve No.	Mass Retained g	Cumulative Mass Retained	Mass Passing	% Sediment Sample Passing	% Total Sample Passing

SOIL MOISTURE SAMPLING REPORT

Observers ____________ and ____________ Weight of plastic bag ________ g

Date ____________ Hours Drying Time ________

Date Last Irrigation ____________ Diameter of king tube ________ cm

Date of next irrigation ____________ Volume of sample 6" = ____ cc 12" = ____ cc

Rep	Trtmt	Depth	WetWt(g)	DryWt(g)	WtH$_2$O	NetDryWt	%MC-Wt	DBD	%MC-Vol	ASM(in/ft)
		1(0-6")								
		2(6-12")								
		3(12-24")								
		4(24-36")								
		5(36-48")								
		6(48-60")								
		7(60-72")								

Rep	Trtmt	Depth	WetWt(g)	DryWt(g)	WtH$_2$O	NetDryWt	%MC-Wt	DBD	%MC-Vol	ASM(in/ft)
		1(0-6")								
		2(6-12")								
		3(12-24")								
		4(24-36")								
		5(36-48")								
		6(48-60")								
		7(60-72")								

Rep	Trtmt	Depth	WetWt(g)	DryWt(g)	WtH$_2$O	NetDryWt	%MC-Wt	DBD	%MC-Vol	ASM(in/ft)
		1(0-6")								
		2(6-12")								
		3(12-24")								
		4(24-36")								
		5(36-48")								
		6(48-60")								
		7(60-72")								

Rep	Trtmt	Depth	WetWt(g)	DryWt(g)	WgH$_2$0	NetDryWt	%MC-Wt	DBD	%MC-Vol	ASM(in/ft)
		1(0-6")								
		2(6-12")								
		3(12-24")								
		4(24-36")								
		5(36-48")								
		6(48-60")								
		7(60-72")								

Rep	Trtmt	Depth	WetWg(g)	DryWt(g)	WgH$_2$0	NetDryWt	%MC-Wt	DBD	%MC-Vol	ASM(in/ft)
		1(0-6")								
		2(6-12")								
		3(12-24")								
		4(24-36")								
		5(36-48")								
		6(48-60")								
		7(60-72")								

TABLE OF LINEAR DIMENSIONS Tolerance (0.005 ft.)

	Specification	Top	Middle	Botton	Other
W					
L					
$B_1=W + L/4.5$					
$B_2=W + L/4.5$					
$L_1=L/3$					
$L_2=2L/3$					
$L_a=2L/9$					
$L_b=5L/9$					
H					
H_a					
H_b					

TABLE OF ANGLES MEASURED

Angles are measured from the vertical wall (or staff gauge) to the floor of the flume in the direction corresponding to the arrows in the attached diagram.

Tolerance: 0.5 degree

	Spec.	Measured		Spec.	Measured		Spec.	Measured
1.			6.			11.		
2.			7.			12.		
3.			8.			13.		
4.			9.			14.		
5.			10.			15.		

SUGGESTED TABULATION FORM

WATERCOURSE

Date	Type of Observation	Depth of WT	Location	HMT

FLOW DEPTH AND TOP WIDTH DATA

Ident (R_E,F_A,F_I,I,F_u):_____ Length:_____ Observer:________ Date:_____

Crop:________________ Furrow Spacing (m):________________

Remarks:

d - Flow depth (cm)
w - Top width of flow (cm)

	Start	End	Start	End	Start	End	Start	End
Time								
Station d/w								

	Start	End	Start	End	Start	End	Start	End
Time								
Station d/w								

FLOW RATE DATA

IDENTIFICATION______________ OBSERVER________________ DATE__________

CROP_________ LENGTH_________ INFLOW_________ or RUNOFF__________

FURROW/BORDER NO._______ FURROW SPACING/BORDER WIDTH_______________

MEASURING DEVICE______________ START TIME_________ STOP TIME_______

COMMENTS:

Clock* Time (1)	Elapsed Time (min) (2)	ΔT (min) (3)	Reading ( ) (4)	Flow Rate ( ) (5)	Average Flow Rate ( ) (6)	Volume ( ) (6) x (3) (7)	Σ Volume ( ) Σ (7) (8)

*All clock times are on 24-hour basis.

WATER ADVANCE/RECESSION DATA

Identification: ____________ Date: ____________ Crop: ____________ Irrigation Start: ____________

Soil: ____________ Observer: ____________ Finish: ____________

Comments: Total Time: ____________

Border: ____________ Border: ____________ Border: ____________

Stream Size: ____________ Stream Size: ____________ Stream Size: ____________

Station (m)	Advance		Recession		Station (m)	Advance		Recession		Station (m)	Advance		Recession	
	Time					Time					Time			
	clock	cum	clock	cum		clock	cum	clock	cum		clock	cum	clock	cum

*Clock times are on 24-hour basis.

