DIAGNOSTIC ANALYSIS OF IRRIGATION SYSTEMS

VOLUME 1: CONCEPTS & METHODOLOGY

M. K. Lowdermilk, W. Clyma, L. E. Dunn, M. T. Haider,
W. R. Laitos, L. J. Nelson, D. K. Sunada,
C. A. Podmore, and T. H. Podmore

C. A. Podmore, Editor

Prepared in cooperation with the Consortium for International Development and the United States Agency for International Development, Contract AID/DSAN-C-0058. All reported opinions, conclusions or recommendations are those of the author (contractor) and not those of the United States government. Mention of commercial products in this publication is solely to provide information. It does not constitute endorsement by CID or USAID over other products not mentioned.

WATER MANAGEMENT SYNTHESIS PROJECT

University Services Center
Colorado State University
Fort Collins, Colorado

December 1983

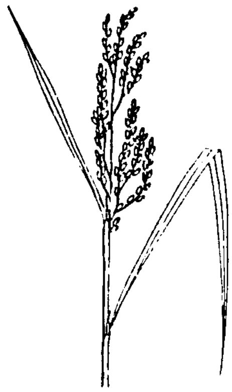
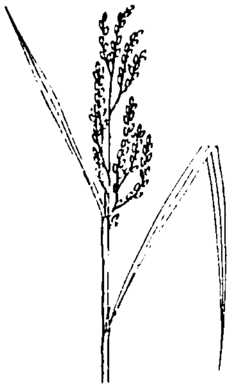


TABLE OF CONTENTS

		Page
List of Figures		v
List of Tables		vii
Acknowledgements		ix
Preface		xi
Chapter		
1	The Development Model	3
2	Diagnostic Analysis	15
3	The System:	37
	Physical	55
	Cropping	73
	Economic	83
	Social-Organizational	105
4	The System's Manager	123
5	Summation	135
6	Bibliography	147
Appendix		
A	Team Building	159
B	Conducting A Team Meeting	173
C	Team Building Exercises	177



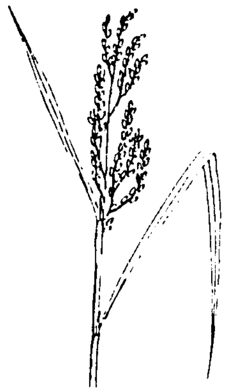
LIST OF FIGURES

Figure		Page
1	The Development Model	4
2	The Monodisciplinary Approach	6
3	The Multidisciplinary Approach	7
4	The Intradisciplinary Approach	8
5	The Interdisciplinary Approach	9
6	The Six Steps of Diagnostic Analysis	18
7	Seven Steps to An Effective Reconnaissance	21
8	Interdependency of Investigator and Farmer	25
9	Analysis and Synthesis: New Insights	26
10	Flow Chart of Detailed Studies	29
11	Distribution Scheme Within An Irrigation System	39
12	Physical Component of An Irrigation System	43
13	Cropping Component of An Irrigation System	45
14	Economic Component of An Irrigation System	47
15	Social-Organizational Component of An Irrigation System	49
16	The Operating Irrigation System	51
17	The Physical System of Irrigation	56
18	The Water Use Subsystem	57
19	The Water Application Subsystem	60
20	The Water Removal Subsystem	68

Figure		Page
21	Classification of Irrigated Cropping System	74
22	The Soil Profile	79
23	Inputs and Constraints Affecting Resource Allocation	87
24	Physical Versus Economic Optimization	90
25	Return, Cost, and the Level of Water Utilization	99
26	Social Organization of Irrigation	109
27	Possible Hypotheses for Social Organization of Irrigation	116
28	The Pivotal Role of the Farmer	124
29	A Fictional Farmer Called Adan	124
30	Constraints to Productivity of Adan's Fields	130

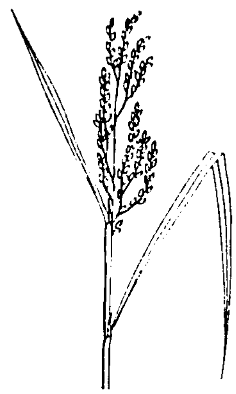
Appendix

1.1	Management Styles and Information Distribution	160
1.2	The Developmental Cycle of Team Cohesion	165



LIST OF TABLES

Table		Page
1	Interdisciplinary Sharing of Data	31
2	Component-Systems: Their Function and Elements	54
3	Example of Equal Marginal Returns Principle	98
4	Example of Evaluating Fixed Investments	103



ACKNOWLEDGEMENTS

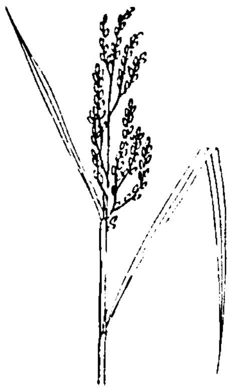
You are about to read many words about an investigative method known as Diagnostic Analysis; again and again, one particular word will appear--team. The ideas, techniques, and information contained in this two volume manual are the products of teamwork spanning more than ten years of labor and professional experience. The members of the team are constantly changing but not their individual commitments to refining an interdisciplinary means of understanding the complexity of an irrigation system. The personnel, including farmers from many countries, who have contributed to the development of this material are indeed too numerous to mention, yet need to be recognized if only collectively.

One person, however, who has had a marked influence throughout the entire period is Dr. M.K. Lowdermilk, now a senior advisor in India for the United States Agency for International Development. He, and Dr. W. Clyma, the Project Co-Director of the Water Management Synthesis I Project, have been responsible for much of the conceptual framework of Diagnostic Analysis. It was their report, along with Gilbert L. Corey, *A Research-Development Process for Improvement of On-Farm Water Management*, which also first reported on the new approach to water management and systems investigation. That publication in 1977 marked the beginning of a series of manuals intended to instruct readers in the concepts, principles, and procedures of Diagnostic Analysis, or problem identification as it was then called. These manuals include one based on work done in Pakistan, Water Management Technical Reports No. 65A-D; the *Problem Identification Training Manual for On-Farm Irrigation Systems* which was compiled for the Egypt Water Use and Management Project; and, the draft version of the present manual called the *Monitoring and Evaluation Manual*. All of these publications, and the teams who contributed to them, serve as the basis for this present effort.

Just as there are past members of a team whose influences are recognized still, there are presently members whose efforts help to communicate what the others have discovered. Joyce Patterson is the able illustrator who graphically translated many of the ideas into visual images. Mary Lindburg headed the physical production of this manuscript and completed it in her usual professional manner.

There also are the larger segments of a team--often overlooked because of their sheer size--who facilitate not only the development of ideas, but their communication. The Consortium for International Development has the contract and along with the Agency of International Development assist in this project.

Finally, there are future members of the team--those of you who will read this manual, learn from it, and, in turn, bring us new knowledge and insights into the dynamic area of irrigation systems and water management. Your ideas and suggestions are not only welcomed, but appreciated.



PREFACE

In a developing country located in South Asia, the first large-scale computer models of the irrigation system calculated that the farm conveyance losses were approximately 10 percent. Based on that estimation, farm conveyance efficiencies were determined to be approximately 90 percent, an exceptionally good performance. A number of years later, however, investigators, working at the farm level, discovered that conveyance efficiencies for the country's irrigation system actually were only between 40 to 50 percent. Many years of costly decision making had been based on that original computer based estimation which was never verified in the field. Diagnostic Analysis is an investigative method that examines an irrigation system as it actually operates, not as it is perceived to be operating.

This manual, with its two volumes, has two separate, yet related, purposes. First, the manual is intended to be used as the textbook for Diagnostic Analysis workshops in which participants are introduced to the investigative method in a step by step manner. Second, the manual is intended to be used by any professionals who are interested in the method, but may not attend a workshop.

Because a workshop participant will come to his or her understanding of Diagnostic Analysis in a more structured manner, it is appropriate to explain more fully the objectives of a workshop as well as what is expected of participants. Each Diagnostic Analysis workshop has three purposes. They are:

1. To teach the concepts, principles and procedures of Diagnostic Analysis so that participants acquire the necessary understanding and skills, both disciplinary and interdisciplinary, for using the method;

2. To involve participants in an actual Diagnostic Analysis, including its field studies of the operating irrigation system; and

3. To offer participants an opportunity to be part of an interdisciplinary team so that they learn the necessary principles and skills of such an approach.

Most participants in Diagnostic Analysis are professionals with a wide range of technical knowledge and experience. Because the workshops are conducted in their own countries, such professionals often possess extensive knowledge of the irrigation system under investigation. Individual expertise is a major contribution on the part of participants; however, it is often this very specialization which may detract from the investigative process if it is not correctly channeled.

ATTRIBUTES WHICH HAMPER DIAGNOSTIC ANALYSIS

In fact, there are six attributes which a participant may possess that will hamper Diagnostic Analysis. They are:

- An inability to perceive the irrigation system as a functioning, interrelated system demanding an interdisciplinary approach;

- An inability to understand the difference between how a system <u>should work</u> and how it <u>actually does work</u>, that is, design expectation verses reality;

- An inability, or incapacity, regardless of its cause, to appreciate the contribution and approach of other disciplines;

- An inability, or disinclination, to understand a problem before attempting to solve it;

- An inability to appreciate the importance of the farmer's role within the irrigation system including impact of his decision making; and

- An inability, or disinclination, to communicate with other members of the team, particularly during the planning stages of a Diagnostic Analysis.

All of the above are stated negatively for they will have a negative effect on any Diagnostic Analysis. Therefore, such attributes need to be recognized and dealt with so that they can be eliminated. Diagnostic Analysis above all is a learning process. As mentioned previously, participants also bring many positive attributes to a Diagnostic Analysis team; it is upon these attributes that a successful Diagnostic Analysis ultimately will be built.

A LEARNING PROCESS

As Diagnostic Analysis is a learning process, it is assumed that every participant automatically will be involved in all its activities. Any learning process also calls for periodic evaluation. During a Diagnostic Analysis workshop, participants will be evaluated in three different ways. First, leaders will evaluate each participant on how well he or she has learned the various skills taught through exercises and field tests. Second, each interdisciplinary team will be evaluated on specific team exercises. Finally, each participant and each team will be asked to evaluate themselves throughout the course. Such evaluations allow leaders to focus in on particular skills which may need reinforcing, and allow participants to identify their own progress, individually and collectively. Participants should feel free to approach the leaders if they need further explanation of any particular skill, help with specific exercises, or simply more insight into the principles and procedures of Diagnostic Analysis. Participants who do successfully complete a workshop are presented with a certificate acknowledging their efforts.

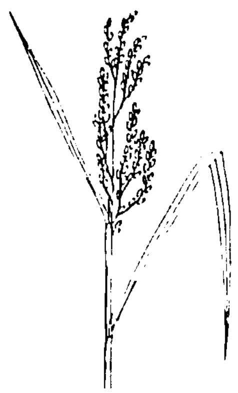
We have made an effort to explain the barriers to a Diagnostic Analysis as well as what is expected of workshop participants because participants often hesitate to ask about these areas. A brief survey of what this volume contains, and what a participant may learn from it, also is appropriate.

CONTENT OF VOLUME ONE

Diagnostic Analysis is the first phase of a three-phase development model. This model is explained in some detail in Chapter One so that participants can understand the relationship between Diagnostic Analysis and the larger development program. Chapter One also examines those characteristics that set this particular development model apart from others, including its systems perspective, an interdisciplinary approach, and the involvement of the farmer throughout all phases. Chapter Two concentrates on the Diagnostic Analysis method itself with its six activity phases: 1) Preliminary Objectives, 2) Reconnaissance, 3) Revised Objectives and Plans, 4) Detailed Studies, 5) Interdisciplinary Analysis and Synthesis, and 6) Report Writing.

The nature of the operating irrigation system with its component systems--the physical, cropping, economic, and social-organizational systems--is described in Chapter 3. The actual evaluation techniques used to examine these different component systems can be found in Volume Two of this manual. Throughout the entire Diagnostic Analysis process great emphasis is placed on understanding the management of the system. Chapter 4 explains the constraints under which the farmer makes his decisions as well as the impact of those decisions. Chapter 5 offers a summation, or synthesis, of the previous chapters so that the complexity of the irrigation system and its management can be more fully appreciated and addressed. Finally, Chapter 6 presents a limited bibliography including those references which were used in this volume and additional references for a further study. Appendices A to B offer important information and insight into the nature and functioning of a team. It has been placed as appendix material so that it could be grouped together in a logical, readily accessible manner. Participants of a Diagnostic Analysis workshop may wish to read this particular section of the manual before attending the workshop.

It is hoped that by using this manual and by attending a workshop, your investigative approach will be radically changed as you discover the dynamic complexity and interdependency found in an irrigation system. Having realized this complexity, and making full use of your own professional expertise, you then will be able to make such improvements to the operating irrigations systems in your country that agricultural productivity will increase and that the well-being of your citizens will continue to improve.



CHAPTER 1

THE DEVELOPMENT MODEL

Irrigated agriculture supports more than two-thirds of the food production for developing countries. The last 30 years featured a massive expansion of the world's irrigated area, at the cost of a correspondingly massive economic investment. As irrigation systems increased in number, however, the anticipated increase in irrigation effectiveness did not materialize. The performances of operating irrigation systems generally have averaged less than 50 percent efficiency. As a result, from the late 1960's onward, there has been a growing tendency to focus less on establishing new facilities and more on improving existing ones. Improving water management has become the guiding principle of this new age.

DEFINING WATER MANAGEMENT

Water management is explained traditionally as those practices needed to apply required amounts of water to the root zones of crops at the appropriate time. This definition often has resulted in an exclusively physical approach to water management, that is the delivery, application, use, and removal of water. In recent years, researchers have challenged the definition as being too narrow, if not fundamentally incorrect. Water management, they offer, is not physical structures or irrigation facilities, neither is it even laws, farmers, cropping systems, nor any other individual component of an irrigation system. Rather, water management is how these components are used to control irrigation water, including rainfall, for plant growth. In other words, water management is the process by which the irrigation system is manipulated and used for the production of food and fiber.

THE DEVELOPMENT MODEL

If the management of an irrigation system is a complex, dynamic process, then any investigative approach to it must incorporate similar qualities. The approach used in this manual is part of a three-phase development model. The model itself is a structured, conceptual strategy with a primary objective of improving irrigation systems. The model, however, is applicable to other situations as well.

The three phases of the development model (Figure 1) are:

DIAGNOSTIC ANALYSIS--an interdisciplinary method of examining both the values, i.e., benefits, and constraints, i.e., restrictions, of a system;

DEVELOPMENT AND ASSESSMENT OF SOLUTIONS--the selection and testing of potential improvements to the system in which constraints are removed, and effectiveness is improved; and,

PROGRAM IMPLEMENTATION--the organizational process of choosing and developing an improvement program based on selected solutions.

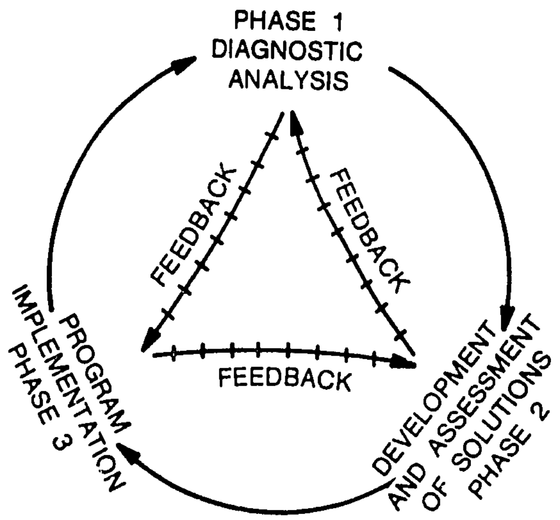


Figure 1. The Development Model

As Figure 1 illustrates, the phases of the development model are sequential and overlap: this allows for continuous feedback throughout the process. A cyclical model, the phases also flow one into another, and the entire process can be repeated continuously. As a result, any improvements to a system can be progressively monitored and refined. Although the primary focus of this manual is on the Diagnostic Analysis phase, it is important to understand that Diagnostic Analysis is only the first step in a strategy for the improvement of irrigation systems.

Just as there are three phases to the development model, there are also three primary characteristics which set it apart from other models. First, it involves a systems perspective which recognizes the complexity inherent in irrigation schemes; second, it uses an interdisciplinary approach; and third, it acknowledges the need for the farmer's involvement within the process.

These characteristics allow an investigator to methodically examine the irrigation system, identifying both its strengths and weaknesses, and suggesting solutions to remove constraints which if followed, will improve the system. The effective use of the development model, therefore, largely depends on how successfully the three characteristics are incorporated into it.

A Systems Perspective

An irrigation system, at whatever level you observe it, is composed of interrelated mutually dependent components (or parts). These components could be grouped under any number of classifications. In this manual, we have classified the components of an irrigation system under the physical, cropping, economic, and social-organizational systems. You need to note that the components of an irrigation system are, at the same time, systems within themselves. In other words, they individually are made up of different parts that are dependent upon each other. None of these component systems--physical, cropping, economic, or social-organizational--are to be studied separately from one another, however, for they also are mutually dependent. It is only together that they accurately represent the operating irrigation system in its entirety.

Historically, researchers have been inclined to look solely at the physical component to correct irrigation problems because it is here that technology is most readily applicable. Yet, limiting ourselves to such narrow solutions in the past, as we briefly noted, has not achieved desired results. The development model acknowledges this by recognizing the broader systems perspective.

An Interdisciplinary Approach

A system, therefore, demands that you perceive the whole as composed of diverse yet related components. No one person, or discipline for that matter, possesses the needed knowledge or experience that a systems perspective requires. It is a perception, because of its comprehensive nature, that is obtainable only by individuals working together as a team--an interdisciplinary team. This fact is seen more clearly if you look at alternative methods of investigation (or research).

Three methods of investigation generally recognized are: the monodisciplinary, the multidisciplinary, and the intradisciplinary methods. A monodisciplinary approach is simply one discipline examining a specific component of the irrigation system. This discipline commonly has been engineering so Figure 2 uses that discipline to indicate a monodisciplinary approach. Of course, the results and any written report will reflect this singular perspective.

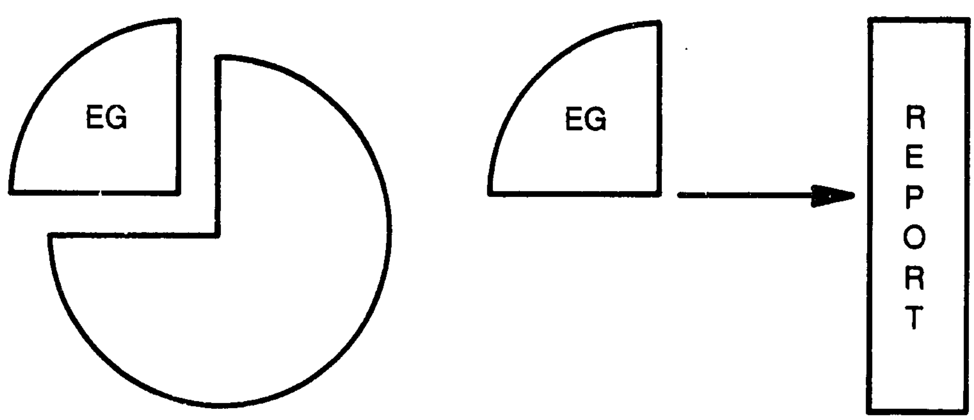


Figure 2. The Monodisciplinary Approach

The second approach, the multidisciplinary one, calls for members of different disciplines to separately examine the system and report accordingly. Figure 3 graphically shows this using the disciplines of engineering, agronomy, economics, and sociology as examples. The difficulty with the multidisciplinary approach is that you run the risk of having four different solutions to the same problem or of defining four different problems!

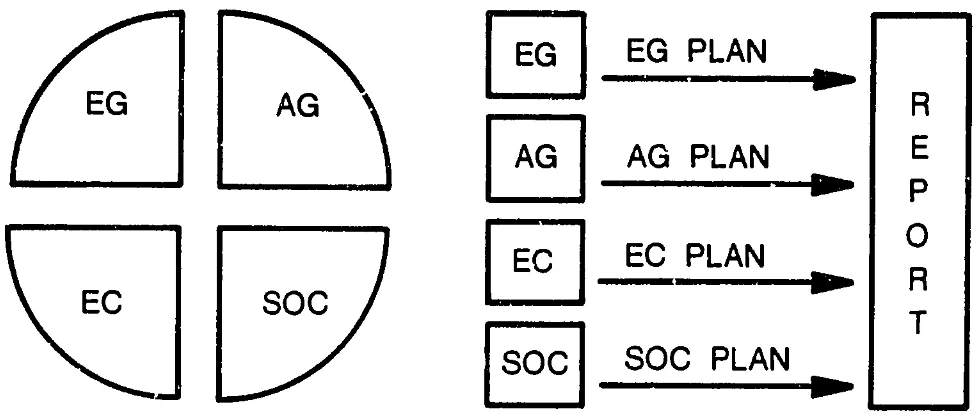


Figure 3. The Multidisciplinary Approach

The intradisciplinary approach (Figure 4) uses all of the previously mentioned disciplines, but places one individual at their center who is theoretically capable of integrating the four different disciplinary views. He or she then would make a comprehensive report based on the four separate investigations.