CYLINDER FILTROMETER

Identification: ____________________ Observer: ____________________ Date: ____________________

____

Remarks:

Station: __________

Infiltrometer No					
Time			Infiltration		
Clock	Diff.	Cum	Depth	Diff.	Cum

Station: __________

Infiltrometer No.					
Time			Infiltration		
Clock	Diff.	Cum	Depth	Diff.	Cum.

Station: __________

Infiltrometer No.					
Time			Infiltration		
Clock	Diff.	Cum	Depth	Diff.	Cum

*All clock times are 24-hour basis.

BULK DENSITY DATA

Identification: ____________ Observer: ____________ Date: ____________

Crop: ____________

Remarks:

Station	Soil Depth cm	Can No.	Wt. Can Tare g	Wt. Can & Soil Moist. g	Wt. Can & Soil Dry g	Wt. Soil Dry g	1st Read. Inst.	2nd Read. Inst.	Soil Vol. cm^3	Bulk Density γ_b

SOIL MOISTURE CONTENT DATA

Identification: ____________ Observer: ____________ Date: ____________

Soil Type: ____________ Crop: ____________ Before / After Irrigation

marks:

Station	Depth cm	Can No.	Wt. Can Tare g	Wt. Can & Soil Moist. g	Wt. Can & Soil Dry g	Wt. Soil Dry g	Wt. Moisture g	Moist. Content % by Weight	Bulk Density γ_b	Moist. Content % by Volume	Moist. depth d mm

IRRIGATION EVALUATION SUMMARY SHEET

Collected: ______________ Mogha # ______________ Distributry: ______________

Coppied : ______________ T/W # ______________ Canal : ______________

Checked : ______________ Chak Village: ______________ $\frac{1}{Ea}$ -%C District : ______________

Sr. No.	Date	Farmer S/O	C/B	Field Location Ac/Sq	K/T	Crop & Height	Field Size	Area (AC)	Time of Irrigation			Doli	SMD (in)	Average Q Nakka (Cfs)	Water applied (in)	Average Q Mogha (cfs)	Discharge Cfs-CTF2 (ft)	Ea	EA %	$\frac{1}{[illegible]}$
									Start	End	Hrs.									

A-IV-19

Location ____________

Start Date ____________

Finish Date ____________

SUMMARY SHEET FOR FLOODED RICE IRRIGATION EVALUATION[1/]

WATER BALANCE COMPONENTS IN INCHES ON A ACRE BLOCK OF LAND

Day	Depth of Irrig. IR	Depth of rainfall RN	Depth of drainage DR	Initial Depth of Surface Storage IS	Final depth of surface storage FS	Depth Change of surface storage ΔS = IS-FS	Pan evaporation depth ET	Residual* seepage & percolation depth residual S&P	Water use efficiency** WUE %
1									
2									
3									
4									
5									
6									
7									
week summary									
1									
2									
3									
4									
5									
6									
7									
week summary									

Basic efficiency relationship

$$\text{Eff.} = \frac{\text{output}}{\text{input}} \times 100$$

* S&P residual calculation

INFLOW - OUTFLOW = change in storage

INFLOW = IR + RN

OUTFLOW = S&P + ET + DR

CHANGE IN STORAGE = IS-FS = ΔS

IR + RN - S&P - ET - DR = ΔS

IR + RN - ET - DR - ΔS = S&P

** Water use efficiency =

$$\left(\frac{ET + S\&P}{IR + RN}\right) 100 = 100\left(\frac{-DR}{IR+RN}\right) + 100$$

The following form is provided in the Irrigation Evaluation Field Book to record the data.

<u>Dead Storage In Watercourse</u>

Date	Q mogha	Time Water Diverted into Watercourse	Time Water Reached Field	(T) Hours	(A) Cross section Area of dead section	(L) Length of Watercourse	$T_n = \frac{AL}{Q}$ Actual time Required	Time for dead storage T-Tn	Volume Wasted Acre In. Q(T-Tn	Remarks

Figure 2

Figure 2. Record of wastage of full or a part of the mogha discharge.

<u>Responsibility</u>: The Agricultural Assistant is responsible for collecting this kind of data with the help of his Field Assistant. He will have to measure the discharge which is being wasted with the help of a Cutthroat flume. If the full mogha supply is being wasted, the readings of the mogha flume will serve the purpose. If a part is being wasted, then he will have to install a flume at the point where it is being wasted.

The data will include the following:

1. <u>Water delivered to a drain</u>

   When it rains, water of the mogha is frequently turned into a drain, or the mogha is shut off.

2. Water delivered to a pond

   The pond may be a traditional village pond, or a fish pond.

3. Brick making or other nonagricultural uses

   Generally for construction purposes.

4. Accidental failure of nakka or watercourse bank upstream

   It frequently happens causing the farmer to suffer accidental losses due to inundation of his crop.

   The data is recorded on this form:

RECORD OF WASTAGE OF FULL OR PART OF MOGHA DISCHARGE

Mogha Number ______________ Month ______________________

Distributary ______________ Chak/Village ______________

Canal ______________________ District __________________

Field Office _________

Date	Average discharge	Time			Volume wasted (Qxt) acre inches	Remarks
		start	end	hours		

Season ______________ Hydraulic Unit __________ Study Site ______________

Date Code	Crop	Date	Operation	Time of Operation			Q(lps)			Vol	Total	Crop	Ave	No. of
				Start	End	Interval	max	min	ave	(m^3)	Area m^3	Area m^2	Depth(Cm)	Readings

Soil Moisture Status vs. Water Applied--Summary Sheet

File Type ______________ Operator ______________ Season ______________

Subfile ______________ Study Field ______________ Observer ______________

Hydraulic Unit ______________ Area ______________ Operator's ______________

Study Site ______________ Crop ______________

Dates		Sm (cm)			Changein SM			Days Between	AVE CHANGE SM/DA			Days Between	Change in d (cm)			TOTAL Change In d (cm)	d IRR (cm)
IRR	SMS	30	60	90	30	60	90	SMS	30	60	90	IRR	30	60	90		

WATER APPLICATION SUMMARY SHEET

istrict ____________ Area ____________ Area Served ____________

a.l ____________ Farm No. ____________ Field No. ________ Season ______ Crop ____________ Yield ____________

operation	Date performed	Interval since last irrig.	Water applied (farmer prac.)	Average application depth	Average appli. over last inter.	Percentage of growth	Water stored in the root zone	Appli. efficiency E_a	Poten. ev. trans. ET_p	Crop factor K_c	Cons. use ET_a	Ave. W.T. depth	W.T. contribution	Water storage effic. E_s	Water use effic. E_s	Cons. use effic. E_{cu}
		days	m^3	mm	mm/day	%	mm	%	mm/int.		mm/int.	cm	mm/day			

CYLINDER INFILTROMETER DATA SHEET

District ____________________

Area ____________________

Canal ____________________

Site ____________________

Feild no ____________________

CYLINDER						CYLINDER						CYLINDER				
TIME			INFILTRATION			TIME			INFILTRATION			TIME			INF	
Watch	diff	cumu	depth	diff	cumu	watch	diff	cumu	depth	diff	cumu	watch	diff	cumu	depth	di

CYLINDER						CYLINDER						CYLINDER				
TIME			INFILTRATION			TIME			INFILTRATION			TIME			INFIL	
watch	diff	cumu	depth	diff	cumu	watch	diff	cumu	depth	diff	cumu	watch	diff	cumu	depth	di

FURROW INFILTRATION DATA SHEET

District ____________ Field No. ____________

Area ____________ Season ____________

Canal ____________ Crop ____________

____

Location ____________ Observer ________ Date

furrow identification ________ Shape ________ cond ition ________ age ____

Soil ____________ moisture content ____________ slope

Comments ____________________

TIME			Station A		INTAKE	Station f	
1	2	3	4	5	6	7	9
Watch time	Difference of time	cumula-,		Flowrate		Flow rate	/00

Location ____________ Observer ________ date ____

furrow identification ________ shap ________ condition ____

Soil ____________ moisture content ____________ slop ____

comments ____________________

Time			station A		INTAKE	Station	
1	2	3	4	5	6	7	8
Watch time	Difference of time			Flow rate		Flow rate	/00

OBSERVATION WELL AND PIEZOMETER DATA SHEET جدول بيانات الآبار والبيزومترات

HYDRAULIC UNIT ______________ الوحدة الهيدروليكية
Site No. ______________ رقم الموقع
Field No. ______________ رقم الحقل

Season ______________ الموسم
Crop ______________ المحصول
Observer ______________ الملاحظ
Month ______________ شهر

الري Irrig or Rain مطر	Day اليوم	Last Reading القراءة الأخيرة												ملاحظات Remarks

WDIMRI

EWUMP

معهد بحوث توزيع المياه وطرق الري

مشروع تطوير الـــري

جسات المياه بآبار الرصـــد

Daily sounding in wells

Form NO! 6 نموذج رقم ٦

District : ________ مركـــز : ________

Area : ________ منطقـــة : ________

Date : ___ ___ التاريخ : ________

ملاحظات Notes	عمق المياه بالبئر Water Soundings	رقم البئر Well NO.

المهندس   المساح   الراصد

WDIMRI

EWUMP

معهد بحوث توزيع المياه وطرق الري

مشروع تطويـــر الـــري

جسات المياه بآبار الرصـــد

Daily Sounding in Wells

Form NO. 6 نموذج رقم ٦

District : ________ مركـــز : ________

Area : ________ منطقـــة : ________

Date : ________ التاريـــخ : ________

ملاحظات Notes	عمق المياه بالبئر Water Soundings	رقم البئر Well NO.

المهندس   المساح   الراصد

SOIL MOISTURE SAMPLE DATA SHEET

District ________ محافظة
Area ________ منطقة
Canal ________ ترعة
Site ________ رقم المزرعة
Field No. ________ رقم الحقل

Season ________ الموسم
Crop ________ المحصول

Location.