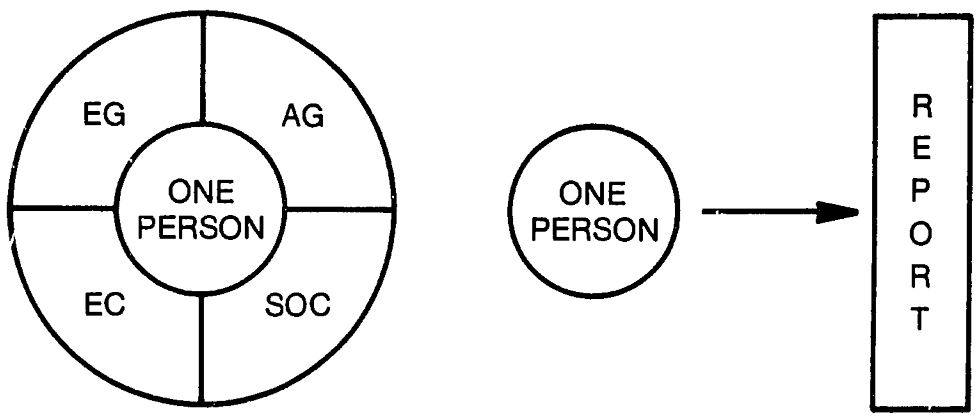


Figure 4. The Intradisciplinary Approach

6

Keeping these three methods in mind, compare them to the interdisciplinary approach as illustrated in Figure 5. Once more you will note that there are the four disciplines, but their functions are not divided, rather they merge and overlap. The final report is a team product reflecting not four separate opinions, but rather the collective knowledge of the team. It is only this approach which allows the expertise of each discipline to be analyzed and then synthesized (or combined) to present a comprehensive understanding of an irrigation system. It is this approach that is used in Diagnostic Analysis, which we will examine later in greater detail.

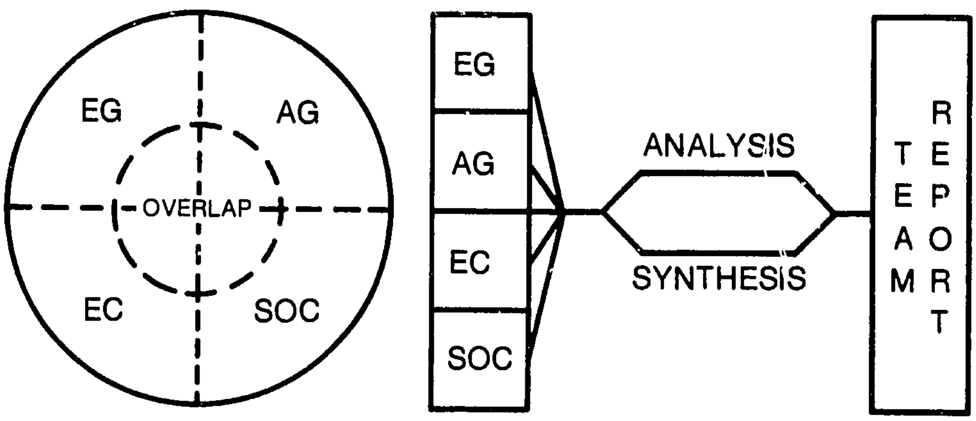


Figure 5. The Interdisciplinary Approach

This is an appropriate point at which to address the nature of an interdisciplinary team. To select a team is one task, to have it work efficiently and effectively together is yet another. The interdisciplinary approach is not without its inherent problems. These problems can be kept in proper perspective, however, if there is commitment, communication, and cooperation on the part of team members (See Appendices A to C). The team must be committed collectively to its task; members must be willing to work at communication; and, above all, they must cooperate with each other.

These attributes will be present in a team if each individual member has a solid knowledge of his or her respective field, maintains a willingness to learn as well as teach, and possesses a strong sense of respect for fellow team members. At times, conflict will arise; it naturally will within any active team. The ability to expand your perspective and examine your own disciplinary bias, however, will assist in the constructive management of any and all conflict.

Needless to say, all of the above will take place only when there has been adequate and extensive planning, and when the roles and responsibilities of each team member has been clearly defined and identified. Team meetings should be frequent, filled with discussion, feedback, and resolution.

When considering the interdisciplinary approach and team selection, one final point needs to be made. Throughout this manual and its illustrations, we have used the disciplines of engineering, agronomy, economics, and sociology simply as examples. It should be noted that an interdisciplinary team can be, and should be, composed of any combination of disciplines. The nature of the investigation will determine the type of expertise you will need to include on a particular interdisciplinary team.

The Farmer's Involvement

The third, and final, characteristic which sets the development model apart from other models is the involvement of the farmer throughout all the phases. The farmer is the primary manager of the irrigation system at the farm level. If any interdisciplinary team wishes to understand the system as it is operating, rather than simply theoretically, it must have an on-going, vital relationship with the farmer.

In the past, when a particular system was less than efficient, government officials and researchers often accused the farmer of poor management practices and even destructive behavior. What researchers have been slow to recognize, however, is that it was just those practices which made the system work! For example, in one situation, farmers who were known for breaking water control structures were found to do so only as a last resort; their water supply had been erratic and unreliable. The farmers had a choice then between tolerating reduced crop yield or breaking a control gate to get needed water. They naturally decided that the water had the highest priority. In other words, farmers have rational reasons, from their perspective, for their actions and decisions.

Including the farmer in all phases of the development model assures that a primary and vital source of information is recognized and respected. When a team understands the constraints under which a farmer labors, his rationale, knowledge, and preceptions, then it begins to understand not only how the irrigation system actually functions, but why.

POINTS TO REMEMBER

Water management is a dynamic process in which the irrigation system is manipulated and used for the production of food and fiber. To understand water management, a mode of investigation is needed that recognizes its complexity while, at the same time, offering a structured approach of analysis. The three-phase development model is composed of Diagnostic Analysis, development and assessment of solutions, and program implementation. A cyclical model, it calls for a systems perspective, an interdisciplinary team approach, and the involvement of farmers throughout its process. This manual will concentrate on the first phase of the development model, Diagnostic Analysis.

9

Chapter 2

DIAGNOSTIC ANALYSIS

Diagnostic Analysis shares and incorporates all the characteristics of the development model of which it is a part--much like brothers and sisters share certain family characteristics. The characteristics that Diagnostic Analysis incorporates are a systems perspective, an interdisciplinary approach, and the involvement of the farmer. Diagnostic Analysis, therefore, can be defined as an interdisciplinary method which involves farmers in the examination of an operating irrigation system with its interrelated components.

Like all human efforts, Diagnostic Analysis has particular goals, or objectives. A humanitarian goal is the recognizable increase of crop productivity and the improved well-being of the farmer and his family. To achieve this ultimate goal, however, more immediate objectives are required. The basic objectives of Diagnostic Analysis, therefore, are: 1) to understand the operating irrigation system so as to recognize both its values (the good features or benefits) and its constraints (the problems or factors which restrict efficient operation); and, 2) to order constraints according to a priority based on predetermined criteria. The fulfillment of these objectives results in a knowledge of the system's problems including their magnitude and causes. Solutions then can be developed to improve the system based on this knowledge.

SO WHAT'S THE PROBLEM?

Researchers have been slow to recognize the need to define the problem before implementing the solution. Instead, they have focused their attention more on correcting the symptoms of a problem than on its probable causes--much like putting a technically perfect splint on a still untreated broken arm! One researcher voiced this need for first identifying the problem as follows:

> *Difficulty in isolating the problem is often due to the tendency to spend a minimum of effort on problem identification in order to get on to the important matter of solving it. Inadequately defining the problem is a tendency that is downright foolish on an important and extensive problem-solving task. A relatively small time spent in carefully isolating and defining the problem can be extremely valuable both in illuminating possible simple solutions and in ensuring that a great deal of effort is not spent only to find that the difficulty still exists--perhaps in greater magnitude.**

For example, you might notice that a particular section of a distribution system is experiencing excessive watercourse losses. If you are an engineer, you might correct the symptom of water losses by lining all the channels with concrete--an expensive, but visually pleasing type of technology. Imagine, however, that an underlaying, and as yet undiscovered, cause of these excessive losses is poor and haphazard channel maintenance. Poor channel maintenance, in turn, might be only another symptom and not the primary problem. Upon investigation, your team might find that the farmers in the area are really a hard working group of fellows; however, there is no organizational structure, either locally or at the governmental level, that supports them in their sincere, if ineffective, maintenance procedures. Therefore, although lined channels may last longer than unlined ones, eventually, given enough time, the actual constraint to the system, i.e., poor maintenance due to an organizational vacuum, again will surface--even as the broken arm remains misaligned inside its splint!

---

* Adams, J.L. 1974. Conceptional blockbusting: a guide to better ideas. W.H. Freeman and Co., San Francisco, CA.

The more logical and effective approach then is to first discover what exactly is "broken" or limiting the efficient functioning of the system, and only then to address possible solutions. Even as a doctor diagnoses a sick patient by asking the patient questions and observing him, there is also a need for a similar diagnostic method of examining an irrigation system.

DIAGNOSTIC ANALYSIS: THE METHOD

Diagnostic Analysis is an orderly method of examining a system and identifying its values and its constraints. Figure 6 shows a flow chart of the primary activities of a Diagnostic Analysis. In order, they include: 1) Preliminary Objectives, 2) Reconnaissance, 3) Revised Objectives, 4) Detailed Studies, 5) Interdisciplinary Analysis and Synthesis, and 6) Report Writing. These steps, though presented as separate in the flow chart, often overlap or occur simultaneously. You will understand the process more fully, however, if you look at it in a step-by-step manner. Yet, only after you apply this information in the field will your understanding be complete.

PRELIMINARY OBJECTIVES

The establishment of objectives is an activity that is repeated throughout the Diagnostic Analysis process. We have discussed the objectives which govern all Diagnostic Analyses. Those objectives include:

- The understanding of the irrigation system as it actually operates, recognizing its strengths as well as its constraints;

- The identification of the major physical, biological, economical, and organizational constraints to an irrigation system which limits agricultural production; and

- The listing of these constraints in an order of priority based on stated criteria so as to assist the development and assessment of possible solutions.

DIAGNOSTIC ANALYSIS

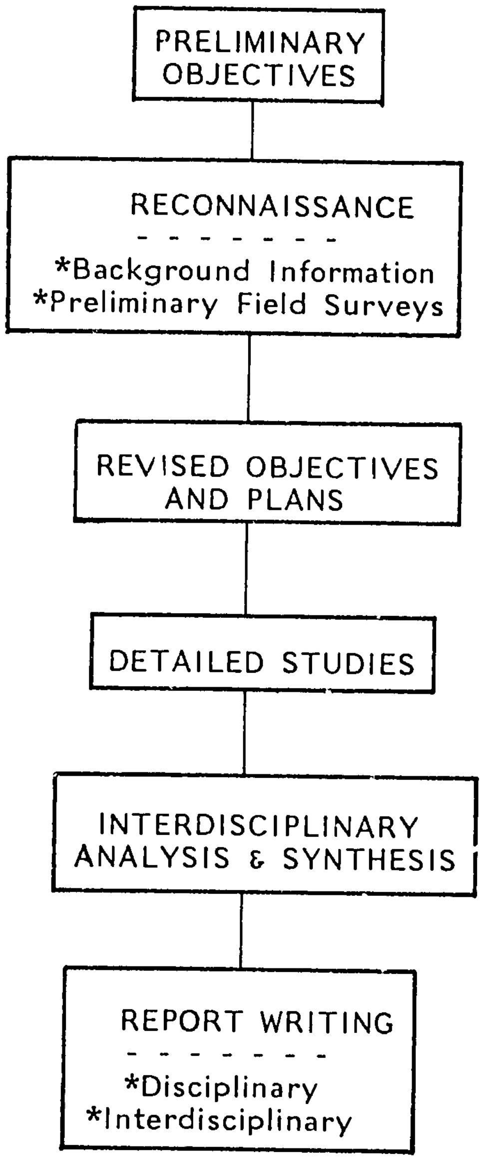


Figure 6. The Six Steps of Diagnostic Analysis

The team is responsible for establishing the criteria upon which priority will be assigned to constraints or problems. The criteria must weigh the magnitude of the problem against the ability of any solution to immediately affect the system. Those problems that might take years before any solution would affect or remove them are not appropriate for a Diagnostic Analysis.

The specific objectives of individual Diagnostic Analysis also will be dictated by a number of variables. It is the task of the interdisciplinary team again to establish these more specific objectives--an activity which often overlaps with the second step of Diagnostic Analysis, i.e., reconnaissance.

RECONNAISSANCE

The geologist scans the profiles of the earth; the engineer with a practiced eye examines the contour of the land; the soldier, alone and weary, crawls under a fence seeking out information about the darkened territory ahead. Knowingly or not, all are participants in a reconnaissance.

"Reconnaissance" is an active, pragmatic word: it is a scanning, an examination, a seeking out of information. It demands action: a reconnaissance is never conducted from an armchair!

It is, therefore, a most appropriate term to delineate the second activity phase of a Diagnostic Analysis. Reconnaissance is the initial examination or survey of an irrigation system. As investigators, you will use the reconnaissance method to quickly examine the entire system as it operates--looking for both its positive and negative aspects. Your examination is not specific at this stage; rather, it is a sweeping <u>overview</u> of all dimensions of the irrigation system whether they be in the engineering, sociological, economic and agronomic spheres. From the beginning, it is an interdisciplinary team effort.

Reconnaissance, when successfully executed, allows the team to identify some potential key constraints which will be more closely examined during the detailed studies phase. Based on the reconnaissance, the team may refine their original, general objectives: problems may be redefined, questionnaires redrafted, and priorities reordered. Ultimately, reconnaissance permits the subsequent detailed studies phase to be planned according to the realities of the system rather than

14

supposition or guesswork, a common but ineffective means of investigation.

Note, however, that the aim of a reconnaissance is not the accumulation of unmanageable amounts of data, but rather the systematic selection of data--however preliminary--that establishes perimeters, or limits, to the team's task. In doing so, those constraints that most limit the viability and effectiveness of an irrigation system will emerge.

The actual field-level reconnaissance can be as short as one day, or last for a week. It is not the time frame, but the careful planning which determines the effectiveness of reconnaissance. The flow chart presented in Figure 7 illustrates the seven steps in an effective reconnaissance.

Objectives of Reconnaissance

It is a foolish person who starts on an important journey without any idea where he is going. Objectives, as we have noted before, are simply ends toward which efforts are directed. Objectives must be understood by the entire team--lest someone wanders off in his own individual direction. Objectives also must be specific so as to focus and limit the preliminary investigation.

Using our earlier example, it could be said that the objective of the reconnaissance method within Diagnostic Analysis is to improve water management. Such an objective, while not incorrect, is too general and offers little direction for a team. We can list, however, the more specific objectives:

- To understand the irrigation system as it presently operates;

- To observe both its values and constraints;

- To order the observable constraints according to priorities based on a predetermined criteria; and

- To use the conclusions for planning detailed studies including documentation of the magnitude and causes of constraints:

15

RECONNAISSANCE STUDY

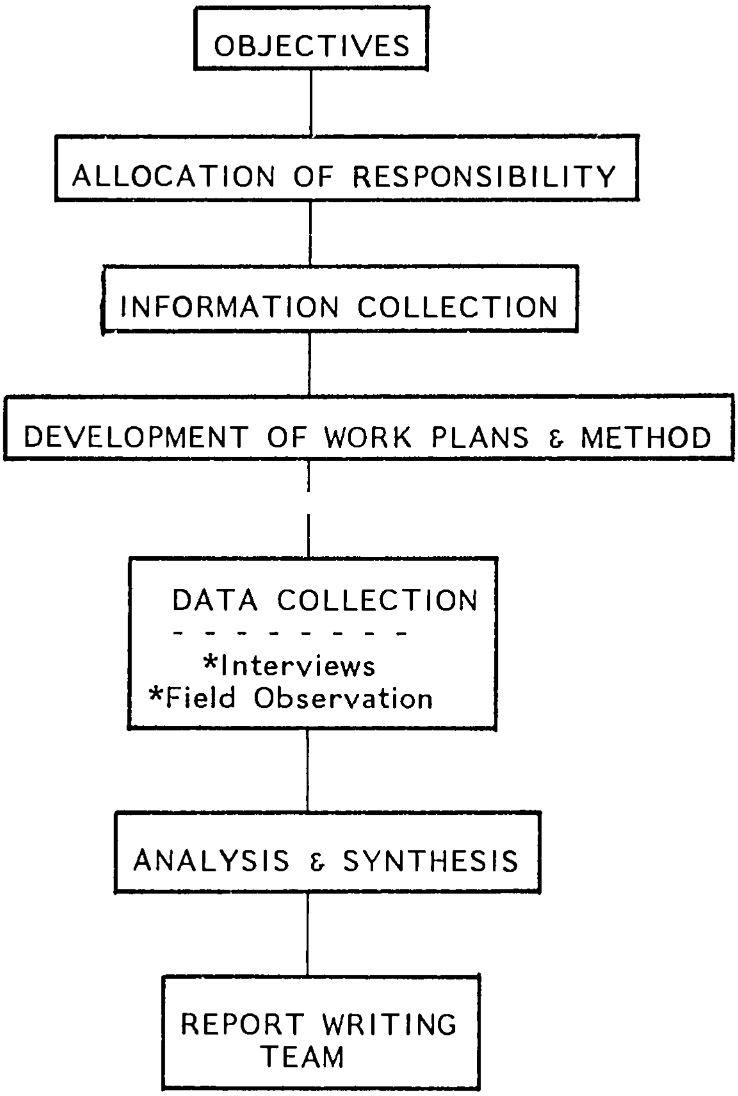


Figure 7. Seven Steps to an Effective Reconnaissance

These four objectives offer a fuller explanation of the purpose of a reconnaissance.

Objectives for a particular investigation can be, and often are, provided by an agency or government. Such objectives usually state the general purpose of a study rather than its specific aims. The team, therefore, still must take the proposed purpose of an investigation and outline its specific objectives.

Allocation of Responsibility

If the objectives of a reconnaissance must be defined to be effective, the same is true of the allocation, or division, of responsibility among team members. A team, by definition, requires a collective and cohesive effort to accomplish its mutual task. It is a primary role of the team leader(s) to assign individuals to specific areas of responsibility and to monitor their subsequent progress.

During the reconnaissance phase, however, responsibilities are shared informally among team members. The understood goal, at this point, is to go out into the system--to whatever boundary level which is appropriate--in order to observe its operation and to interact with farmers and local officials. The leader might ask the engineer to concentrate on the conveyance system or the sociologist to collect preliminary information on available institutional services, but both the engineer and the sociologist (and all the other team members for that matter) function collectively. This collaboration allows for an interdisciplinary approach from the very beginning of the investigation.

Information Collection

The team is now at a point where all pertinent background information must be reviewed if it has not been already. The required information includes available monographs, research studies, project reports, and pertinent written materials about the area under investigation. This information should be condensed and combined, if possible, into a readily accessible form that is available to all team members. It is important to remember that while at times information may be collected along disciplinary lines, the entire thrust of a Diagnostic Analysis is interdisciplinary. Mutual education, therefore, is a continual by-product of its procedures.

During a Diagnostic Analysis workshop this phase of the reconnaissance also would include guest lecturers who through their addresses and papers offer expert information about the system under investigation. Prior to a workshop, interviews also would have been conducted with officials, relevant personnel, and selected farmers.

Development of Work Plans and Methods

The team all along has been functioning within a work plan. There are understood objectives; the leader has assigned general tasks; and, members have reviewed necessary resources and information. Flexibility is a primary characteristic of a functional work plan; therefore, team leaders and members will review and change plans as needed. This revision is particularly appropriate with the completion of the information collection step.

It is also an appropriate time to review and/or finalize data collection methods. Lengthy research methods are not suitable for the limited time allowed in a reconnaissance. Simpler methods of diagnosis are needed along with intelligent observation and team collaboration. The trained agronomist easily spots the visual signs of nitrogen deficiency; the engineer needs only walk a distribution channel to know much about its conditions; and the sociologist or economist can determine general socio-economic conditions by simply viewing the size and quality of houses and roads. Collaboration among team members--that is, the sharing of data collection and observations--allows the focus of the reconnaissance to be constantly revised so as to gain a better understanding of specific aspects of the system. Such collaboration is fundamental to any systematic, interdisciplinary undertaking.

Data Collection

With the completion of preparation phase, the field reconnaissance is undertaken. Although data collection sounds like quite a formal procedure, during reconnaissance it is the simple gathering of certain facts based on informal conversation with project personnel and farmers, and through visual observations. It is from these facts that tentative conclusions and perimeters will be drawn concerning the system. Informal, however, does not mean unsystematic. A sociologist can lean against the side of the community's well, chatting with villagers in a casual manner while learning much about the local water users group; or he can conduct a structured interview, based on previously designed questionnaires and acquire the same information.

With both approaches, the sociologist is acquiring information in a systematic manner--one situation is simply more formal than the other.

As mentioned above, reconnaissance uses a two-fold approach to data collection: field observation and interviewing. Neither technique is used solely by any one discipline. If an engineer walks a watercourse and learns much about the physical problems of the system, he also gains understanding by observing and questioning the farmers. Likewise, if a social scientist interviews a variety of persons to understand the social-organizational component of the system, he or she also learns much from simply walking, looking, and listening. In other words, intelligent observation is a basic tool of reconnaissance.

In addition to observation and informal discussions with farmers and villagers, initial agronomic sampling may take place at this time as well as other preliminary measurements of the soil and cropping system. A pretesting of the questionnaires to be used later during the detailed studies also may be conducted by the economists and sociologists.

Reconnaissance is field oriented; you cannot avoid going out into the system. At the end of the reconnaissance, however, the team will have acquired--along with soiled hands and clothes--sufficient preliminary information upon which to develop a hypothesis, or tentative assumption, about the primary values and constraints of the system. These values and constraints will be documented later in the detailed studies phase of Diagnostic Analysis. In addition, the team will have begun a working relationship with the farmers and villagers which allows them to have a first hand experience of the system as it functions--something no laboratory based research can ever faithfully duplicate.

This step of the reconnaissance, therefore, is the initial link between the world of the investigator (or researcher) and that of the farmer. This link should stimulate mutual learning, communication, and understanding as seen in Figure 8. If you had not done so already, you will recognize by the end of the reconnaissance how vital the farmer is to your understanding of the system.

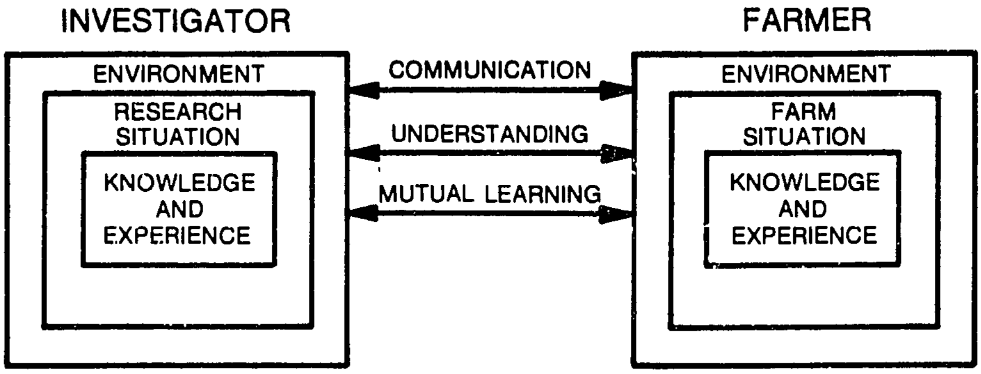


Figure 8. Interdependency of Investigator and Farmer

Analysis and Synthesis

By definition, these two words, analysis and synthesis, are opposites. When you analyze anything you separate it into its parts or components in order to examine them critically. To synthesize means you assemble or bring separate parts into a whole. How then does one analyze and synthesize at the same time? It is like attempting to cut up an orange while keeping it whole!

In reality, however, analysis and synthesis are sequential activities: first, you analyze and then you synthesize. In other words, first you take the system apart, look at all its components, ponder, learn, discuss, and then, you put it back together again. You will need all your judgment, skill, and experience at this point. The idea is not to take the system apart or put it together along disciplinary lines--like some academic zigsaw--for that would be simply a <u>multi</u>disciplinary approach. Rather, synthesis indicates a putting together of the different parts so that different relationships can be observed, causes and effects can be discovered, and new insights can be formed (Figure 9). Synthesis, by its very nature, crosses all disciplinary lines and results in an interdisciplinary understanding of the system and its possible improvement.

10

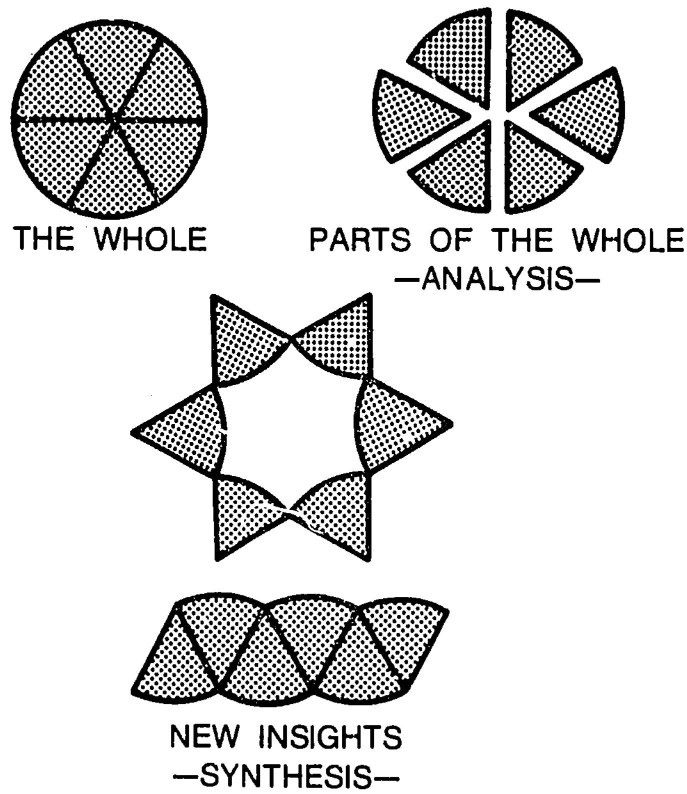


Figure 9. Analysis and Synthesis: New Insights

Remember our earlier example of the poorly maintained watercourses? If you do not analyze the separate facts, for example, excessive losses, hard working farmers, and poor maintenance procedures, you might decide to treat the problem as simply a technical one. Indeed, you might continue to identify symptoms of a problem rather than the problem itself. Synthesis, however, when it follows careful disciplinary and interdisciplinary analyses, allows the causes of the problems--both their nature and magnitude-- and not simply their symptoms, to be understood.

To analyze: to separate in order to examine closely. To synthesize: to assemble different parts into a whole.

Amazingly, we have spent much time on analysis and synthesis, when within the reconnaissance phase it will, of necessity, be conducted quickly so as to identify those particular aspects of the system upon which the later detailed studies will focus. The process of analysis and synthesis, however, will occur again later on in the Diagnostic Analysis.

Report Writing

The final step in the reconnaissance segment of Diagnostic Analysis demands that you put your thoughts and conclusions on paper. Having scanned the system, examined its components, and searched out new information, the reconnaissance is finished. The report will contain the results of your team's analysis and synthesis; this hypothesis details constraints to the system which appear to be hampering its efficient operation. The objectives and plans of the Diagnostic Analysis will be revised as a result of this hypothesis; the detailed studies phase, however, will either confirm or disprove the hypothesis.

REVISED OBJECTIVES AND PLANS

The third activity phase of the Diagnostic Analysis (Figure 6) is the on-going revision of the team's objectives and plans. On the basis of the reconnaissance and the team's hypothesis, objectives will become more specific. Once again, we can use the example of the watercourse with its excessive losses. Let us imagine that the reconnaissance confirmed these losses--some fields were found to be dry while other fields at the upper end of the system displayed signs of waterlogging. During your team's brief analysis, all of the possible constraints we mentioned earlier are offered, i.e., lack of local organizational structures, poor extension service, and so forth. The agronomist also might suggest that the soils are simply unsuitable for the selected crops. Collectively, the team revises their ideas concerning all possible causes. The hypothesis is then developed prior to going back into the fields to conduct more extensive and elaborate tests and measurements.

Revised planning may be necessary also in light of the revised objectives. For example, specific objectives may include identification of the causes for the water losses or the effects of conflict and the lack of organization on poor maintenance. Therefore, careful planning will be needed to fulfill these specific objectives. Sociologists and economists may need to review and refine their interview questions and techniques, particularly as a result of the pretesting. The team then assembles the necessary equipment and schedules interviews with farmers and other key informants, that is, persons who are particularly knowledgeable about different aspects of the irrigation system. If the reconnaissance phase has been a scanning, then the detailed studies will be the closer inspection; individual components of the irrigation system now will be care-

1V

fully examined in an attempt to support or disprove the team's hypothesis.

DETAILED STUDIES

Detailed studies, like Diagnostic Analysis itself, are not restricted to any particular time frame. During a Diagnostic Analysis workshop, this phase normally will last for three weeks. Separate from a workshop this phase still should be short, but could continue for one or more cropping seasons when dealing with particularly complex problems. Detailed studies are limited only by costs and availability of personnel.

The entire period of detailed studies consists of field investigations and data analysis. The interdisciplinary team continues to function collectively although there may be a disciplinary focus within the team activity. Specialized activities do not detract from the team's cohesion because of the collective objective of the group is being pursued and all members function with a particular mind set--that is, an interdisciplinary openness which guides, if not structures, the entire investigation. Figure 10 is a flow chart of the detailed studies phase of Diagnostic Analysis. The five activity steps of this phase include: objectives, allocation of responsibility, formal field studies, data analysis, and disciplinary report writing.

Objectives of the Detailed Studies

The first step of the detailed studies offers a good example of the overlapping nature of some phases within Diagnostic Analysis. The revised objectives for the entire Diagnostic Analysis, based on the team's hypothesis, in turn, will become the objectives of the detailed studies. Indeed, many of the steps within the detailed studies are very similar, if not exactly like those of the reconnaissance phase. The principal differences are those of time and depth: detailed studies are conducted over a longer period of time using formal investigative procedures. Many of these investigative procedures can be found in Volume 2 of this manual. Once again, it is planning and interdisciplinary collaboration which will allow for effective, in-depth field studies.

DETAILED STUDIES

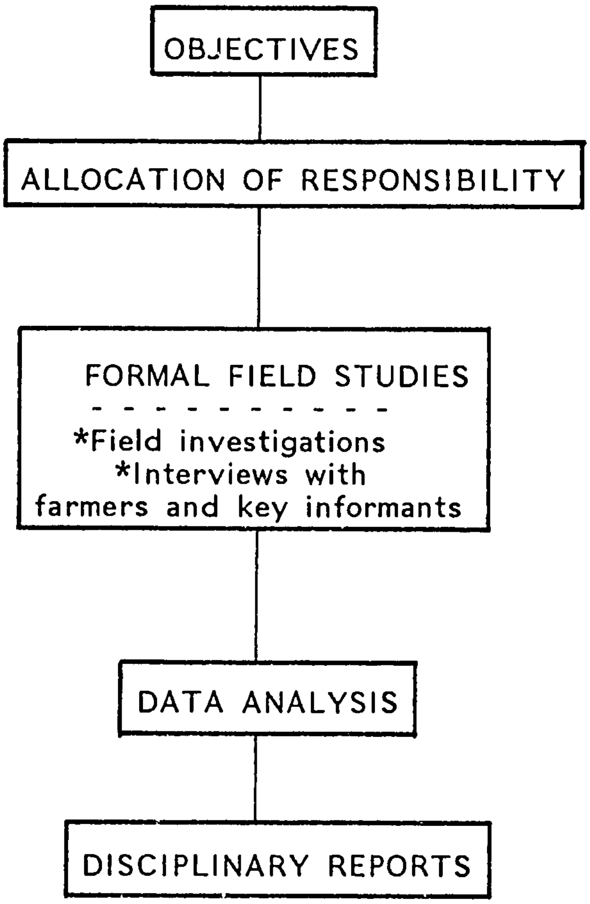


Figure 10. Flow Chart of Detailed Studies

Allocation of Responsibility

As mentioned previously, the team possesses a particular mind-set, or frame of reference, which sets it apart from other investigation approaches. Responsibilities, although they may demand a high degree of expertise within specific areas, are jointly planned and executed by the entire team. Data and information are collected with a high degree of cooperation. Interaction and collaboration among team members are constant throughout the entire Diagnostic Analysis, but even more so during the detailed studies. It is in the field that all team members, regardless of individual expertise, must observe, measure, and analyze the operating system within an informed interdisciplinary frame of reference. All information, therefore, remains complimentary in assembly and use. This is more clearly shown in Table 1 where possible types of data are displayed. Although these data are primarily collected by one discipline, they are shared with others.

The team leader has the responsibility of assigning different team members to designated areas of investigation. He or she also will see that data are available to all members. Although tasks are now much more specific than with the reconnaissance, a flexible attitude and mutuality continues to characterize the procedures.

Formal Field Studies

You will find the following chapter on "The System" helpful in understanding the extent and depth of the formal field studies. If you know what all the components of an irrigation system are and generally how they function, you can expand the intellectual perimeters of your own disciplinary investigation. The particular procedures used for interviewing and for conducting necessary tests and measurements are presented in Volume 2 of this manual. What is involved throughout this phase is a methodical examination of specific constraints as based on your initial insights. The number of constraints themselves will be limited by the time and resources available for the detailed studies.

Data Analysis

Data analysis is the on-going evaluation and codification of the diverse information collected throughout the formal field studies and will include some degree of synthesis as well. This phase simultaneously takes place along with the formal field studies. The types of analysis you will employ need to be appropriate to the data; again, you are referred to Volume 2

Table 1. Interdisciplinary Sharing of Data

Primarily Collected By:	Used By:	Types of Data
Sociologists	Sociologists Engineers Agronomist	Farmers' perceptions about night and day irrigation, major water problems inhibiting increased yields, solutions to major water problems.
Sociologists Economists	Engineers Agronomists Sociologists Economists	Farmer decision-making processes related to crop production, when to irrigate a given crop, when to stop irrigation, water lift methods, who applies water at given irrigation?
Sociologists	Engineers Agronomists Sociologists	Farmers' estimations of infiltration depth of water, depth of the crop's root penetration, crop water requirements, critical water demand periods and stages of growth, sources of major losses, magnitudes of losses, waterlogging.
Sociologists	Engineers Economists Sociologists	Tendency of farmers to cooperate in water lifting, trading of irrigation turns, farm implements and machinery sharing, sharing of workload, patterns of both formal and non-formal cooperation.
Agronomists	Economists Engineers Agronomists	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, harvest methods, storage methods, crop water requirements, soil characteristics, problem soils.
Sociologists Economists	Agronomists Sociologists	Adoption of improved technologies; rate of adoption, information sources used at each stage in the process, characteristics of the innovation, farmers trust in information sources.
Economists	Engineers Economists	Economic returns and costs, lifting water (alternative methods), various crop mixes, storage systems, transportation, marketing.
Sociologists Economists	Economists Agronomists Sociologists	Legal and organizational factors, delivery of water to command area, distribution of water, pricing of water, settlement of disputes--formally and informally, farmers' interaction with irrigation officials, use of incentives.
Engineers	Agronomists Engineers	Water supply and removal, conveyance efficiency, field application efficiency, water quality, consumptive use, return flow, field topography.
Economists Sociologists	Engineers Economists Sociologists	Information used for farm-level decision-making: marketing and irrigation schedules, closures, extension, quality and quantity of information.

v6

for more specific information. It is legitimate to stress, however, the need for predetermined and consistent methods of handling your data. This particular phase largely will determine the ease or difficulty of subsequent Diagnostic Analysis phases.

Disciplinary Report Writing

The final activity of the detailed studies phase is preparation of disciplinary reports. These reports will become the basis of the interdisciplinary analysis and synthesis, which is the next activity phase of Diagnostic Analysis. Some elements of good writing are dealt with shortly, but it is important to make sure disciplinary conclusions are well supported by the data and presented clearly.

INTERDISCIPLINARY ANALYSIS AND SYNTHESIS

All aspects of reconnaissance and detailed studies, ultimately, are directed towards this major phase of Diagnostic Analysis. During our previous discussion of reconnaissance, we reviewed in detail the nature of analysis and synthesis. The initial use of these latter processes was brief--as demanded by the reconnaissance phase. It is at this point within Diagnostic Analysis, however, that much more time will be devoted to the interdisciplinary evaluation. Taking the whole apart, the team examines the separate components and then synthesizes the results so that the exact causes of the constraints now can be substantiated by the detailed studies. Remember our watercourse with excessive water losses? Now is the time that primary constraints within the system would be identified for which future solutions could be developed. If there is more than one feasible solution to a problem, the recommendations should be placed in an order of priority based on stated criteria. In this manner, the team's recommendations will be ranked and of greater benefit in the later development of solution period. It is also important to note that part of this process will recognize the values, or benefits, of the system as it now functions. Such positive information can be just as valuable to system management.

REPORT WRITING

Final report writing is another simultaneous phase which takes place along with analysis and synthesis. Normally, two reports will be prepared: a disciplinary report and an interdisciplinary report. The disciplinary reports from the detailed studies will serve as the draft manuscript for the final disciplinary summation of the irrigation system. More importantly, the conclusions it contains will serve as the primary framework or outline of the interdisciplinary report.

Like the disciplinary report, the interdisciplinary report itself should illustrate the systems perspective, the interdisciplinary approach, and the involvement of the farmer (which we will describe more fully in Chapter 4). Your team may wish to address the system in terms of water control, resource allocation, resource conservation, or in any similar manner which recognizes a system as an entity with mutually interdependent components. Such an approach automatically eliminates any writing consisting simply of disciplinary recommendations and summations. The report then should not reflect simply parallel views of the system, for that is a multidisciplinary approach. Rather, as a result of the synthesis process, the interdisciplinary report presents the irrigation system, and the team's findings about it in such a manner so as to reflect the mutually interdependent components, the team's collective understanding of how it is functioning, and proposed recommendations. This report will be the important starting point for all future activities in the development of solutions, whether it be the application of already available technology, the formation of more effective organizational structures, or the establishment of a long-term action research.

This is a logical point at which to offer a few technical suggestions about report writing. Whether your efforts are disciplinary, interdisciplinary, technical, or non-technical, all good writing is accurate, clear, and concise! You can incorporate these qualities into your writings, if you remember the following suggestions:

- Avoid the use of disciplinary jargon, for example, calling a farmer a sociological unit;

- Define all specialized terms and local units of measure;

- Be consistent in your use of terms;

- Present your material in a logical, coherent order, for example, moving from purpose to procedure to results to conclusions;

- Avoid repetition and vagueness; and,

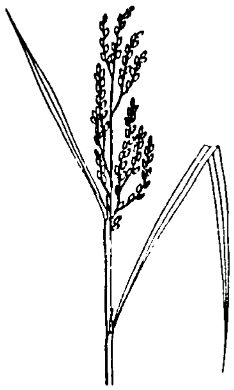
23

- Avoid duplicating your material in narrative, graphs, tables--all three forms of information should complement each other, not duplicate.

There are millions of words written about how to write properly (See Bibliography); you will have little need of them, however, if you simply remember to write accurately, clearly, and concisely.

POINTS TO REMEMBER

We now return to the whole. We have looked at Diagnostic Analysis phase by phase. We have noted the sequential and, at times, simultaneous flow of activities. Above all, we have seen that, while flexible, the entire procedure is a structured, methodical means of investigation. At each step of the investigation, objectives need to be consistently revised and plans need to be continually evaluated. Team members, though they may focus on their own particular area of expertise, are part of a cohesive, interdisciplinary group which not only cooperates, but more importantly collaborates. The thrust of the entire Diagnostic Analysis is the identification of those constraints within the operating system that are limiting effectiveness and productivity. The reconnaissance offers an overview of the system; detailed studies confirm or reject the proposed hypothesis. The final interdisciplinary report presents the team's conclusions and recommendations in a clear, concise, and accurate manner. Most importantly, these conclusions and recommendations, are put together (synthesis) after careful analysis of all the systems' components. They reflect neither an individual nor a disciplinary viewpoint, but rather offer collective, perhaps new insights into the system. Diagnostic Analysis, if it is performed in such a manner, is then a practical, effective tool for examining the irrigation system, its components, and the pivotal role at the farm level of its manager, the farmer.



Chapter 3

THE SYSTEM

*Failure to grasp the vital principle of interaction of systems components is the greatest present technical handicap to agricultural development in the newly developing countries.**

To say that a farm is a system is a simple enough statement to make, but much more difficult to comprehend. This is especially true when we have been trained in one particular discipline--often isolated from each other not only by education, but by experience as well. We are like the four blind men in that ancient tale who, coming upon an elephant, attempt to describe it to one another. Each man feels a different part of the beast while vividly explaining that specific part to the others; but, alas, no one man accurately describes the entire elephant! They were incapable of combining their knowledge to understand the whole.

The word system comes originally from a Greek word that means to combine. A system then is a combination of diverse yet related parts that form a unified whole. Diagnostic Analysis, as you have seen, demands that you cross disciplinary lines so as to accurately describe and understand the farm irrigation system in its entirety. This requires more than a

---

* Kellogg, C.E. 1973. Interaction in agricultural development. Volume III, Agriculture, Science, Technology and Development Series. U.S. Superintendent of Documents, Washington, DC.

superficial knowledge of the irrigation system--its boundaries, characteristics, and components.

BOUNDARIES OF THE SYSTEM

During a Diagnostic Analysis, the boundaries of an irrigation system can be established at any point along the system. If needed, you could examine the entire system beginning with the main water source, through the main canal, down the distributary canals to the farm and field channels, and eventually to the field outlets (Figure 11). In Diagnostic Analysis the primary focus of the investigation is at the farm level: those farms which are served by a common water source. As illustrated by the screened areas in Figure 11, the farms and fields are selected from throughout the command area to have a representative sample of the total area. Such a sample allows investigators to understand how the system, at that level, is actually functioning. This is why it is important that the sample be truly representative and includes farms and fields at both the head or tail of the canals and channels.

It also is important to note that although Diagnostic Analysis has a farm focus, the investigation is not limited only to that level. Investigators will, and must, follow the system as far up as necessary to understand the problems or constraints being examined. For example, in the previously mentioned case in which a watercourse was experiencing high water losses, the investigators might need to examine closely the operation of the canal outlet (Figure 11). The social-organizational system that influences the operation of the canal outlet would be of major concern to a Diagnostic Analysis team. If the water supply above the canal outlet proved to be a major constraint, then the main system would be investigated. This interdisciplinary examination, of course, would include all the relevant components of the system and not simply the physical component.

In this example, then, the canal outlet might mark the boundary of the system under investigation; however, those boundaries could have been established at any point along the system. It is the team's need to identify and explain the constraints to the system and their causes that ultimately determine where the boundaries are fixed. In other words, although Diagnostic Analysis has a farm focus, the boundaries of any system under investigation will be determined by the nature, extent, and magnitude of that system's constraints.