Drain ________
Middle ________
Marwa ________

	الشخص	الزمن	التاريخ	نوع العمل
ACTION	PERSON	TIME	DATE	
Collected Samples				جمع العينات
Delivered Samples				نقل العينات
Received Samples				تسلم العينات
Weighed Samples				وزن العينات
Made Calculations				عمل الحسابات
Checked				المراجع

M	L	عمق العينة K	نسبة الرطوبة بالحجم J	الكثافة الظاهرية I	نسبة الرطوبة H/•	مقدار الرطوبة G	وزن العينة الجافة F	وزن الجفنة بالعينة الجافة E	وزن الجفنة والعينة قبل التجفيف D	وزن الجفنة C	رقم العلبة B	رقم الجفنة	عمق العينة A	Remarks
Σd •	d (cm) (J x K)	ΔD (cm)	P vol (%) (H x I)	A_s	P_{wt} (%) (G/F)	Moisture Content (D-E)	Dry Soil (E-C)	Dish + Dry Soil	Dish + Wet Soil	Dish Wt.	Can No.	Dish No.	Sample Depth	ملاحظات Remarks

الأرصاد اليومية لمناسيب القناطر والترع والمصارف

DAILY GAUGE RECORD FOR CANALS & DRAINS / HYDRAULIC UNIT NO. 3

Notes ملاحظات	Observer الملاحظ	Flumes المبارات			STAFF GAUGE 2nd Reading القراءة الثانية		STAFF GAUGE 1st Reading القراءة الأولى		Site الموقع	Date التاريخ
		D.S.L قراءة الخلف	U.S.L قراءة الأمام	Time الوقت	LEVEL المنسوب	TIME القراءة	Level المنسوب	Time الساعة		

بيان وتسجيل خطة العمل الاسبوعي

WEEKLY JOB PLANNING AND RECORD SHEET

Name ________________ الاسم

Date ________________ التاريخ

Site ________________ رقم الموقع

Field no. ________________ رقم الحقل

Job	On- FARM DATE							WATER BUDGET DATA							
Day العمل اليوم	Irrigation ري	Run-off	SMS	Obs. Wells	Obs. Wells Recorders	Staff Gage رخامات	Irro-Meter اروميتر	Obs. Wells آبار	Flow out Flow	In Flow Recorder	Water Quality	Staff GAGE رخامات	Piezo-Meter	Off أجازة	Other أعمال أخرى

DATA RECORD SHEET - TECHNICIANS

Hydraulic Unit: ------------- Area: --------------- Month: ------------

Study Site & Field: --------- Crop: --------------- Observer: ----------

INDEX DAY	Soil Samples	IRR	Adv/Rec	DRAINAGE	Obs. Wells	Piezometer	Tensiometer	Water Samples	Fertilization	Pest Control	Weed Control

WATER APPLICATION & RUNOFF SUMMARY SHEET

File Type ______________ Operator ______________ Season ______________

Subfile ______________ Study Field ______________ Observer ______________

Hydraulic Unit ______________ Area ______________ Operator's ______________

Study Site ______________ Crop ______________

Date	Water Delivered (IRR+PPT) (cm)	Accumulated Water (cm)	Water Runoff (cm)	Accumulated Runoff (cm)	RUN / DEL (%)

WATER BUDGET SUMMARY SHEET

DATE	I_1 MAIN canal m^3	I_2 Supplemental m^3	I_D DRAINS m^3	I_W Wells m^3	S Storage m^3	E Ditches m^3	E Bare land m^3	P Precipitation m^3	O_1 Outflow trans canal	U consumptive use		O TOTAL outflow
1	2	3	4	5	6	7	8	9	10	11	12	13

$$O = I_1 + I_2 + I_D \quad I_W - S - \quad E - U - O_1 + P$$

RUNOFF,

ON FARM IRRIGATION,/CONVEYANE LOSS SUMMARY SHEET

District ______________ المحافظة

Area ______________ المنطقة

Canal ______________ الترعة

Site ______________ الموقع

Field No. ______________ رقم الحقل

Season ______________ الموسم

Crop ______________ المحصول

Observer ______________ اسم الملاحظ

F

Date التاريخ	TIME			IRRIGATION		RUNOFF		CONVEYANCE LOSS			INFILTRATION	E_{app}	E_{con}
	Start بداية	Finish نهاية	Hours ساعات	D_{av} متوسط الصرف	D_{irr} الري	D_{av} متوسط الصرف	D_{rnf} عمق الصرف	1	D_{av2}	D_{con}	$(D_{irr}-D_{rnf}-D_{con})$	(D_{rnf}/D_{irr})	$(D_{irr}-D_{av2}/D_{av})$