31

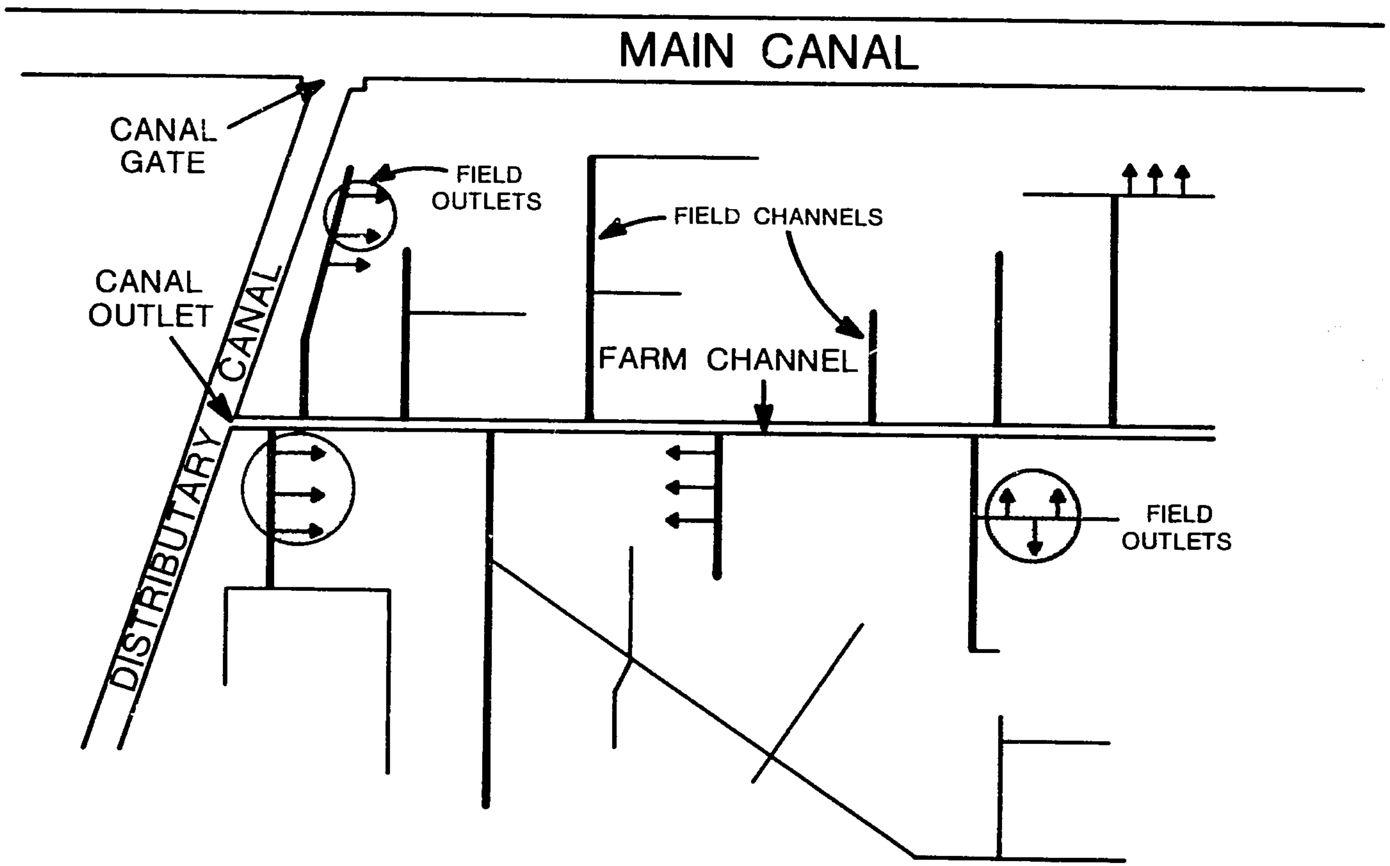


Figure 11. Distribution Scheme Within An Irrigation Scheme

CHARACTERISTICS OF A SYSTEM

An irrigation system also can be explained in terms of .ts characteristics. At the farm level, the system is an open one for it is connected to, and even dependent upon, the main system. It is an adaptive system in that it can and does change. It is also a man-made system: humans physically have manipulated natural resources so as to improve productivity and well-being. These, however, are very general characteristics: although descriptive, they do not sufficiently explain the system. To acquire a more complete definition, we need an interdisciplinary understanding of the specific components--individual systems in themselves--which, when combined, accurately represent the entire irrigation system.

These specific components could be called by any number of names, but we have labeled them the physical system, the cropping system, the economic system, and the social-organizational system. In the past, an irrigation system was defined primarily by its physical boundaries--that is, from the source of water, through a distribution scheme, to the fields, and finally, drainage (Figure 12). It is here that both the engineer and his technology have felt most comfortable. In reality, however, the physical component is only one part of the entire system--remember our elephant!

IMPORTANT COMPONENTS

The cropping system, the rightful domain of agronomists, concerns itself with the natural, biological, and chemical environment of crop production (Figure 13). To understand the economic system, and indeed the economist, you must learn such things as maximization of profits, inputs, outputs, and above all, allocation of resources (Figure 14). And finally, there is the social-organizational system of relationships and organizational influences which affect human behavior (Figure 15). Social scientists are our guides in this often over-looked area.

Therefore, each component--long separated by disciplines even as Figures 12 to 15 are separated--can be combined so that the total irrigation system can be seen as an interrelated, dynamic, functioning whole (Figure 16). You can neither change one component without affecting the others, nor can you describe the entire irrigation system if one of its component systems is missing.

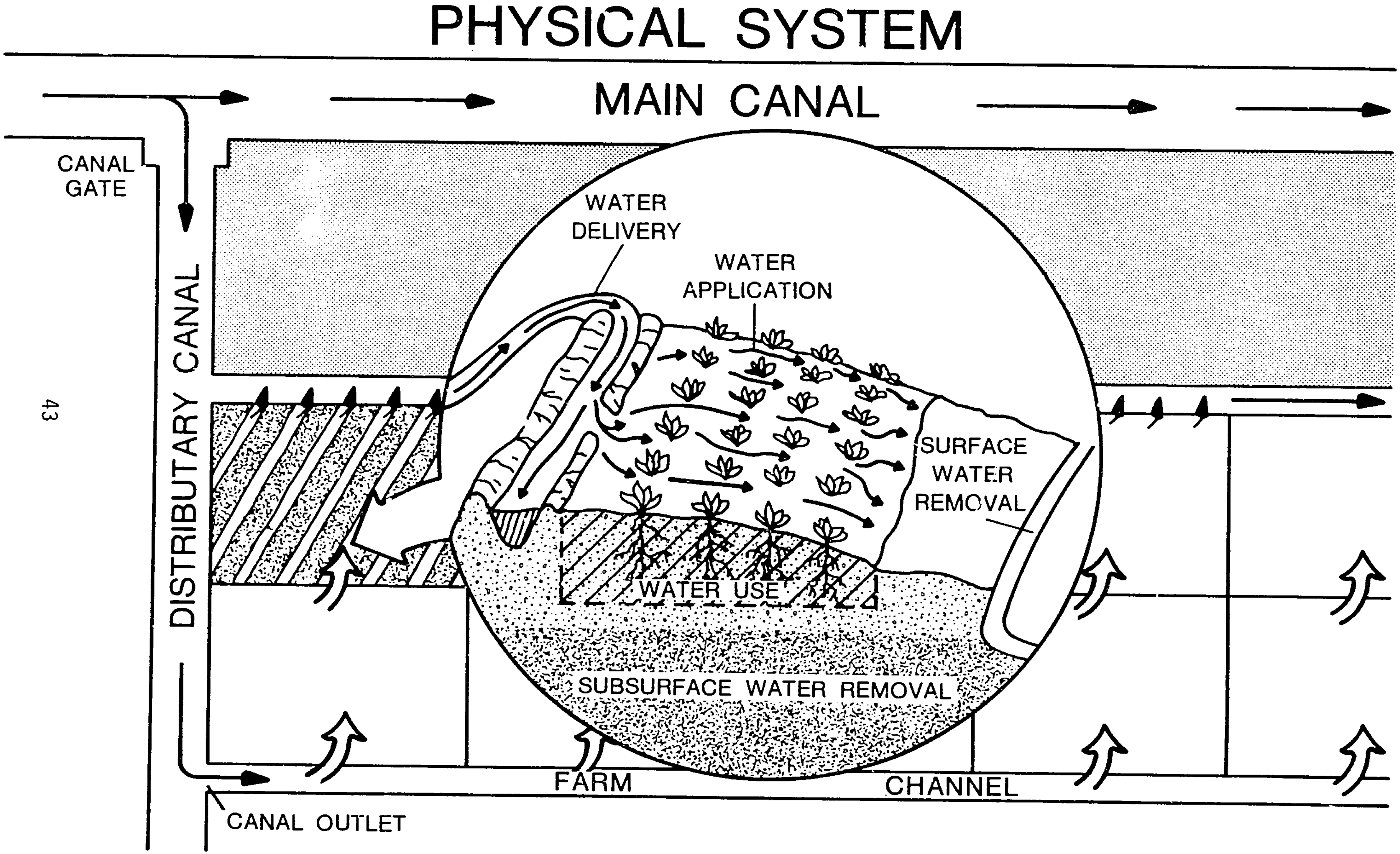


Figure 12. Physical Component of An Irrigation System

CROPPING SYSTEM

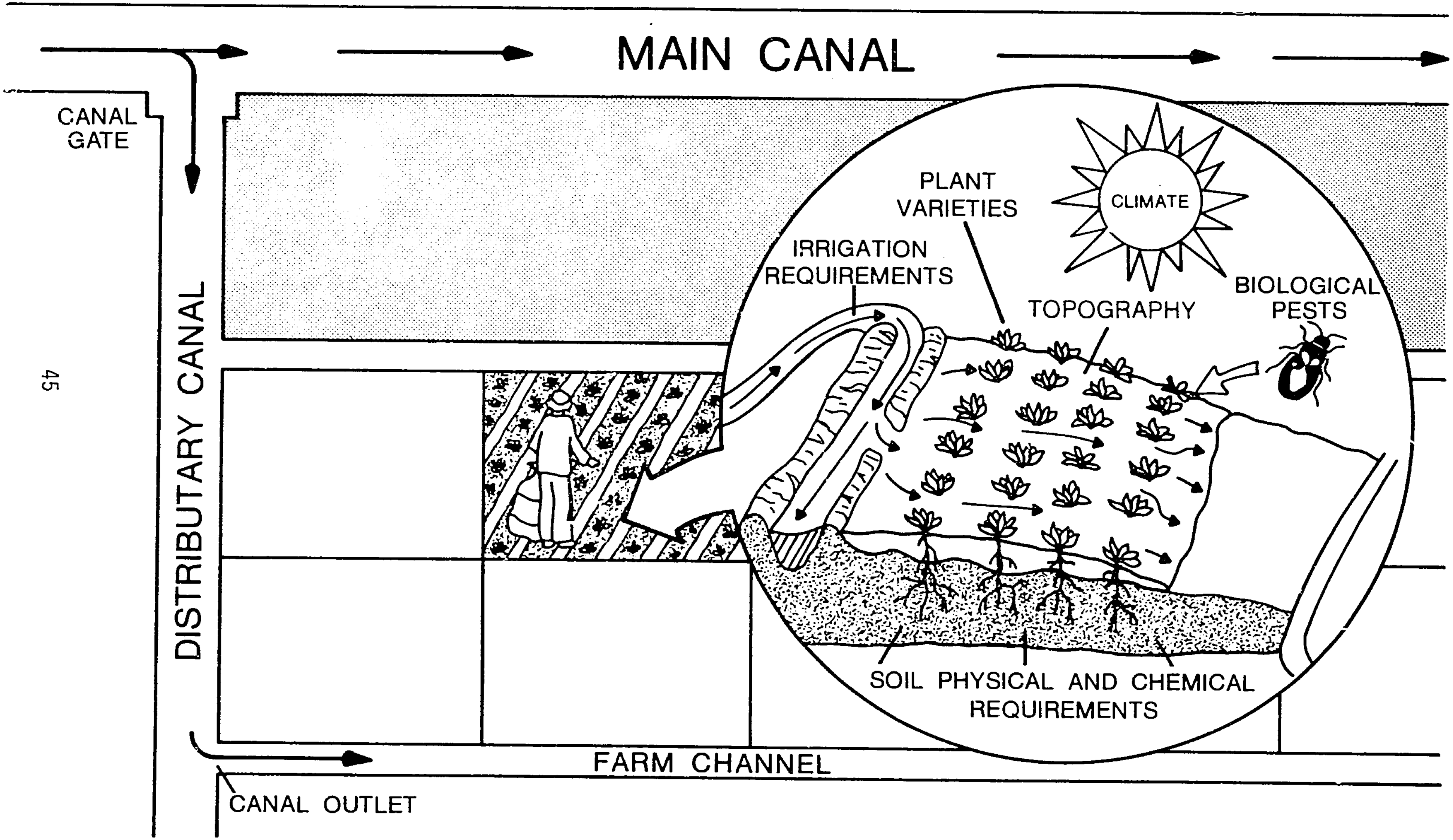


Figure 13. Cropping Component of An Irrigation System

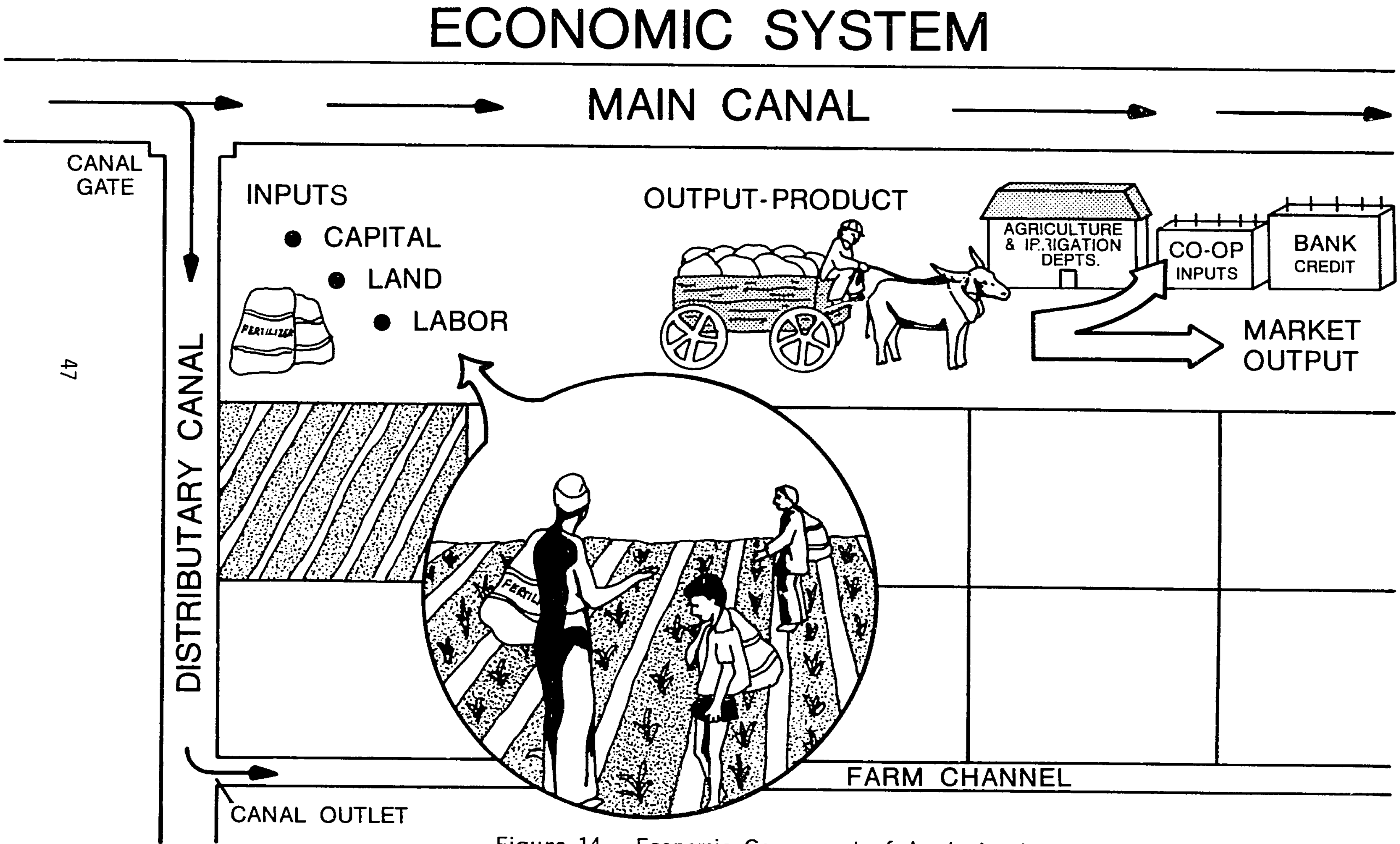


Figure 14. Economic Component of An Irrigation System

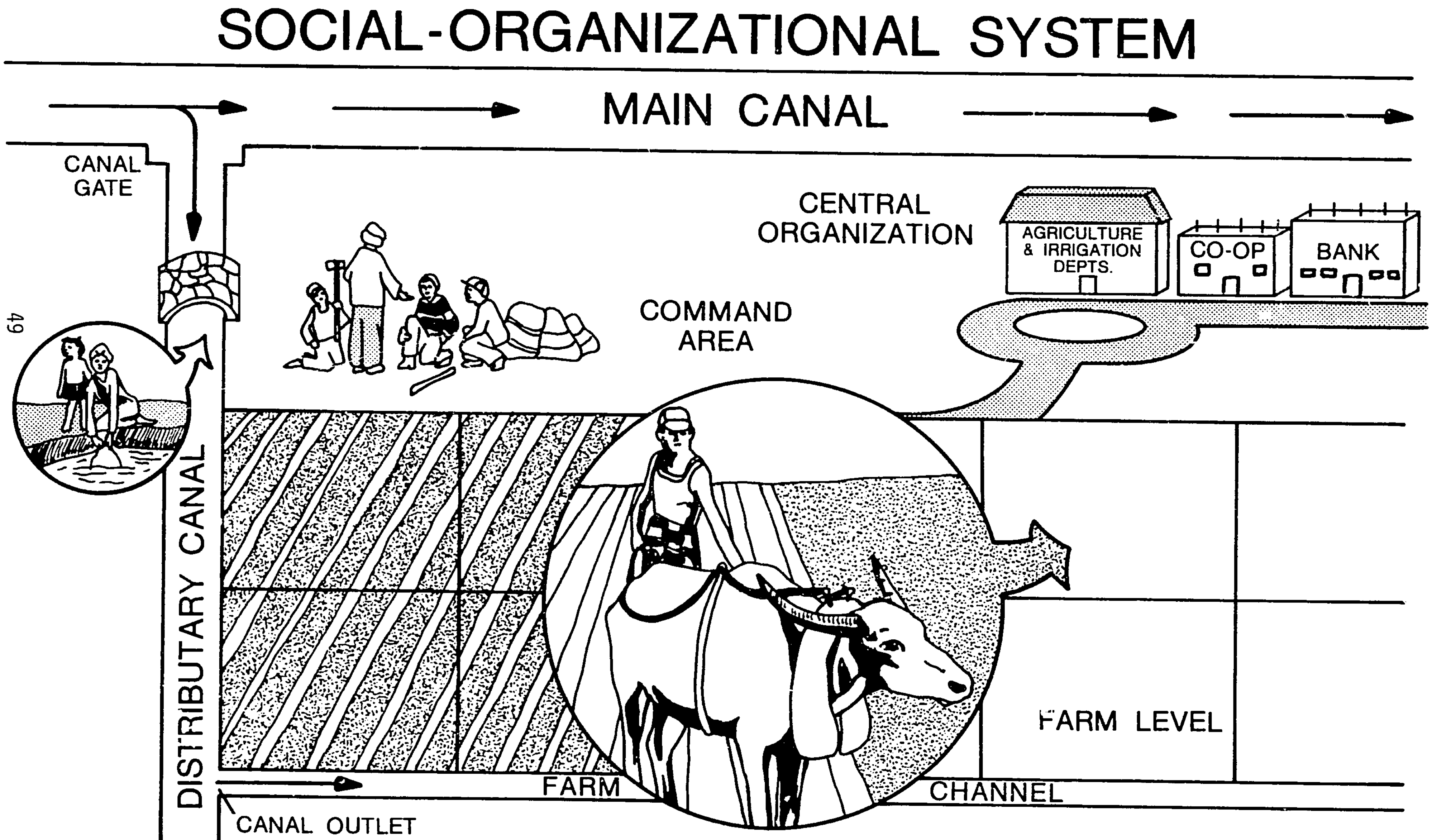


Figure 15. Social-Organizational Component of An Irrigation System

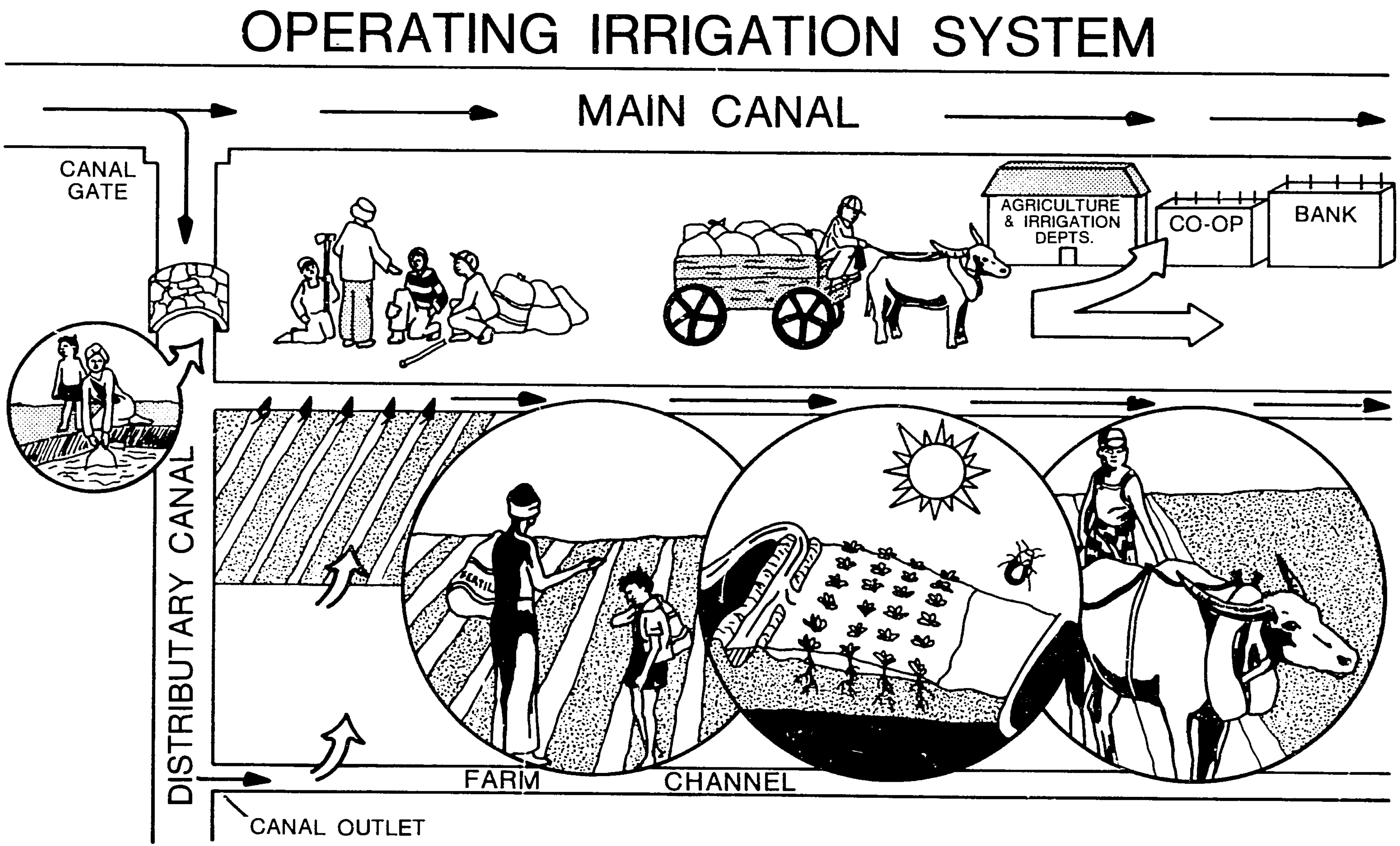


Figure 16. The Operating Irrigation System

A CIRCLE OF INFORMATION

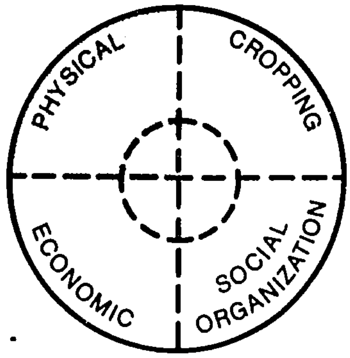
We now turn our attention to a more detailed examination of each of these component systems. Table 2 offers a summary of each along with its major functions and elements. Each of the succeeding sections is headed with a circle in which the four components are noted; the one being immediately discussed is highlighted. This is a simple, graphic way of reminding you that each component, although separately detailed, is interrelated to the other three. It is only together that they create the whole: a point to well remember lest we remain as blind men, limited in our understanding of the whole because we only understand a part.

Table 2. Component-Systems: Their Function and Elements

COMPONENT-SYSTEMS	MAJOR FUNCTIONS	MAJOR ELEMENTS
Physical		
•Water Delivery	Delivery of sufficient quantity and quality of water to the field.	Main canal, distribution channels, field ditches, slope, size and shape of channels.
•Water Application	Application of water to meet the requirements of the Water Use subsystem and satisfy leaching and erosion central standards.	Water supply rate, field geometry, field topography, soil infiltration rate, and irrigation method.
•Water Use	Supply water requirements for crop growth. Maintain acceptable levels of salinity. Maintain an appropriate environment (soil-air) temperature. Insure adequate nutrients. Provide appropriate soil conditions.	Crop requirements, evapotranspiration, water quantity and quality, soil type, and nutrient availability.
•Water Removal	Provide necessary surface and/or subsurface drainage. Maintain given salinity levels. Provide aeration of the root zone. Improve workability of land.	Leaching requirement, evapotranspiration rate, drainage facilities, soil type/subsoil type.
Cropping	Management of natural, biological, and chemical resources to produce food, fiber, and specialty crops. Ensure long-term productivity of crops.	Plants, climate, temperature, water, topography, physical, biological, chemical aspects of of soil, nutrient supply, insect control, and management practices.
Social-Organizational	Provide the social and organizational supports needed for successful operation of farm irrigation systems thereby achieving individual and social goals.	Facilities/institutional services, activities/collective. rules/norms/laws, communication/extension, linkages/institutions/beliefs, and knowledge.
Economic	Efficient allocation of agricultural resources. Maximize income. Evaluate the impact on production and income of changes in government policies and market conditions.	Land, labor, capital, markets, risk/uncertainty, cost/benefits, and consumption.

80

IRRIGATION SYSTEM



THE PHYSICAL SYSTEM

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

The purpose of each subsystem is as follows:

- Water Delivery: To convey water from the water supply source by way of the main canal and distributary canals to a canal outlet, and from there through farm and field channels.
- Water Application: To distribute water over the field to fulfill the water requirements of the crop.
- Water Use: To store and supply water to plants for crop production.
- Water Removal: To remove excess water to maintain conditions for optimum crop production.

The physical system of irrigation consists of the four subsystems in a flow process as shown in Figure 17. The most important part of the irrigation system is the water use subsystem since it is within this system that the water requirements are determined. The amount and timing of irrigation water for crop use through evapotranspiration and for leaching of salts and other purposes set the input for the water use subsystem. This demand, in turn, defines output from the water application subsystem. Similarly, the requirements for water removal are determined by the water use subsystem. The water delivery subsystem output, the supply of irrigation water, is set by the water application subsystem.

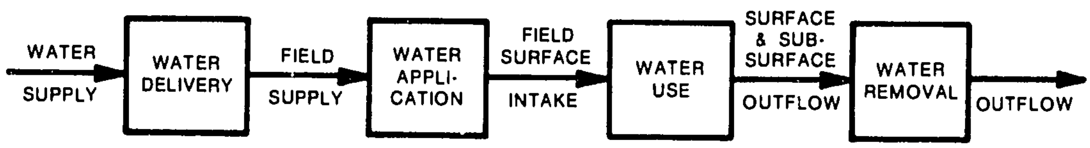


Figure 17. The Physical System of Irrigation

Traditionally, the supply of irrigation water has been dealt with in a flow process from supply to field as in Figure 17. However, because of the role of the water use subsystem, it is important to consider it first, and then to examine its impact on the other subsystems.

THE WATER USE SUBSYSTEM

The water use subsystem (Figure 18) accepts water from the water application subsystem and transmits water through the soil for storage or deep percolation. The plant transports water from the plant roots through the plant structure and then to the leaves where it is transpired. At the soil surface water 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.

42

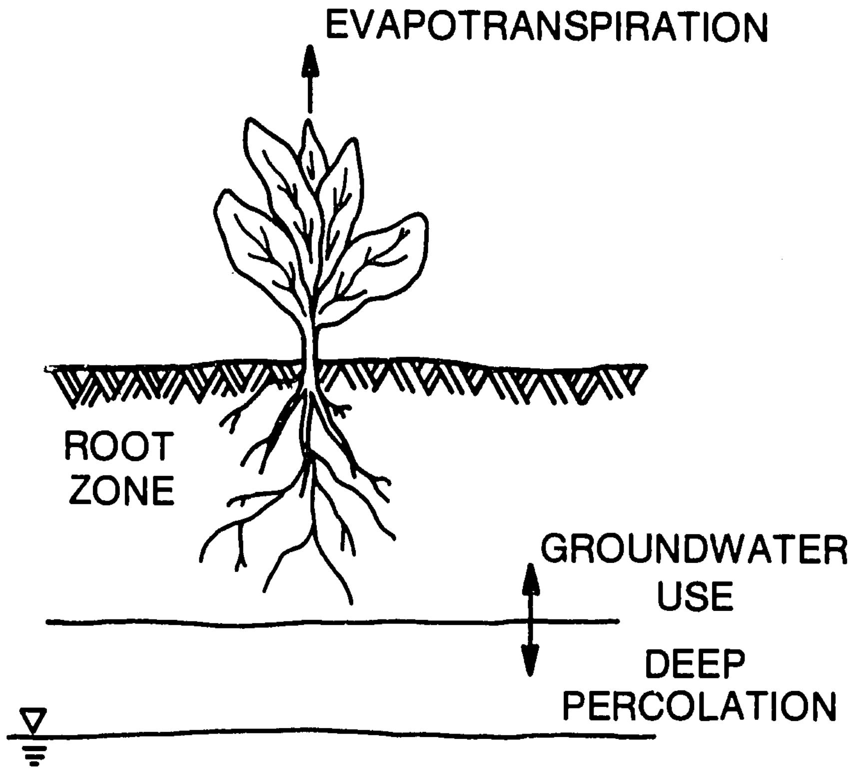


Figure 18. The Water Use Subsystem

43

The water use subsystem has the following functions:

1. To supply the water requirements for crop growth (quantity and quality) for:

   a. The peak rate of use,

   b. The total seasonal requirement,

   c. The prevention of excessive stress, and

   d. The provision of adequate aeration and acceptable inundation;

2. To maintain acceptable levels of soil salinity;

3. To maintain appropriate environmental (soil and air) temperatures;

4. To insure adequate nutrients;

5. To provide soil conditions for:

   a. Supporting plants,

   b. Preventing soil crusting,

   c. Facilitating tillage and harvesting operations, and

   d. Providing water for germination and seedling emergence.

Supplying water requirements for crop growth, Function 1 listed above, is 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 permit the desired amount of water to infiltrate is too long and would cause crop damage.

d\(\)

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, and
5. Economics.

In order to prevent excessive crop stress it is necessary to supply irrigation water at the appropriate time. Some crops are more tolerant of stress than others while some are particularly sensitive to water shortage at specific times in their growth cycle. Management of irrigation for maximum crop yield is one possible objective for the operation of the irrigation system. Meeting this objective involves the knowledge of the critical periods and the ability to supply water at those times to meet crop needs. An alternative objective might be to supply less than optimum amounts of water in order to conserve water at the expense of a reduced crop yield.

The soil type affects the level of water stress for a given water content in the soil. Climate also affects the water availability by controlling the maximum rate of evapotranspiration. Information about soil characteristics in a particular location is best obtained by field investigation and by consultation with local authorities. Climate effects on crop response and soil water availability can be determined through the collection of information on crops, soils, and weather data. Economic considerations are derived from the cost of inputs to obtain maximum crop yield or alternatively a reduced level of yield and the value of the crop realized. The irrigation system characteristics govern the ability to supply water at the required time and in the specified amount for a given irrigation. These characteristics will be determined with reference to the water application subsystem.

THE 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 19). Water application must provide water for the functions of the water use subsystem as well

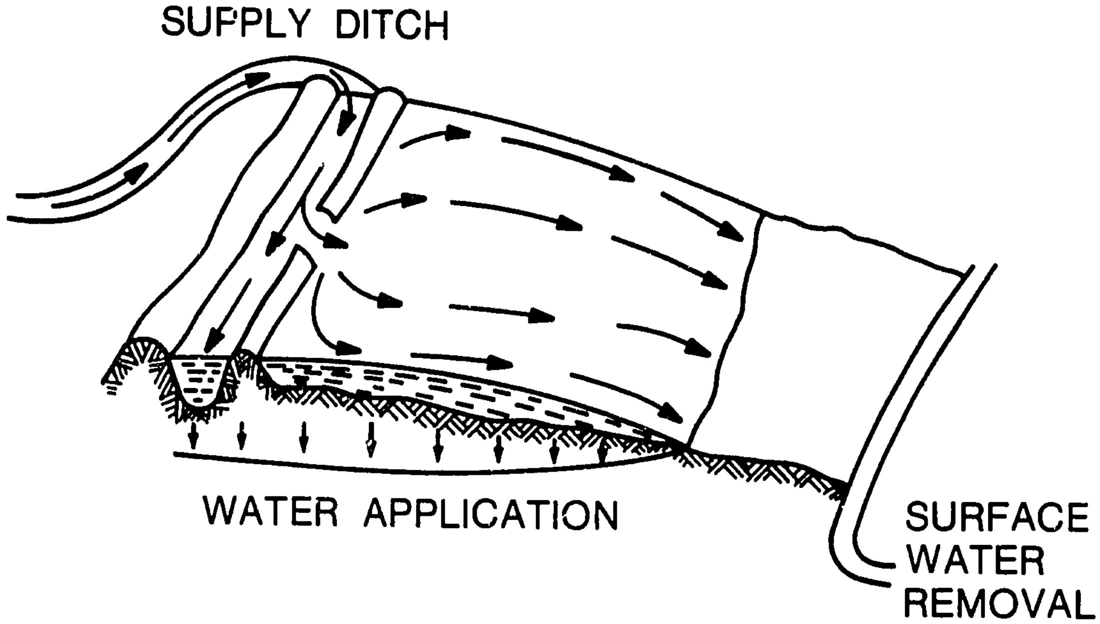


Figure 19. The Water Application Subsystem

as fulfill the functions of water application. The traditional functions of the water application subsystem are as follows:

1. To distribute the desired amount of water with the designed uniformity;

2. To satisfy erosion control standards;

3. To provide necessary surface drainage; and,

4. To be 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 variables:

1. Field geometry (length and width),

2. Water supply rate,

3. Slope (and levelness),

4. Infiltration rate,

5. Surface roughness,

6. Channel shape, and

7. Management.

The significance of the variables listed above is dealt with in detail in Volume 2 of this manual as are the procedures needed for accomplishing the various analyses which are discussed. The boundary and initial conditions of the system must also be specified to completely describe the state or condition of the system.

The water application subsystem is managed 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:

41

1. How do I irrigate?

2. When do I irrigate?

3. How much water do I apply?

The operation of the water application subsystem can be described by measurement of the subsystem variables. Knowledge of the appropriateness of these variables can be determined by comparing the existing values with the values of an appropriate design. Performance also can be determined by use of the variables measured. The input of irrigation water to the water application subsystem is supplied by the water delivery subsystem.

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 that which is 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 water delivery subsystem will consist typically of main and farm components. The purpose of the 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 water use subsystems.

As stated above, the water delivery system has a main and a farm section. The main section is located above the canal outlet and is frequently managed by a government or some other organization. The section located below the canal outlet is usually managed by farmers.

The following description of the water delivery subsystem applies to both the main and the farm sections. The canal outlet marks the boundary between the two sections, but it is the requirements of the farm section which will define the requirements of the main section.

The water delivery subsystem serves the water application subsystem which, in turn, supplies the water use subsystem. The functions of the water use subsystem and the water application subsystem also must 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 the particular method of irrigation. 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. All other defined functions of the water application subsystem also must be met by the water delivery subsystem.

The function of the water delivery subsystem is to convey water from the supply source to the field:

-- At a constant, regulated rate,

-- At the proper elevation,

-- With seepage controlled,

-- Without excessive erosion or sedimentation,

-- At appropriate water quality, and

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

FACTORS INFLUENCING WATER DELIVERY

These functions listed above are performed by a delivery system based upon the physical and management factors. The factors that influence water delivery are:

1. Flow rate,
2. Cross section,
3. Hydraulic radius,
4. Roughness,
5. Slope,
6. Seepage rate, and
7. Management.

The management factor is reflected in the decisions of the farmer as affected by the water allocation rules and operational norms for the system. The first five physical factors are the basic parameters in an equation which is 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.

Flow Rate

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

- Total quantity,
- Supply peak demand (rate),
- Constant flow for an appropriate time for application, and
- 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 also must 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.

Cross Section, Hydraulic Radius, Roughness

An appropriate channel cross section must be provided to maintain head and to deliver water at an appropriate elevation. The cross section also must be provided for the design flow rate as defined by the water application subsystem. The hydraulic radius should be a minimum for the design flow in order to minimize the cuts and fills associated with channel construction 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 roughness of a channel must be carefully selected for the design to conform to the design cross section.

Slope

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 subsystems, 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.

Seepage Rate

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 subsystem should be evaluated and explicitly included in the design. Realistic assumptions concerning the system's maintenance should also be considered in designing a 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 high seepage losses are explicitly considered. Selection is frequently based on economic considerations.

Management

Management is a process of operating a system or subsystem to achieve established objectives. The management process must contain the steps as follows:

1. Set the purpose and objectives of a system or subsystem;

2. Establish ways to meet objectives which are termed "needs";

3. Assign priority of needs;

4. Set goals for meeting needs;

5. Determine what needs to be measured and activities necessary to meet goals;

6. Monitor goals to feedback for management; and,

7. Operate the system according to the above process.

The purpose of a delivery subsystem is to deliver water to the application subsystem. The objective would require the delivery to be in a controlled manner. Clearly, the performance of a system should be based upon its ability to meet its objectives.

With the objective defined then, ways to meet this objective must be established; these are the system's needs. For the delivery subsystem, water needs to be delivered in a dependable, adequate, equitable manner and at the correct water surface elevation.

The system needs must be assigned priorities. What is most important to make deliveries adequate or equitable? For example, during a water shortage, should all farmers get smaller amounts of water, or should farmers with certain crops receive larger amounts?

How these needs are met are termed goals. Each priority need requires the establishment of at least one goal to measure how it has been met. For the delivery subsystem, if the priority need is a dependable water supply, then there must be some measure of dependability within acceptable range.

Variables which impact upon the system or subsystem must be determined in order to be measured. For the delivery subsystem the important variables would be flow rate, duration, volume, and frequency of delivered water. Dependability, as an example, could be based on one or more of the above variables. What activities are needed also must be set at this time. How and who will make a flow rate measurement?

The measured goals and set goals must be monitored for management. This is the feedback link for improving the system's operation. If the adequacy of delivery is low, what should the manager of the system do to improve the condition? The feedback link is critical to the management of the system. Without feedback the system is being operated, but not managed.

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 salinity control. In most irrigated areas, natural drainage is inadequate 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 overirrigation or a leaky canal. The major components of the water removal subsystem are depicted in Figure 20.

The water removal subsystem has the following primary functions:

- To provide proper root aeration;
- To maintain appropriate salinity levels within the soil profile; and
- To improve workability of lands.

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 from the atmosphere to the root zone at a rate sufficient to supply the respiration needs of the plant. Carbon dioxide, a respiration product of roots and microorganisms, may accumulate in toxic concentrations around the roots. In addition, anaerobic decomposition of organic residues may produce phytotoxic compounds, such as sulfides and methane. All of these factors limit production of most crops.

Excess water in the soil profile also affects the availability of mineral nutrients. Many essential elements become more soluble and are leached below the root zone. Concentrations of other elements, such as iron and aluminum, may reach toxic levels in some soils.

A notable exception is rice which is able to survive in submerged soil for a long time because the 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.

The depth to water table should be considerably greater for heavy clays as compared to uniform sands. The zone of aeration is more difficult to maintain for clay than for sand due to capillarity. Note that the soil is assumed to be fairly homogeneous while in nature we would expect layering. Consequently less permeable zones may restrict and even prevent

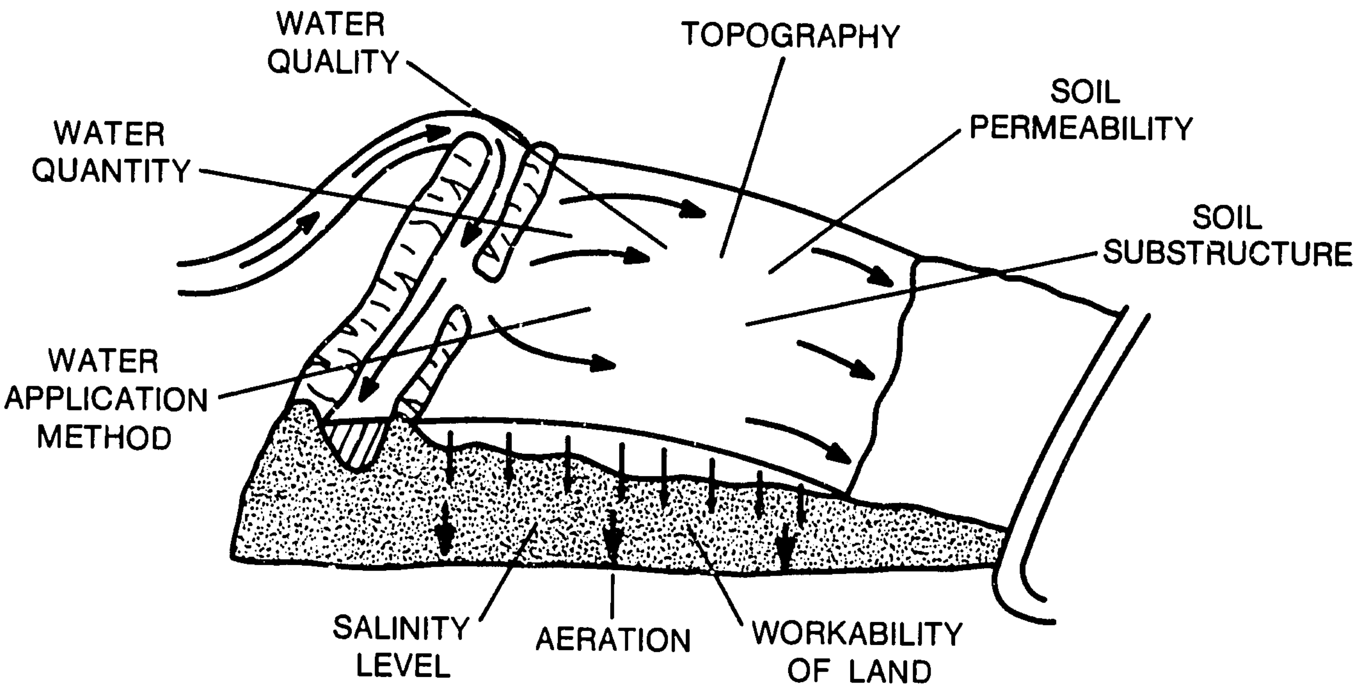


Figure 20. The Water Removal Subsystem

54

downward movement of excess water. This creates local perched water table conditions and regionally has the same effect as high water conditions. We would want to maintain a depth to water sufficiently large to provide an adequate zone of aeration for the root system.