ـ سري بيوار ـ ر

A-IV-37

District : ____________   ____________ : مركز

Area : ____________   ____________ : منطقة

Month : ____________   Year: السنة ____________ : الشهر

Field No : ____________ رقم الحقل: Site No. ____ رقم الموقع Canal: ____ : الترعة

Remarks ملاحظات	Soil Moisture العينات						Aerometer قراءة الأروميتر							Date التاريخ
	٤٠"	٣٦"	٢٤"	١٨"	١٢"	٦"	٤٨"	[illegible]	[illegible]	٢٤"	١٨"	١٢"	٦"	
	١٠٠سم	٩٠سم	٦٠سم	٤٥سم	٣٠سم	١٥سم	١٢٠سم	[illegible]	[illegible]	٦٠سم	٤٥سم	٣٠سم	١٥سم	
														١
														٢
														٣
														٤
														٥
														٦
														٧
														٨
														٩
														١٠
														١١
														١٢
														١٣
														١٤
														١٥
														١٦
														١٧
														١٨
														١٩
														٢٠
														٢١
														٢٢
														٢٣
														٢٤
														٢٥
														٢٦
														٢٧
														٢٨

IDENTIFICATION ____________________

SUPPLEMENTAL WORKSHEET 1. ESTIMATION OF RECEIPTS FROM CROP SALES

PRODUCTION				SALES			
CROP	FEDANS	YIELD	TOTAL PRODUCTION	MONTH	QUANTITY	EXPECTED PRICE	VALUE

FARM IDENTIFICATION ____________________

WORKSHEET 1A. ESTIMATION OF CASH FARM RECEIPTS: CROP AND OTHER INCOME

		CROP SALES						OTHER FARM INCOME 2/		CASH FARM OPERATING RECEIPTS 3/
		THIS YEAR			NEXT YEAR 1/					
MONTH	CROP	QUANTITY	PRICE	VALUE	QUANTITY	PRICE	VALUE	THIS YEAR	NEXT YEAR	
Jan.										
Feb.										
Mar.										
Apr.										
May										
Jun.										
Jul.										
Aug.										
Spt.										
Oct.										
Nov.										
Dec.										
TOTAL										

1/ From supplemental worksheet No. 1--Estimation of Receipts from crop Sales.
2/ Include income from work performed for others, rental of land, water, draft animals, or machinery to others and sales of used machinery of equipment. Do not include income from livestock or livestock products.
3/ Value of next ear crop sales plus other farm income next year plus total expected receipts for livestock products (from Worksheet No. 1B).

F. ꟷ)ENTIFICATION ____________________

WORKSHEET 1B. ESTIMATION OF CASH FARM RECEIPTS: LIVESTOCK PRODUCTS AND LIVESTOCK SALES

	LIVESTOCK PRODUCTS SALES: MILK & EGGS							RECEIPTS LIVESTOCK SALES		
MONTH (PRODUCED)	NUMBER OF ____	PRODUCTION PER ______	TOTAL PRODUCTION	PRICE PER ____	RECEIPTS THIS YEAR	MONTH (RECEIVED)	EXPECTED RECEIPTS NEXT YEAR	THIS YEAR	NEXT YEAR	TOTAL RECEIPTS FROM LIVESTOCK PRODUCTS & LIVESTOCK NEXT YEAR
Dec.						Jan.				
Jan.						Feb.				
Feb.						Mar.				
Mar.						Apr.				
Apr.						May				
May						Jun.				
Jun.						Jul.				
Jul.						Aug.				
Aug.						Spt.				
Spt.						Oct.				
Oct.						Nov.				
Nov.						Dec.				
TOTAL										

FARM IDENTIFICATION ______________________________

SUPPLEMENTAL WORKSHEET 2. FAMILY LIVING EXPENSES

MONTH	FOOD	CLOTHING	DWELLING& HOUSEHOLD EXPENSE	PROPERTY & INCOME TAXES	UTILITY & TRANSPORT. EXPENSE	PAYMENT INTO SAVINGS & NON-FARM INVESTMENTS	OTHER FAMILY EXPENSES	CREDIT PAYMENTS	TOTAL FAMILY LIVING EXPENSE
Jan.	______	______	______	______	______	______	______	______	______
Feb.	______	______	______	______	______	______	______	______	______
Mar.	______	______	______	______	______	______	______	______	______
Apr.	______	______	______	______	______	______	______	______	______
May	______	______	______	______	______	______	______	______	______
Jun.	______	______	______	______	______	______	______	______	______
Jul.	______	______	______	______	______	______	______	______	______
Aug.	______	______	______	______	______	______	______	______	______
Sep.	______	______	______	______	______	______	______	______	______
Oct.	______	______	______	______	______	______	______	______	______
Nov.	______	______	______	______	______	______	______	______	______
Dec.	______	______	______	______	______	______	______	______	______
TOTAL	______	______	______	______	______	______	______	______	______

FARM IDENTIFICATION ______________________________

SUPPLEMENTAL WORKSHEET 3. SCHEDULED DEBT PAYMENTS

MONTH	DEBT PAYMENTS - PRINCIPAL AND INTEREST*							TOTAL SCHEDULED DEBT PAYMENTS
	______	______	______	______	______	______	______	
Jan.	____	____	____	____	____	____	____	____
Feb.	____	____	____	____	____	____	____	____
Mar.	____	____	____	____	____	____	____	____
Apr.	____	____	____	____	____	____	____	____
May	____	____	____	____	____	____	____	____
Jun.	____	____	____	____	____	____	____	____
Jul.	____	____	____	____	____	____	____	____
Aug.	____	____	____	____	____	____	____	____
Sep.	____	____	____	____	____	____	____	____
Oct.	____	____	____	____	____	____	____	____
Nov.	____	____	____	____	____	____	____	____
Dec.	____	____	____	____	____	____	____	____
TOTAL	____	____	____	____	____	____	____	____

*Include all scheduled payments: Real estate loans, liens on livestock and equipment, payments to machinery dealers, etc. Be certain to include payments on loans that will be added during the year.

WORKSHEET 2A. ESTIMATION OF CASH FARM EXPENSES: LABOR AND FEED AND LIVESTOCK PURCHASE

MONTH	LABOR PERCENT CHANGE ______ THIS YEAR EL	NEXT YEAR EL	FEED PURCHASE PERCENT CHANGE ______ THIS YEAR EL	NEXT YEAR EL	LIVESTOCK PURCHASE* PERCENT CHANGE ______ THIS YEAR EL	NEXT YEAR EL
Jan.	______	______	______	______	______	______
Feb.	______	______	______	______	______	______
Mar.	______	______	______	______	______	______
Apr.	______	______	______	______	______	______
May	______	______	______	______	______	______
Jun.	______	______	______	______	______	______
Jul.	______	______	______	______	______	______
Aug.	______	______	______	______	______	______
Sep.	______	______	______	______	______	______
Oct.	______	______	______	______	______	______
Nov.	______	______	______	______	______	______
Dec.	______	______	______	______	______	______
TOTAL	______	______	______	______	______	______

*Livestock purchased for feeding - growing and later resale should be included here. Livestock purchased for draft or head expansion should be included as capital items in worksheet 4.

FARM IDENTIFICATION ______________________________

WORKSHEET 2B. ESTIMATION OF CASH FARM EXPENSES: MACHINERY

	CUSTOM WORK HIRED PERCENT CHANGE _____		REPAIRS PERCENT CHANGE _____		FUEL PERCENT CHANGE _____		TOTAL MACHINERY EXPENSE
MONTH	THIS YEAR LE	NEXT YEAR LE	THIS YEAR LE	NEXT YEAR LE	THIS YEAR LE	NEXT YEAR LE	NEXT YEAR LE
Jan.	_____	_____	_____	_____	_____	_____	_____
Feb.	_____	_____	_____	_____	_____	_____	_____
Mar.	_____	_____	_____	_____	_____	_____	_____
Apr.	_____	_____	_____	_____	_____	_____	_____
May	_____	_____	_____	_____	_____	_____	_____
Jun.	_____	_____	_____	_____	_____	_____	_____
Jul.	_____	_____	_____	_____	_____	_____	_____
Aug.	_____	_____	_____	_____	_____	_____	_____
Sep.	_____	_____	_____	_____	_____	_____	_____
Oct.	_____	_____	_____	_____	_____	_____	_____
Nov.	_____	_____	_____	_____	_____	_____	_____
Dec.	_____	_____	_____	_____	_____	_____	_____
TOTAL	_____	_____	_____	_____	_____	_____	_____

FARM IDENTIFICATION ______________________________

WORKSHEET 2C. ESTIMATION OF CASH FARM EXPENSES: CROPS

MONTH	LIME AND FERTILIZER PERCENT CHANGE ____ THIS YEAR LE	NEXT YEAR LE	SEEDS AND SPRAYS PERCENT CHANGE ____ THIS YEAR LE	NEXT YEAR LE	CROP EXPENSE NEXT YEAR LE	LAND RENT PERCENT CHANGE ____ THIS YEAR LE	NEXT YEAR LE
Jan.	____	____	____	____	____	____	____
Feb.	____	____	____	____	____	____	____
Mar.	____	____	____	____	____	____	____
Apr.	____	____	____	____	____	____	____
May	____	____	____	____	____	____	____
Jun.	____	____	____	____	____	____	____
Jul.	____	____	____	____	____	____	____
Aug.	____	____	____	____	____	____	____
Sep.	____	____	____	____	____	____	____
Oct.	____	____	____	____	____	____	____
Nov.	____	____	____	____	____	____	____
Dec.	____	____	____	____	____	____	____
TOTAL	____	____	____	____	____	____	____