Salinity Levels

All irrigation water contains salts which, if allowed to accumulate within the root zone, will reduce crop yields. Some water must percolate through the root zone to remove excess salts. This excess water must be removed from the area either naturally or by artificial drainage 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:

- Amount of salts in the irrigation water,
- Evapotranspiration rates,
- Crop type to select appropriate salinity levels within the soil, and
- Disposal site.

Irrigation water brings salts into the root zone of the crop. Additional salts may be added through fertilizers, but this is usually small compared to that added by irrigation water. The crops use the water stored in the root zone for evapotranspiration and leave the salts behind. In time, the salts build up until the yield of the crop is affected.

To ensure long-term productivity it is necessary to apply more irrigation water than that required for the crop's evapotranspiration. The excess water percolates through the root zone, removing the excess salts and maintaining the balance of salts. The concentration of salts in the root zone is determined by the salt tolerance of the crop. On a long-term basis it is necessary to maintain the salt concentration at a level below that which would reduce crop yield.

The leaching requirement is determined from the water use of the crop and the salts contained in the irrigation water. The salinity level tolerated by the crop should be obtained from local advisors. Note that the drainage water containing the removed salts must go somewhere. 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.

Workability of Lands

The presence of water in soils reduces 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 interfere with the preparation of the seed bed, and the dense, less permeable layers 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 effect is the increase in heat capacity due to the presence of water. More heat is required to raise the temperature of wet soil than is 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 delaying seed germination during the planting season as well as retarding growth after germination. Conversely, wet soil remains warmer during periods of decreasing atmospheric temperatures and can reduce the effects of freezing conditions.

The concentration and type of salts in the water affect the mechanical behavior of soils because 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 subtypes differing in respect to crystalline form. The three main types are: kaolinite, montmorillonite, and illite.

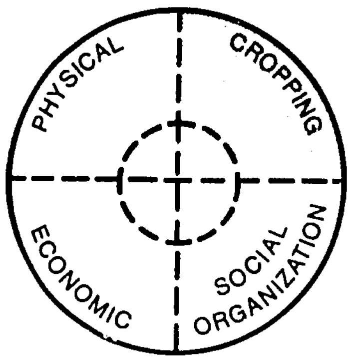
Water that is highly concentrated with electrolytes has less potential for entering space between the clay plates. In addition, some ions such as Al^{+++} inhibit swelling and dispersion more than for example Ca^{++} or Na^{+}.

56

In the dispersed state, the clay will have lower permeability and poorer aeration because 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 the 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.

POINTS TO REMEMBER

The physical irrigation system is represented here as a flow system from the supply or source of irrigation water via the water delivery and water application subsystem to the point of water use. The water removal subsystem completes the flow of water to the point of disposal. It is important to remember that the crop's water use requirements, as defined within the water use subsystem, are critical to the entire process. The design and management of the irrigation system must incorporate the water requirements determined by the water use subsystem.



THE CROPPING SYSTEM

This section provides a general overview of the Diagnostic Analysis procedures used to investigate an irrigated cropping system. First, we will classify an irrigated cropping system according to the pattern of cropping and the rotational patterns used. Second, the natural, chemical, and biological environment of cropping systems will be described in sections on climate, soils, and biological constraints to crop production. Finally, we will look at important aspects of the farmers' management practices as they relate to the cropping system.

An irrigated cropping system may be defined as all of the elements required for the production of a particular crop or a set of crops and the interrelationships between the crop or set of crops and the environment. The function of this system is to produce food, fiber, and other organic products at optimum levels with the desired quality and to insure long-term productivity. Implied in both the definition and function of a cropping system is the interdependency among the crop system, man (the manager), and the natural environment (the input). This section will deal specifically with those aspects that affect the biological productivity of irrigated cropping systems.

A METHOD OF CLASSIFICATION

A cropping systems approach, as used here, recognizes that we are dealing with a complex system involving several hundred crop species and a variety of methods of crop management. In order to reduce this complexity, irrigation cropping systems are classified according to the pattern of cropping and rotational patterns (Figure 21). A brief description of this flow chart follows.

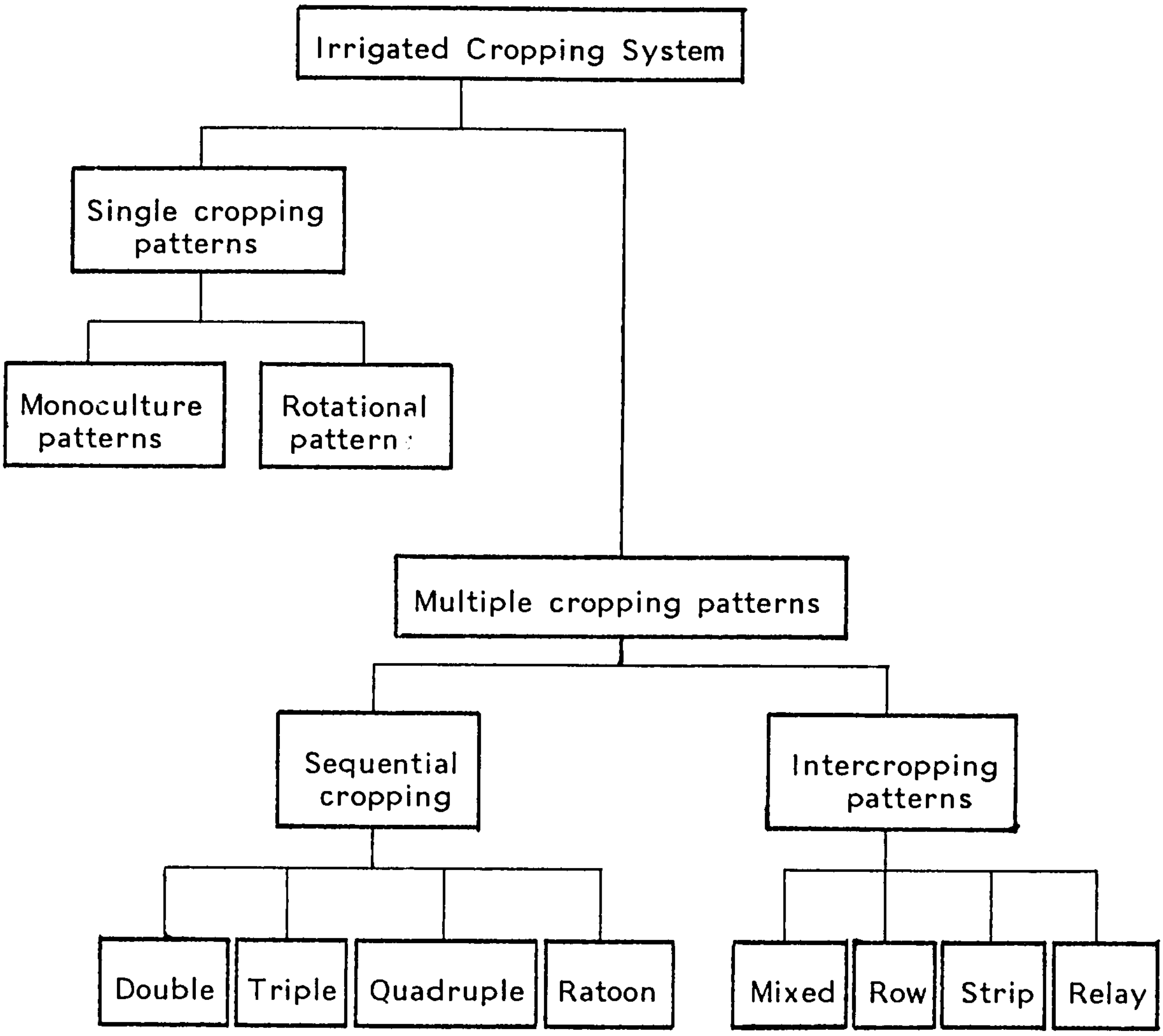


Figure 21. Classification of Irrigated Cropping System

The first subdivision separates various cropping systems by the pattern of cropping, i.e., the number of crops grown in a field during a year. Single cropping patterns are those in which only one crop is grown on a field during a year. Whereas, the multiple cropping patterns feature the growth of more than one crop on the same field during a year. Both

51

single and multiple cropping patterns may involve the growth of annual crops (those which are grown for one year or less), biannual crops (those which are grown for two years), perennial crops (those which are grown for more than two years), or any combinations of the above.

Single cropping patterns are further subdivided into monocultural and rotational patterns. A monocultural pattern is characterized by the growth of the same crop on a field year after year as opposed to an alternation of two or more crops in multiples of a yearly rotational pattern. Monocultural and rotational patterns are most often characteristic of temperate zone climates, but they are found also in tropical or arid zones on irrigation systems incapable of supplying crop water requirements on a year round basis.

Similarly, multiple cropping patterns are subdivided into sequential cropping patterns and intercropping patterns. Sequential cropping patterns are multiple cropping patterns in which one crop is planted immediately after the harvest of the previous crop. Specific sequential cropping patterns that may be identified on an irrigation system are double, triple, quadruple, and ratoon cropping. Double, triple, and quadruple refer to the number of crops grown sequentially in a year; ratoon cropping refers to the cultivation of crop growth after harvest from the same root stock.

Intercropping patterns are distinguished from sequential cropping patterns in that two or more crops are grown simultaneously in the same field. The four intercropping patterns shown in Figure 1 (i.e., mixed, Row Strip, Relay) are differentiated by the arrangement of the plants in time and space. Mixed intercropping patterns have no distinct row arrangement while row intercropping patterns maintain distinct row arrangements. Strip intercropping patterns feature the growth of two or more crops in strips wide enough to permit independent cultivation, but narrow enough for the crops to interact agronomically. Relay intercropping refers to those cropping patterns in which two or more crops are grown simultaneously during part of the life cycle of each. Usually, a second crop is planted after the first crop has reached its reproductive stage.

THE PLANT ENVIRONMENT

In addition to identifying the specific crops and cropping patterns on an irrigation system, it is important to understand the plant environment in which the various irrigated cropping systems function. Data concerned with the climate, soils, pest infestations, and farmers' management practices are useful for evaluating the current cropping systems found on an irrigation system. While a great deal of this information is provided by soil survey reports, climatic records, and previous research in the area, it is necessary to gather specific data on the soils, irrigation water, crops, pests, and management practices of the farmers in the study area. Some of the data, particularly that associated with field irrigations, is obtained through the cooperative efforts of the agricultural engineer and the agronomist. Other information dealing with the farmers' management practices, availability and use of essential inputs, markets, and so forth, is obtained usually by the agricultural economist and/or extension team members who make it available to the agronomist. The remaining data on climate, soils, crops, and pests are obtained by the agronomist using both historical records and on-site surveys. Some of the more important data used to describe the irrigated cropping systems are summarized in the following sections.

CLIMATE

Climate exerts a major influence on the soils, natural vegetation, and types of crops which are grown in a given area. Differences in climate are due chiefly to differences in latitude, altitude, distances from large bodies of water, ocean currents, and the direction and intensity of winds. Climatic parameters that are considered important in evaluating irrigated cropping systems are:

> <u>Solar radiation</u> - Both the intensity and daily duration of light are useful for determining the suitability of a crop for a given area and the most favorable periods of growth. Daily or average daily solar radiation values are also used in some of the empirical evapotranspiration equations for determining crop water requirements.
>
> <u>Temperature</u> - Average daily temperature and maximum/minimum temperatures are just as important as solar radiation for determining favorable growing periods and the suitability of a crop for a given area. Average daily temperatures are used also in some evapotranspiration equations.
>
> <u>Precipitation</u> - Average daily rainfall is also an important factor which influences when a crop may be sown and the suitability of that crop for the particular area. Daily rainfall values are important also

61

for determining the irrigation or drainage requirements of a particular cropping system.

Relative Humidity - Daily relative humidity values often exert an influence on the performance of a crop. This is particularly true during the flowering period of some crops. Daily relative humidity values affect evapotranspiration rates and are used in some evapotranspiration equations.

Climatic extremes - An indication of the relative frequency of untimely heavy typhoons or monsoons, frosts, hail, and so forth, are often factors which influence the choice of crops grown in a particular area.

Wind - Daily values for wind speed are used in some evapotranspiration equations and influence the growth of certain crops.

SOILS

The second most influential aspect of the plant environment which affects an irrigated cropping system is the soils that exist on a particular irrigation system. A soil is a highly complex matrix of disintegrated and decomposed rocks and organic materials that plants exploit for anchorage, nutrients, and moisture. Soils are heterogeneous in nature and may be contrasted from one another by differences in their natural, chemical, and biological properties. The description of the soils and their properties is basic to the understanding of a particular irrigated cropping system. Normally, the agronomist relies on historical records, particularly soil survey reports, as major sources of information on the soils as they exist on a particular irrigation system. Field surveys are used then to confirm and to add to the information provided by these historical records.

An analysis of the soils on an irrigation system requires that each soil be described both vertically (with depth) and horizontally. The morphological characteristics observed with depth are used to identify specific soils. Changes in these characteristics in the horizontal direction distinguish one soil from another. Some of the soil parameters considered important in analysis are:

- Topography - the physical features of the land surface such as relief and position of roads, rivers, irrigation systems, and so forth.

62

- Soil horizon - a soil horizon is a layer of soil, approximately parallel to the surface with characteristics developed by the particular soil-forming processes to which it has been exposed (Figure 22). Several of the soil properties listed below, among others, are used to distinguish one horizon from another. Each of these properties vary both horizontally and vertically in the soil.

- Soil depth - the vertical thickness of the soil, usually established by the presence of compacted layers or parent material which prevent root penetration.

- Soil texture - the proportions of sand, silt, and clay in the soil material.

- Soil structure - the aggregation of individual soil particles into larger units with planes of weakness between them.

- Bulk density - the ratio of the mass to the bulk volume of soil particles plus pore spaces in a soil material.

- Soil moisture regimes - a number of parameters which define, in one way or another, the amount of water available to plants that a soil can hold. Soil moisture holding capacities of a soil are primarily a function of the texture and bulk density properties of each soil horizon.

- Infiltration and permeability - the rate at which water moves into and throughout the soil profile.

- Organic matter content - the relative amount of partially decomposed and resynthesized plant and animal residues present in the soil.

- The soil reaction - the relative acidity or alkalinity of the soil material.

- Soil mineral nutrient status - the relative availability of those minerals considered essential to plant growth.

- Salinity - the total amount of salts present in the soil material.

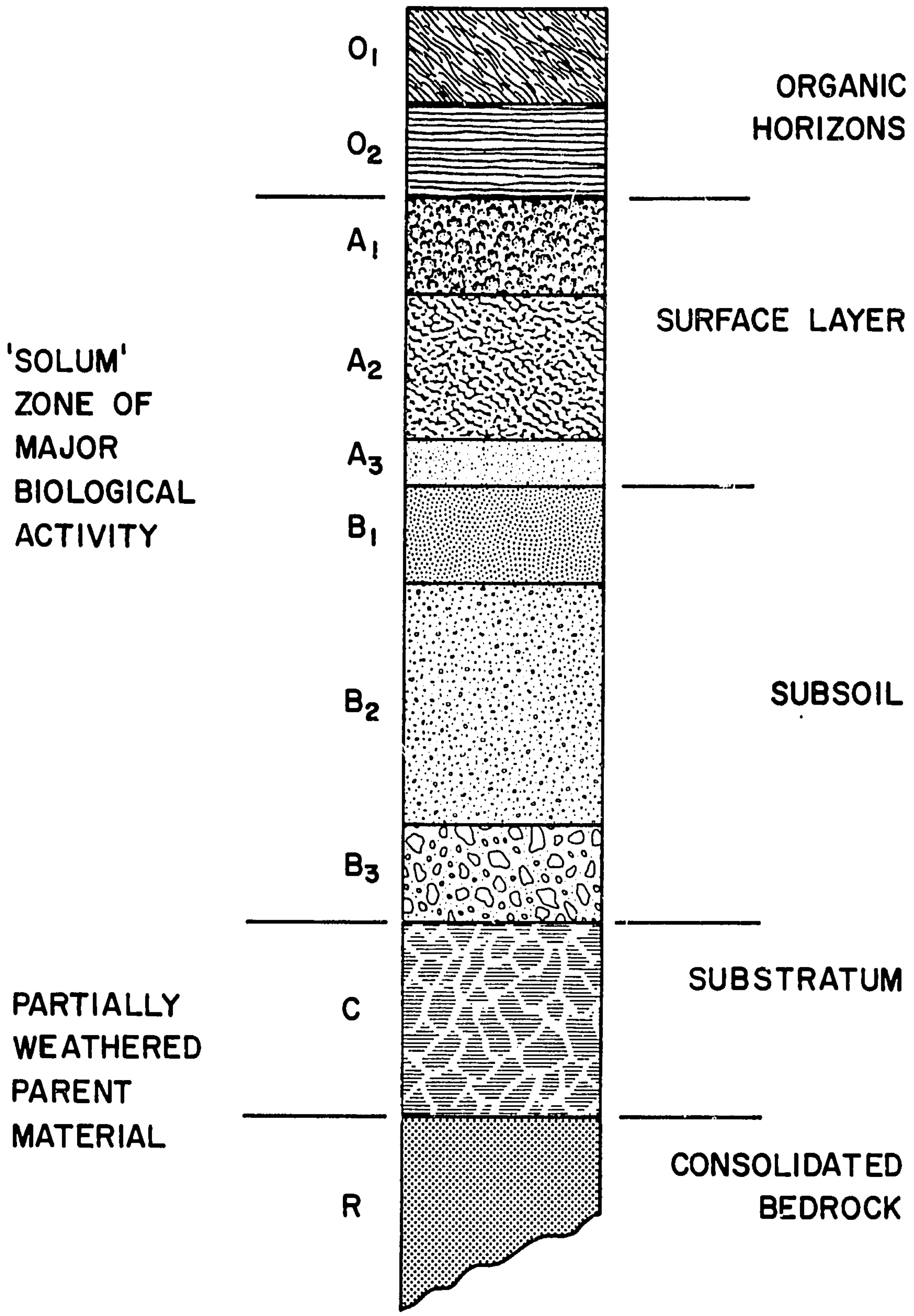


Figure 22. The Soil Profile

64

- Sodicity - the total amount of sodium present in the soil material.

- Specialized soil problems - nutrient toxicities or imbalances, high water tables, periods of uncontrolled flooding, and plowpans are examples of a number of other natural and chemical properties that affect the biological productivity of a cropping system.

BIOLOGICAL CONSTRAINTS TO CROP PRODUCTION

The identification of biological pests and their damage is another aspect of analysis important to the understanding of the irrigated cropping system. Biological pests may be subdivided into two categories: 1) those that affect the irrigated crops, and 2) those that physically may affect the farmer and his family.

Agricultural pests of concern in the first category include animals, insects, weeds, plant diseases, and parasites. Background information concerning the identification of the most serious agricultural pests in the study area is obtained usually from local, national, or international agricultural agencies. In addition, field surveys are used to identify pests and assess the damage caused by them.

The second category of pests may directly affect the farm family and indirectly affect the biological productivity of irrigated cropping systems through their effects on the farmer and his family. Many of these organisms, such as the anopheles mosquitoes and schistosomes, are associated with the introduction of irrigation and in some instances they have become the most important factor limiting crop production.

Knowledge of such health hazards on an irrigation system is important to the understanding of the overall system as well as the safety of the team members involved in the field investigations. Because of the latter, it is important that information on health hazards be obtained from local or national health organizations before field investigations begin. Knowledge of the existence of malaria, encephalitis, or schistosomiasis in the study area allows individual team members an opportunity to minimize personal exposure to these disease carrying organisms.

MANAGEMENT PRACTICES OF THE FARMER

The last aspect of analysis is concerned with the management practices of the farmer and the effects these practices have upon the irrigated cropping system. A familiarity with the management techniques used by the farmer is critical to the understanding of the biological potential of the irrigated cropping system. Ideally, the agronomist would prefer to observe the farmer's management practices throughout a cropping season. However, time restrictions placed on most Diagnostic Analysis surveys usually permit field observations only during a portion of the cropping season. Therefore, the agronomist must obtain most of this information from interviews with farmers that are ordinarily conducted by the agricultural economist and extension team members. Whenever possible, the agronomist supplements this information with field observations of the farmer's current activities. This procedure is sufficient usually to identify areas of the farmer's management techniques that may be limiting the biological productivity of a particular irrigated cropping system. Some of the more important aspects of the farmer's management practices are:

- <u>Land preparation and tillage operations</u> - the types of tillage implements used by the farmer, the sequence and timing of tillage operations and the relative efficiency with which the various implements work the soil.

- <u>Irrigation practices</u> - methods of irrigation, irrigation scheduling, water application efficiencies, water quality, and so forth as described in the previous water use section under the physical system.

- <u>Soil fertility management</u> - the types of amendments applied to the soil, whether they be organic or inorganic amendments, the rates of application and the methods and timing of the amendment applications.

- <u>Seedbed management</u> - the methods of seed and seedbed preparation, the source of seed and its quality, the seeding rate, method of seeding and any special techniques used during the period of stand establishment.

- <u>Crop management practices</u> - variety of crop grown, plant spacings used by the farmer, methods of harvest and storage, and the crop rotations used by the farmer.

• Pest management - of concern are the farmer's ability to recognize various pests and the measures applied to minimize pest infestations. These measures may vary from the use of crop rotations to the application of agricultural chemicals.