FARM IDENTIFICATION ______________________________

WORKSHEET 2D. ESTIMATION OF CASH FARM EXPENSES: REAL ESTATE EXPENSES

MONTH	LAND AND BUILDING EXPENSE (REPAIRS, ETC.) PERCENT CHANGE _____ THIS YEAR LE	NEXT YEAR LE	PROPERTY TAXES PERCENT CHANGE _____ THIS YEAR LE	NEXT YEAR LE
Jan.	______	______	______	______
Feb.	______	______	______	______
Mar.	______	______	______	______
Apr.	______	______	______	______
May	______	______	______	______
Jun.	______	______	______	______
Jul.	______	______	______	______
Aug.	______	______	______	______
Sep.	______	______	______	______
Oct.	______	______	______	______
Nov.	______	______	______	______
Dec.	______	______	______	______
TOTAL	______	______	______	______

FARM IDENTIFICATION ______________________________

WORKSHEET 2E. ESTIMATION OF CASH FARM EXPENSES; UTILITIES, MARKETING, MISC.

MONTH	UTILITIES PERCENT CHANGE ____		MARKETING (TRANSPORTANTION, ETC.) PERCENT CHANGE ____		MISCELLANEOUS PERCENT CHANGE ____	
	THIS YEAR LE	NEXT YEAR LE	THIS YEAR LE	NEXT YEAR LE	THIS YEAR LE	NEXT YEAR LE
Jan.	____	____	____	____	____	____
Feb.	____	____	____	____	____	____
Mar.	____	____	____	____	____	____
Apr.	____	____	____	____	____	____
May	____	____	____	____	____	____
Jun.	____	____	____	____	____	____
Jul.	____	____	____	____	____	____
Aug.	____	____	____	____	____	____
Sep.	____	____	____	____	____	____
Oct.	____	____	____	____	____	____
Nov.	____	____	____	____	____	____
Dec.	____	____	____	____	____	____
TOTAL	____	____	____	____	____	____

FARM IDENTIFICATION ______________________________

WORKSHEET 3. SUMMARY OF CASH FARM EXPENSES

MONTH	LABOR (2A)	FEED (2A)	LIVESTOCK (2A)	MACHINE (2B)	CROP (2C)	RENT (2C)	LAND BUILDING (2D)	TAXES (2D)	UTILITIES (2E)	MARKETING (2E)	MISC. (2E)	TOTAL
Jan.												
Feb.												
Mar.												
Apr.												
May												
Jun.												
Jul.												
Aug.												
Sep.												
Oct.												
Nov.												
Dec.												
OTAL												

FARM IDENTIFICATION ____________________

WORKSHEET 4. CAPITAL PURCHASES PLANNED

MONTH	LAND & BUILDING ITEM	LAND & BUILDING COST**	MACHINERY ITEM	MACHINERY COST***	DRAFT AND PRODUCING LIVESTOCK* ITEM	DRAFT AND PRODUCING LIVESTOCK* COST	TOTAL CAPITAL PURCHASES
Jan.							
Feb.							
Mar.							
Apr.							
May							
Jun.							
Jul.							
Aug.							
Sep.							
Oct.							
Nov.							
Dec.							
TOTAL							

*Capital purchases of livestock include all livestock purchases for planned expansion. Replacement purchases are livestock expenses and should be entered in Worksheet 2A.

**Cost is monthly payment on loans.

***Cost is cost after trade-in is deducted.

FARM IDENTIFICATION ______________________________

WORKSHEET 5. CASH INFLOW AND OUTFLOW FOR NEXT YEAR: INCLUDING NONFARM; EXCLUDING CREDIT

MONTH	1 CASH FARM RECEIPTS (FROM WORK-SHEET 1A)	2 NET NON-FARM CASH INCOME*	3 TOTAL CASH INFLOW (EX. BORROWING)	4 CASH FARM EXPENSES (FROM WORK-SHEET 3)	5 CAPITAL PURCHASES (FROM WORK-SHEET 4)	6 FAMILY LIVING EXPENSE**	7 TOTAL OUTFLOW (EX. PRIN-CIPAL PAY-MENTS)	8 CASH INFLOW (COL. 3) MINUS CASH OUTFLOW (Col. 7)
Jan.								
Feb.								
Mar.								
Apr.								
May								
Jun.								
Jul.								
Aug.								
Sep.								
Oct.								
Nov.								
Dec.								
TOTAL								

*All non-farm receipts minus non-farm business expenses. Family living expenses are included in column 6.