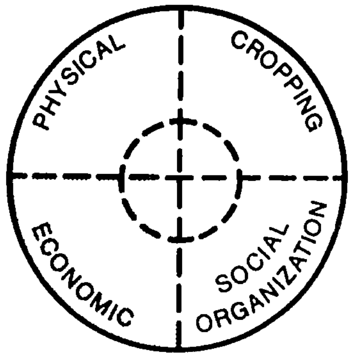
• Special management procedures - often a farmer adopts specialized management procedures to minimize environmental constraints such as high water tables, soil crusting, chemical imbalances, and periods of temperature extremes. A knowledge of why and how these procedures are used is important.

POINTS TO REMEMBER

It is important that a constant dialogue exist between team members during the period of Diagnostic Analysis. Discussions of each others findings insures that all of the implications of a particular constraint are thoroughly investigated. For example, low yields associated with a lack of fertilizer use may result from its high cost, availability, a lack of market facilities, roads or transportation, poor relationships between landlord-tenants, labor availability, water availability or inadequate yield responses - just to name a few! Therefore, the disciplines must work together to determine the relative contributions each factor has on fertilizer usage. This cooperation is necessary then if the cropping system is to be understood as an effective component of the irrigation system.

b1

IRRIGATION SYSTEM



ECONOMIC SYSTEM

The economic system is concerned with the productivity and allocation of resources. It impacts on all other systems as well as the ultimate decision-making process by the farmer.

Productive resources, also known as factors of production, usefully are grouped into four main categories: 1) natural resources, 2) labor, 3) capital, and 4) management. Land, which is a natural resource, is defined as the original and indestructible properties of soil. Land is productive as a result of human effort in cultivating, fertilizing, irrigating, and draining. The construction of dams and canals improves the supply of water. The results of these efforts are classified as a form of capital.

The term <u>labor</u> describes the effort of human beings, including the family and hired workers. The results of past human effort again is classified as <u>capital</u>. This category includes a wide range of items from durable capital, such as roads and machinery, to expendable capital, such as stocks of seed and fertilizer which may be used up within a single season. These resources of land, labor, and capital are organized into a productive unit we call the farm. It is a unit that must be managed.

THE DECISION-MAKING PROCESS

Every farmer, whether he is working one hectare for subsistence or 100 hectares for profit, makes decisions about the allocation of his productive resources. The farmer first needs to decide what crops to produce. Will his resources best be employed in production of cash crops such as cotton or groundnuts, or food crops? The farmer must decide to either specialize in one crop or produce a combination of several crops.

Given the limited inputs directly under the control of an individual farmer, expansion of one activity will involve contraction of another. In other words, if a farmer decided to expand his production of cotton, he may have to reduce the area available for food crops. The level of outputs per unit of land, on the other hand, can be increased within limits by increased use of other types of inputs.

Decisions also need to be made about the methods of production. Should the cultivation be carried out with the use of animal or mechanical power? What variety of seed should be sown? What fertilizers are to be applied?

Furthermore, decisions are needed regarding long-term payoff investments of items such as pumps and drainage channels. If greater income can be generated by making improvements in the irrigation aspect of production rather than in the marketing phase, then the resources should be allocated in that direction. Additionally, there are other essential and direct linkages between various farming activities and operations. For example, for an increase in the effective water supply to make the maximum contribution to a farmer's economic well-being, marketing constraints may need to be removed.

CHANGES WITHIN TRADITIONAL FARMING

Farmers may make their management decisions by following tradition. They, as their fathers before them, grow the same crops by the same method they always have used. This practice insured their subsistence. Today, a greater awareness of opportunities for an improved standard of living causes farmers to consider and accept change. Science and technology provide new varieties of crops and new methods of producing them. With improved management, progressive farmers can increase the output from their limited resources of land, labor, and capital.

The technical and socio-economic constraints that prevent farmers from achieving the output potential of their farm differ among countries and even among regions within a country. In this section we will:

1. Describe the role of economics in farming and as part of a Diagnostic Analysis;

2. Define the difference between economic and physical efficiency;

3. Explore various farm management activities;

4. Demonstrate some of the economic principles utilized in the decision-making process at the farm level; and,

5. Examine briefly the economic implications of long-term investments.

ECONOMICS AND FARMING

The contribution of economics to the farmer's decision-making process lies in estimation of cost and returns. The word cost is used here in its broadest sense meaning not only an expenditure of money, but also the sacrifice of leisure, food, or anything else that is valued by the farm family.

Where money or other objective measures are used, the value of income over cost is called profit. It is assumed that a farmer attempts to maximize profit; however, security, which cannot be measured objectively, plays a major role in the farmer's decision-making. Growing traditional crops for home consumption, as well as cash crops, provides protection against various risks. The cash crops may fail, their prices may fall, or the cost of staple food may rise. The farmer's objective then is the maximization of his well-being. A farmer's well-being is increased by the benefits of farm output and decreased by the costs of sacrificing food, leisure, money, and/or taking risks.

Before you can make a comparison of benefits and costs, you need technical information on the physical relationships between inputs of land, labor and capital, and the expected outputs for each alternative open to the farmer. Allocation of farm resources also needs to be assessed in an environment of social and governmental regulations as well as changing market conditions (see Figure 23).

Therefore, when you investigate a particular farm problem, you need the following diverse information:

1. The availability of resources, both on and off the farm, such as land, labor, water, fertilizer, credit, and equipment;

2. The technical information from various disciplines including agricultural engineering and agronomy. (This information would include improved farming practices as demonstrated in irrigation, planting, and weed control.);

3. Market price information for both inputs (e.g., credit, fertilizer) and products (e.g., rice, wheat); and,

4. The governmental and social-organizational constraints that limit the farmer's production choices. (For example, these constraints would include the price distortions resulting from agricultural policies at the government level, the farmer's attitudes and behavior toward new inputs, and changes in cropping patterns and farming practices.)

An economically efficient and viable solution to any farming problem will be found and successfully implemented only when it is based upon a comprehensive assessment of all the above factors.

ECONOMICS AND DIAGNOSTIC ANALYSIS

The role of economics in the Diagnostic Analysis is to delineate economic problems, to identify linkages between economic and other constraints, and to determine the losses associated with technical, institutional, social, and economic constraints. The type of the interaction between economics and the other disciplines and the contribution it makes, varies within each phase of the investigation. For example, the

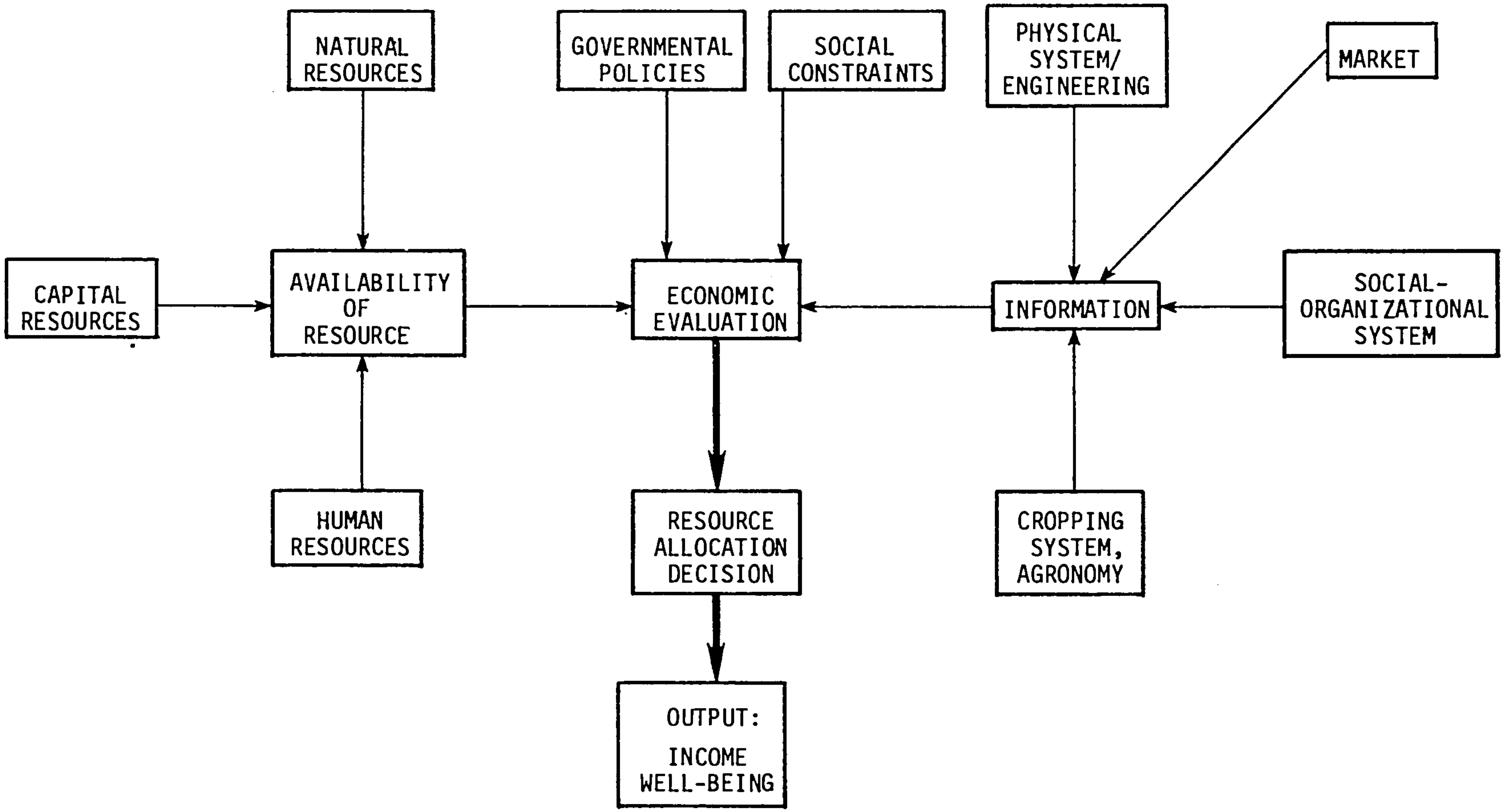


Figure 23. Inputs and Constraints Affecting Resource Allocation

problem of inadequate water supply to part of the command area will be measured by irrigation engineers. It also needs to be evaluated by economic analysis which includes yield data, use of supplementary inputs, cropping pattern, and cropping intensity. The overall impact of inadequate water supply on output and farm income then can be assessed. The difference between actual income from farms operated under the inadequate water supply situation and the potential income will indicate the magnitude of the problem.

Furthermore, in searching for a solution to inadequate water supply, an irrigation engineer may look at the possibilities for increasing the water allotment to the command area, improving the distribution within the command area, minimizing conveyance and seepage losses, and supplying ground water. In this situation, an economist would collect the relevant cost and return information and identify the least costly and economically feasible alternative. Economic principles and tools also can be employed to establish priorities for the problems that need to be resolved. In short, the decision to implement a solution or select among alternative solutions needs to be based on economic considerations and implementation rather than simply the engineering feasibility. The social soundness of the proposed solutions also must be considered.

In the following section, the relationship between the economics and physical components of an irrigation system is further highlighted by exploring the concept of efficiency and the difference between physical and economic efficiency.

EFFICIENCY: PHYSICAL AND ECONOMIC

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 use of input. Output can be a physical good or a service, and the input can be a physical input or knowledge.

Economic efficiency, on the other hand, is concerned with the optimal allocation of resources among alternative uses, and optimal combination of inputs in a production activity with the objective of maximizing profit. Economic efficiency consists of both technical and allocation efficiency.

-- Technical efficiency measures the differences in output as a result of full use of resources as opposed to over or under use. It also measures different methods of production.

-- Allocative efficiency deals with optimal use of input combinations.

The objective of irrigation engineering is to improve the physical efficiency of the system so as to improve crop production. Such an objective would include minimum water loss in delivery and application, uniformity of application, and minimum erosion. The agronomist, on the other hand, concerns himself with factors affecting yield maximization on a sustained basis.

The maximum physical efficiency of an irrigation system or the maximum yield per acre coupled with the improvement in the farmer's welfare, however, can be achieved only if all resources were free! In other words, inputs and practices that might achieve maximum physical efficiency (maximum output per unit of land) might be undesirable or inefficient from the economic point of view.

This 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. For this example we will consider all the other inputs as fixed and will focus only on water application and its impact on yield (see Figure 24).

The total output curve describes the response of yield (output of wheat) to water application. At zero supplemental or irrigation water an output level w is achieved from the application of other inputs and water from the rain. Water application 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 waterlogging which will lower the yield or output.

Without considering either the cost of the water or the cost of the produced output (or when there is a zero cost for water) the rational choice would be to apply water level B and achieve maximum output level x. However, water is not free: there may not be a delivery cost, but there is always an application cost. If water is priced on the basis of supply and demand conditions, then the cost of water would include its scarcity value as well. For example, suppose the price of water is fixed at L dollars per unit as shown by horizontal line LS in Figure 24.

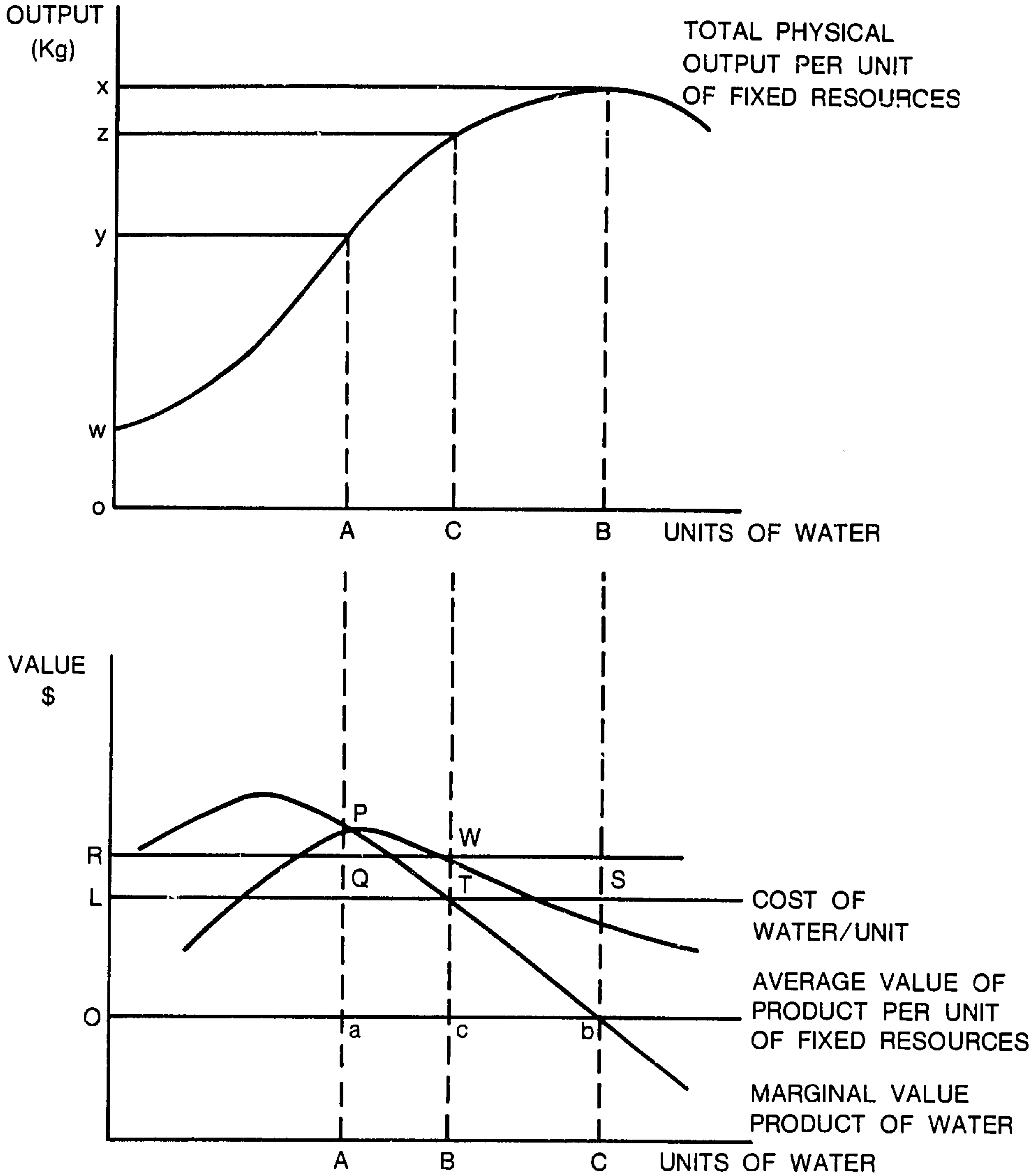


Figure 24. Physical Versus Economic Optimization

The increase in yield from each additional unit of water continues to decline as more and more units of water are applied (that is c lled the law of diminishing returns) as well as the value or return from each additional unit of water. 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 to the farmer is equal to the area ORWc and cost of water equal to area OLTc and the return to the other input factors and farmer's effort is equal to LRWT.

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

FARM MANAGEMENT ACTIVITIES

Farm management also affects decisions regarding the economic optimum. The economic aspects of farm management includes five broad categories: production activities, capital building activities, commercial activities, financing activities, and accounting activities. These activities require a series of decisions that are to be made by the farmer. Examples of each of these activities are as follows:

Activity	Example
1. Production activities	Input level and combination, Enterprise choice and combination, Tillage practices, Irrigation practices;
2. Capital building activites	Purchase of machinery, Lining ditches, Drainage construction, Leveling land;
3. Commercial activities	Marketing outputs, Purchase of inputs;
4. Financing activities	Acquiring funds, Using funds, Forecasting future financial needs; and,
5. Accounting activities	Production records, Transaction records, Tax records.

It is in the production and capital building activities that such disciplines as engineering, agronomy, economics, and sociology come together to assist farmers in their decision-making process. Farm production activities involve decisions on resource allocation, adoption of new inputs such as chemical fertilizer, high yielding crop varieties, and/or changes in farming practices.

Capital building activities refer to accumulation and improvement of durable inputs. These activities include investment in durable inputs, such as farm equipment and investment in farm improvement, as irrigation and drainage systems. Improvement also could be made in human capital, for example, the training of farmers. Capital building activities generally require large investments; the benefits from these investments occur over an extended period of time.

Commercial activities involve decisions on marketing agricultural commodities and the purchase of non-capital farm inputs. Financing activities are concerned with obtaining and using funds or financial capital. Commercial and financial activities primarily fall in the realm of the economist. All these activities and the related decisions, however, are influenced by social-organizational factors.

Accounting activities assist farmers in making technical, commercial, and financing decisions. Specific records are kept by the farmer and accounting statements may be prepared to meet the requirements of governmental agencies and other institutions.

A more detailed review of these five activities would be beneficial.

Production and Capital Building Activities

Decisions, undertaken by farmers, concerning production and capital building may be classified under:

- Variable or short-run production activities.
- Fixed or long-range investments and commitments.
- Farming practices for both short and/or long-range activities.

In any particular year, the farmer must decide what to produce and how much. This decision is dependent upon the availability of inputs, the farm family's food requirement, and the product and input prices. Costs and benefits associated with short-range production decisions generally occur within that particular production season.

Decisions on long-term investments--such as irrigation pumps or the installation of tile drains--have protracted impact on the profitability of the farm. Benefits that accrue over the years from these investments need to be assessed and compared against the cost of such investments.

Farming practices (or methods of production) are included both in short and long-range decisions. For example, a change in the level or method of irrigation, without a major structural change or investment in machinery, often does not require substantial change in production cost. On the other hand, the introduction of machinery, major improvements, and the use of chemical fertilizer are recognized as an intensive farming practice. Expanding the land area by renting or buying is another extensive farming practice.

Commercial Activities: Marketing Decisions

Farmers engage in a series of post-harvest activities that are classified as marketing. Such activities include some on-farm processing, storage, and transportation. They also involve cost while at the same time adding value to the farm commodities. If the efficiency of these activities is increased, production and the supply of agricultural commodities available for sale increase.

Proper storage reduces losses; the optimal storage time is determined by the changes in market price of the products stored as compared to the cost of storage. Reduction of the loss due to the processing of certain crops at the farm level may be accomplished by switching from traditional to modern methods.

Large seasonal price fluctuations occur in low income countries. The farmer's need for cash to pay his debts or to make cash purchases forces him to sell his crops soon after harvest when prices are low. Financial planning by farmers may remove this pressure therefore allowing for more efficient marketing practices.

If farmers are aware of prices in other regions and urban centers of the country, their bargaining position is improved. This is particularly true when the number of buyers is limited. Likewise, agricultural cooperatives can provide a farmer with a collective and, therefore, stronger, bargaining position in the sale of his products. Knowledge of market conditions and farm cooperatives also can assist farmers in the purchase of inputs such as fertilizer and seeds.

Financing Activities: Credit Decisions

Financing activities at the farm level becomes important when there is a move from subsistence farming to diversified or mixed agriculture. The amount of funds at the farmer's disposal affects production decisions. Funds are required to purchase various traditional and non-traditional inputs essential for production and therefore the profitability of the farming operation. Such funds can be acquired by production of cash crops, off-farm employment, and/or borrowing from various governmental or private lending institutions.

The use of high payoff non-traditional inputs, such as chemical fertilizer, fuel, and pumps, requires economic and financial analysis of these changes. A farmer needs to identify his various sources and uses of cash funds and undertake a 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.

Accounting Activities: Sources of Information

Farm records are sources of information which readily aid the farmer in the improvement of his farming operations. Information can be analyzed by the farmers themselves or by outside researchers or various governmental agencies involved in assisting the farmer.

Farm records provide information about crop yields, levels of purchased inputs used, hours of hired and family labor allocated to various crops, input costs, and product prices. Differences in the use of inputs, production practices, and profitability of farms of a similar resource base can be used in identifying various problems.