**Supplemental worksheet 2 is provided to assist in calculating family living expenses.

Table 1. Basic Input-Output Data and Related Costs and Returns for the Production of Berseem with Alternative Members of Irrigation1/

Physical Input-Output Data				Economic Data											
				Total Costs			Average Costs			Marginal Costs		Returns			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Units of Water Applied (input)	Kerat Cuts of Berseem (total product)	Marginal Product of Fertilizer per Unit	Average Product of Fertilizer per Unit Col 2 ÷ Col 1	Fertilizer Cost (Variable Cost) Col 1 x LE 4	All Other Costs (Fixed Costs)2/	Total Cost Col 5 + Col 6	Average Variable Cost Col 5 ÷ Col 2	Average Fixed Cost Col 6 ÷ Col 2	Average Total Cost Col 8 + Col 9	Cost per Unit of Additional Input (MFC) Col 5 ÷ Col 1 3/	Cost per Unit of Additional Output (MC) Col 11 ÷ Col 3	Total Return (TR) Col 2 x LE2	Net Returns (Profit) Col 13 - Col 17	Marginal Return per Unit of Input (MVP) Col 3 X LE 2	Marginal Return per Unit of Output (MR) Col 15 ÷ Col 13
Irrigations		Kerat Cuts		Egyptian Pounds											
0	0	0	0	0	20	20	0	-	-	4/	-	-	-20	-	-
1	5	5	5.00	4	20	24	.80	4.00	4.80	4	.80	10	-14	10	2
2	16	11	8.00	8	20	28	.50	1.25	1.75	4	.36	32	-4	22	2
3	26	10	8.70	12	20	32	.46	.77	1.23	4	.40	52	20	20	2
4	35	9	8.75	16	20	36	.46	.57	1.03	4	.44	70	34	18	2
5	42	7	8.40	20	20	40	.48	.48	.96	4	.57	84	44	14	2
6	47	5	7.80	24	20	44	.51	.43	.94	4	.80	94	50	10	2
7	51	4	7.30	28	20	48	.55	.39	.94	4	1.00	102	54	8	2
8	54	3	6.75	32	20	52	.59	.37	.96	4	1.33	108	56	6	2
9	56	2	6.20	38	20	56	.68	.36	1.04	4	2.00	112	56	4	2
10	55	1	5.50	40	20	60	.73	.36	1.09	4	4.00	110	40	2	2

1/ The data do not represent actual output, costs and returns for berseem production. Egyptian terminology has been used to facilitate the learning process.

2/ Fixed costs per feddan are assumed to be LE 20.

3/ Difference between successive total products divided by differences between successive total input units.

4/ E ch unit of variable input costs LE 4.

Matrix 1

Title: Egypt Farms

Variable Number	Objective Function	Lower Bounds	Upper Bounds	Variable Name	Constraint 1 (Winter land)	Constraint 2 (Summer land)	Constraint 3 (Winter labor)	Constraint 4 (Summer labor)	Constraint 5 (Capital)	Constraint 6 (Water)	Constraint 7	Constraint 8	Constraint 9	Constraint 10	Constraint 11	Constraint 12
1	72	1	5	Wheat	1	0	30	0	35.2	5						
2	113	0	5	Flax	1	0	39.5	0	32.3	6						
3	103	0	5	Berseem	1	0	18	0	43.2	11						
4	55	0	5	Beans	1	0	28	0	26.7	4						
5	135	1	5	Cotton	0	1	0	70.5	45.3	7						
6	84	.5	5	Rice	0	1	0	48	30.1	34						
7	263	0	5	Eggplant	0	1	0	234	265	36						
8	304	0	5	Tomato	0	1	0	248	296	22						
9	49	0	5	Maize	0	1	0	32	55.3	9						
Constraint Type (<=, =, >=)					<=	<=	<=	<=	<=	<=						
Constraint Values					5	5	600	600	1200	120						

Title: Egypt Farms

Matrix 2

Variable Number	Objective Function	Lower Bounds	Upper Bounds	Variable Name	Constraint 1	Constraint 2	Constraint 3	Constraint 4	Constraint 5	Constraint 6	Constraint 7	Constraint 8	Constraint 9	Constraint 10	Constraint 11	Constraint 12
1	72	1	9	Wheat	1	0	30	0	35.2	5	0	0				
2	113	0	3.5	Flax	1	0	39.5	0	32.3	6	0	0				
3	103	1	4	Berseem	1	0	18	0	43.2	11	0	0				
4	55	0	9	Beans	1	0	28	0	26.7	4	0	0				
5	135	1.5	9	Cotton	0	1	0	70.5	45.3	7	0	0				
6	84	1	9	Rice	0	1	0	48	30.1	34	0	0				
7	263	0	2	Eggplant	0	1	0	234	265	36	0	0				
8	304	.2	2	Tomato	0	1	0	248	296	22	0	0				
9	49	0	9	Maize	0	1	0	32	55.3	9	0	0				
10	-1.0	0	200	Hire WL	0	0	-1	0	1	0	0	0				
11	-1.0	0	250	Hire SL	0	0	0	-1	1	0	0	0				
12	-30	0	100	Rt wld	-1	0	0	0	30	-12	1	0				
13	29.5	0	5	Rt wldo	1	0	0	0	-29.5	12	0	0				
14	-30	0	100	Rt sld	0	-1	0	0	30	-12	0	1				
15	29.5	0	5	Rt sldo	0	1	0	0	-29.5	12	0	0				
Constraint Type (<=, =, >=)					<=	<=	<=	<=	<=	<=	<=	<=				
Constraint Values					5	5	300	300	950	120	4	4				