Productivity differences between progressive and traditional farmers are revealed in farm records and can be useful. Quantitative evidence can make a strong case to the traditional farmers for the need to change. Progressive farmers, who are in closer contact with research institutions and government extension agencies, often are more responsive to the adoption of new techniques and inputs. Farm records of these farmers make it possible to evaluate the increased profitability of such techniques and inputs.

Experienced researchers and extension workers, who are familiar with a particular farming region, can use production records to identify possible sources of problems which then can be evaluated by an interdisciplinary team. An evaluation then could identify and evaluate possible solutions.

In summary, farm records are kept for the five reasons listed below:

- To establish a factual basis on which the performance of other comparable operations and the past year's performance can be compared. The actual records of inputs and outputs also are used for planning and setting targets.

40

- To determine the existing profitability and the income potential of the system based on farm level data collected during the Diagnostic Analysis or on long-term farm records. Farm records also can be used as baseline data for the monitoring and evaluation of various solutions when they are tested and/or implemented.

- To aid planning by providing data that can serve as a base in estimating the effect of operational changes on productivity and the income of the farm.

- To aid in obtaining credit.

- To meet any tax reporting requirements and to assist in tax planning and management.

ECONOMIC PRINCIPALS USED IN DECISION MAKING

Opportunity Cost Principles Applied to Labor Utilization

Labor is one of the major inputs in traditional farming. The farm family contributes a large number of person-hours or days to farming. It is essential for the farmer to recognize and estimate the contribution of this labor input to the total farm output and income. The members of a farm family also may work on another farm or in the industrial or service sectors of society thereby receiving outside income. The money that could be earned in alternative employment is given up if these family members only work on their own farm. The income from outside employment is an opportunity cost to the family farm and must be considered in decision making.

The farm family interested in increasing its profit will allocate labor so that the total family income from both the farm and outside employment is maximum. The economic optimization principle applied to this situation equalizes the marginal value product of a unit of farm labor and the opportunity cost of a unit of labor. The opportunity cost is the unit labor wage rate that the family member can obtain from outside employment; the marginal value product is the value of farm output if the family member worked on the farm. Farm labor is optimally allocated between the family farm and other employment

91

when the hourly wage from outside employment equals the value of additional farm output if that labor would be used on the farm. However, socio-cultural factors, such as the high value placed on staying in close proximity to one's family, may lead to an allocation of labor that is not economically optimal.

Principles of Equal Marginal Returns

Where there is a cost associated with water use, for example, or a limit placed on the quantity of water available for each farm, a farmer's income may be influenced by his water allocation decisions. If water is unlimited and free, each field or crop should be irrigated to its physical maximum. In this situation the physical maximum also would be the economic optimum. However, even when unlimited water is provided at no direct charge to farmers, there are costs associated with its application, for example, pumping or irrigation labor time.

Under the principle of equal marginal return, water would be allocated between crops or fields so that the value of output of the last unit of irrigation water, the Marginal Value Product (MVP) of that crop, equals that of every other crop or field. For example, if a farmer has a limited allocation of water at zero cost per unit and is producing equal areas of three crops, the optimal resource allocation condition would require that:

$$MVP_A = MVP_B = MVP_C$$

$$VMP_i = MPP_i \times P_i$$

where, A, B, and C are the three crops.

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.

Table 3 shows an example of the equal marginal returns principle. If a farmer had 20 units of water, he would want to allocate 5 units to Crop A, 7 units to Crop B and 8 units to Crop C. Any other allocation of 20 units of water will not provide the 215 dollars this distribution yields.

Table 3. Example of Equal Marginal Returns Principle

Input Water (units)	Crop A TVP ($)	Crop A MVP ($)	Crop B TVP ($)	Crop B MVP ($)	Crop B TVP ($)	Crop B MVP ($)
1	15	15	16	16	15	15
2	27	12	30	14	29	14
3	37	10*	42	12	42	13
4	45	8	52	10*	54	12
5	51	6**	61	9	65	11
6	54	3	69	8	75	10*
7	54	0***	75	6**	83	8
8	50	-4	79	4	89	6**
9	45	-5	81	2	93	4
10	39	-6	81	0***	95	2
11	32	-7	78	-3	95	0***
12	24	-8	73	-5	93	-2

* Water price = 10 dollars per unit
$MVP_A = MVP_B = MVP_C = 10$ (3+4+6 = 13 units of water)

TVP = Total Value Product
MVP = Marginal Value Product
A,B,C = Crops A, B, C

** Water Allocation = 20 units
$MVP_A = MVP_B = 6$ (5+7+8 = 20 units of water)

*** Water price = 0 dollars per unit
$MVP_A = MVP_B = MVP_C = 0$ (7+10+11 = 28 units of water)

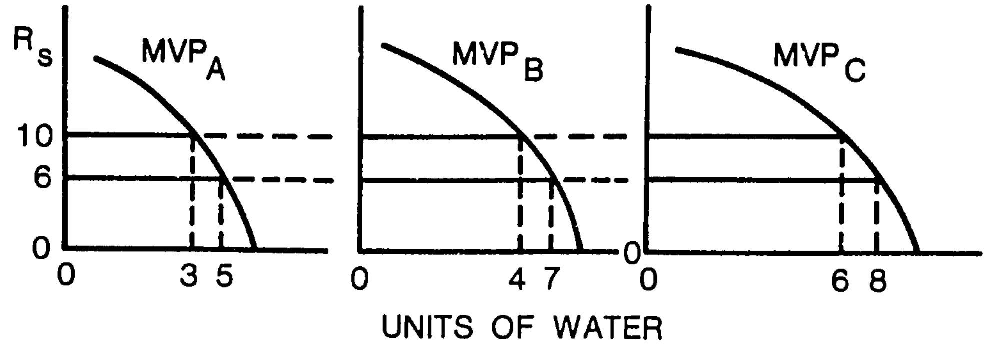


Figure 25. Return, Cost, and the Level of Water Utilization

If unlimited water was provided free of charge, 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 7 units are applied in the production of Crop A, 9 units in the production of Crop B, and 10 units in the production of Crop C. The value of total farm production would be a maximum of 230 dollars with this water application pattern. However, in the real world, water is neither free nor unlimited!

If water has a price greater than zero, a farmer would not want to irrigate beyond the level where the MVP of the given crop equals the cost of the water applied--even when the quantity of water is unlimited. Therefore, based on Table 3 and Figure 25 a charge of 10 dollars per unit of water would dictate that only 3, 4, and 6 units of water be applied to the three crops.

Farmers who attempt to use more than the 13 units of water when the price of water is 10 dollars per unit would have an increase in water costs greater than the return from the additional units of water applied. This pattern of water application results in a maximum farm production value of 164 dollars. Given no change in the 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 3).

Principle of Substitution

In resource allocation analysis we view the various crops which are produced as fixed (or given) and then search for the optimal allocation of inputs among them. Conversely, a farmer assesses the various inputs, such as land, machinery, water, as well as the market value of various crops, to select an optimum combination of farm enterprises. In addition, the farmer considers social constraints and governmental policies in making this decision. This extremely important economic decision is made by the farmer before each planting season.

The most profitable combination of farm enterprises is achieved when the expansion of one farm enterprise and the consequent reduction of other enterprises from associated resource reallocations, cannot lead to a further increase in the farm income.

For example, in the case of one factor and two products, the decision rule requires that the marginal rate of product substitution (MRPS) between the two products equals the inverse of the negative price ratio of these two products.

$$\text{MRPS of Crop A for Crop B} = \frac{\text{MRPS}_A}{\text{MRPS}_B} = \frac{\Delta A}{\Delta B}$$

where, ΔA and ΔB are the changes in production when resources are reallocated between Crops A and B.

$$\text{Negative Prices Ratio} = -\frac{\text{Price}_B}{\text{Price}_A} = -\frac{P_B}{P_A}$$

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

In a real farm situation, however, a large number of inputs and outputs enter the decision-making process. Linear programming could be used as an analytical technique in determining the optimal choice of farm enterprises.

FIXED INVESTMENT DECISIONS

Production decisions at the farm level, however, go beyond short-term resource allocation. Long-range investments in and improvements of the farm--such as land leveling, the construction of lined ditches, drainage systems, and/or the introduction of machinery--also need to be evaluated on the basis of their economic merits. Such investments have implications at both the farm and national levels. Investments in farm machinery that replaces labor may directly increase the benefit of a number of individual farmers, but also may add to a national unemployment problem.

An individual farmer, however, makes his investment decisions on the basis of costs and benefits directed at his operation rather than the economy or society as a whole. Yet they are mutually related: changes in national monetary valuation and policy, for example, would be reflected in the cost and price structure which, in turn, affects the farmer's investment decisions.

Consider the case where an improvement in the irrigation system could be made by land leveling. Land leveling requires a large investment in terms of equipment and labor when undertaken, but the benefits from it continue over an indefinite period of time. You would need to include an analysis of the benefits that may arise from yield increases and reduction of water use over the life of the improvement. The cost of leveling would include the actual leveling cost plus interest, which reflects the cost for borrowing the funds, and/or the opportunity cost of using the farmer's savings. The discounted value of the benefits are then compared to 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.

Land leveling itself would need to be compared, however, to other available investment alternatives. A reorganization and improvement of the water delivery system at the farm level could be another area of proposed improvement. Still a third alternative might be a major investment in a well and irrigation pumps, perhaps as a joint venture with neighboring farmers.

These three areas of alternative investment are not mutually exclusive technically. The initial investment requirements, though somewhat different, could be assumed to fall within the farmer's financial resources. However, the large investments required by each one and the farmer's financial constraints necessitates that a choice be made.

The farmer's decision depends on several variables that affect the investments profitability and implementation. Among others, these variables include:

-- The initial investment required,

-- The productive life of the investment,

-- The discount rate,

-- Annual operation and maintenance cost,

-- Amounts and schedule of receipts,

-- The nature of relationships with other operations on the farm,

-- Socio-cultural factors, and

-- Governmental policies.

Assuming that each one of the three alternatives could be implemented and were equally desirable from the social and governmental points of view, then the choice would be based on the net increase these investments could bring about in the farmer's income. Such an economic analysis and comparison can be made by estimating the internal rate of return or by a partial budget analysis. (See Volume 2).

If projects needed different levels of investment capital, they should be undertaken in order of their internal rate of return. Table 4 shows three projects in which each has a different level of investment capital, annual return, and annual internal rate of return. Although alternative C has the highest annual return, the other two projects have higher annual internal rates of return and should be undertaken first.

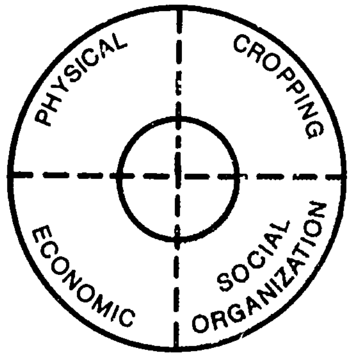
Table 4. Example of Evaluating Fixed Investments

Project	Investment ($)	Annual Return ($)	Annual Internal Rate of Return (%)
A	5,000	1,500	30
B	10,000	2,000	20
C	25,000	4,000	16

POINTS TO REMEMBER

To correctly diagnose problems within an irrigation system and to identify their appropriate solutions, it is essential that the economic efficiency be determined and included in any criteria which might be used. The loss of income associated with the various problems and the potential benefits that might result from the proposed improvements need to be correctly assessed in economic terms. The economic system affects all the other components of the irrigation system. Conversely, economic decisions also need to recognize and address the physical, biological, and social-organizational components of an irrigation system.

IRRIGATION SYSTEM



THE SOCIAL ORGANIZATIONAL SYSTEM

Irrigation is a supremely social process. Some form of organization must exist in an irrigation system to provide even minimal operational efficiency. If there are two or more potential users of the water, collective action by those people must exist to manage the irrigation system. How people are organized or not organized will have a great effect on the management of that water. Defects in water delivery, application, use, and removal will often be associated with problems in the social organization of the irrigation system, including constraints on farmers and official decision making. Therefore, while the engineers and agronomists involved in a Diagnostic Analysis examine the "tools" of irrigation, the social scientists must look at the "rules."

Human and natural resources as well as certain organizational procedures are needed to effectively manage an irrigation system. These resources and procedures, however, do not emerge on their own; people must first organize to create and maintain irrigation works. Irrigation water does not simply spring from the ground or sky magically working its way through rivers, dams, canals, watercourses, and fields. Water is only delivered effectively to a farmer's field--at the right time and in the right quantity--when people have organized to supply the water and maintain the delivery system. Some social arrangements must exist to manage the water.

By viewing an irrigation unit as a kind of organization, a field sociologist can identify certain patterns of behavior and social interaction. In Diagnostic Analysis, we study these patterned social relations and the organizational arrangement necessary to manage the water. We examine the social and cultural structures and relationships within and between the suppliers and users of irrigation water.

A field sociologist in Diagnostic Analysis must look at the patterned social web of relationships among people, organizations, and the environment. For instance, what are the relations among the farmers in an irrigation system and between the farmers and the irrigation agency? How do these relations and patterns of social behavior and human interaction influence irrigation system management? The sociologist needs to study how the physical irrigation technology is linked with the social organization of irrigation.

It is important to realize, however, that these patterns of behavior which make up the social organization of irrigation can be either formal or informal. It is important in Diagnostic Analysis to examine both types of behavior. Formal behavior patterns are made up of written and explicit rules, penalties, rewards, and values. These patterns of behavior usually evolve into organizations such as an Irrigation Department or a farmers' cooperative society. Informal patterns of behavior usually contain unwritten and implicit rules, penalties, rewards, and values; they often involve people in face-to-face relationships. Informal behavior patterns might include a small group of farmers agreeing to clean a canal and share water or the same farmers meeting with irrigation officials to discuss water distribution.

FARMER IRRIGATION BEHAVIOR AND DECISION MAKING

A Diagnostic Analysis of an irrigation system should include a study of the factors which influence farmer behavior. A sociologist working in the field needs to understand farmer irrigation behavior and how the farmer makes decisions regarding irrigated agriculture. Mistakenly, we often do not study the farmers themselves, but merely the consequences of their behavior, such as irrigation efficiencies and crop yields. By directly studying farmers' behavior patterns and decision making, a richer and more detailed picture emerges of how an irrigation system operates and the possible constraints on that system.

One possible method of examining farmer behavior and decision making involves dividing the farmer's social environment into situations and actions. Situations are composed of the particular setting of the farmer, the culture of the area, and the social structures and processes surrounding the farmer.

The actions are the actual results and decisions made by the farmer. The factors making up the farmers' situation then result in a set of behavior patterns and decisions.

Setting

The setting refers to the physical and social environment in which the farmer works. Under this category, the sociologist might want to look at the size of the irrigation system and the farms, the timing of crop planting and harvesting, and the type of agricultural technology available to the farmer. The setting should give an idea of possible natural determinants of farmer decisions.

Culture

Culture describes the patterned ways of thinking, feeling, and behaving within the social setting. Here one must study the various rules which influence behavior, the relationships between farmers and between farmers and various governmental officials, and the values which the farmers hold. The farmers' informal cultural rules often will have a greater influence on his behavior than any legal or written laws.

Structure

The structure of the social organizational system describes the form of that system and sets the boundaries for farmer irrigation behavior. Various tenancy arrangements in an irrigation system could be studied as well as the power relationships in the area. Who are the most powerful farmers? Is it those farmers who have large landholdings, those who associate with influential families or higher castes, or those with political connections?

Processes

Processes are long continued actions by individuals or organizations that create different social arrangements. The process of communication, for instance, through an extension program can change old farming habits so that farmers may increase their yields.

A study of the adequacy of important institutional services also might be conducted here. Are farmers served by a set of organizations which can reliably provide important services of high quality? Such services might include credit, transportation, seeds, fertilizer, pesticides, and extension advice. An analysis might be made of agricultural and irrigation bureaucracies to determine the quantity and quality of such inputs and services. We need to look at the knowledge, skills, and information sources of farmers to understand their decision making and its impact on the management of an irrigation system.

Results

The results of all these factors which make up the farmer's situation is the actual decision making and irrigation behavior of the farmer. As a result of the setting, culture, structure, and processes facing the farmer, how does he actually irrigate his fields? When and how much water does he apply to his crops?

A study of farmer behavior and decision-making should be a part of Diagnostic Analysis. As the farmer is the basic building block of any irrigation system, a knowledge of how and why he acts in a certain way is very important. If we are to study the patterns of human behavior which manage an irrigation system, it is also necessary to examine how those behavior patterns and decisions come about.

SOCIAL ANALYSIS OF AN IRRIGATION SYSTEM

While the analysis of farmer behavior and decision making might be carried out in the manner just described, the study of the social organization of irrigation itself requires a slightly different strategy. By examining different irrigation tasks at different levels of analysis, an irrigation system can be studied from a social perspective. Just as an agronomist takes a certain strategy out to the field to study the plant-soil-water relationship, so too, the social scientist needs a framework to examine the social and organizational aspects of irrigation. Such a scheme or framework is presented in Figure 26.

In any irrigation system, whether in the developed or developing world, certain fundamental tasks must be performed. Three of these tasks are displayed in Figure 26: water allocation/distribution, system maintenance, and conflict management. (See Freeman and Lowdermilk, 1983; and Coward, 1980).

Water allocation/distribution refers to the task of allotting and dividing the irrigation water among the various users. In any type of irrigation system, the water must be distributed from the source to the farmers. In a groundwater irrigation system using only water from tubewells, the task of water distribution can be studied in a relatively compact area.

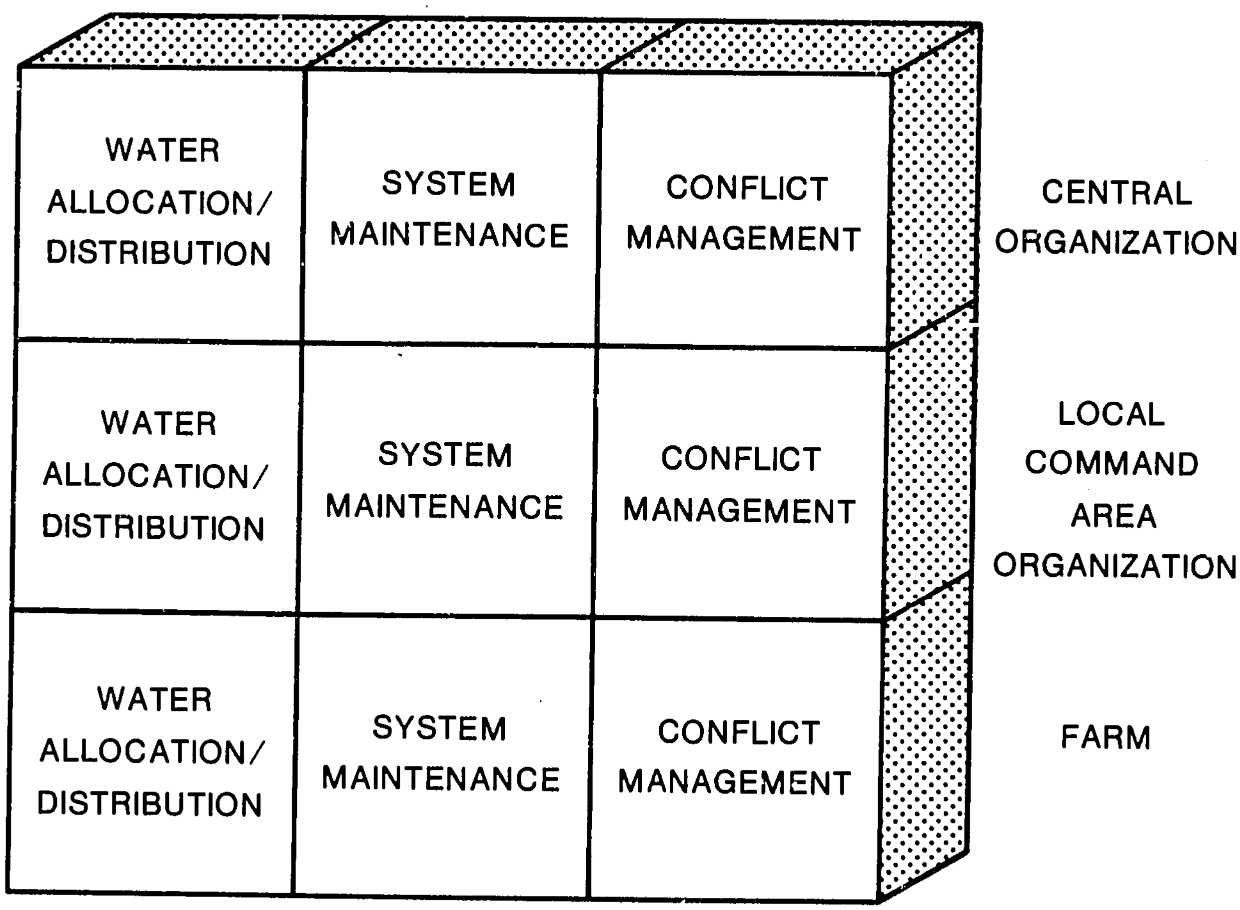


Figure 26. Social Organization of Irrigation

In a surface water gravity system, however, the distribution of water may take place over hundreds of kilometers and thousands of hectares.

Another fundamental task that must occur is system maintenance, which is also a part of water management. The cleaning and repairing of the physical structures in the system are necessary but often neglected. If canals and watercourses are not properly cleaned and maintained, if no timely service is given to tubewell pumps, or if diversion structures are not periodically repaired, the task of properly managing the irrigation water becomes extremely difficult. System maintenance must be performed to ensure an efficient irrigation system.

A final critical task or action is conflict management. In virtually every irrigation system around the world, some degree of conflict exists. Where water is scarce at the farmers' fields, competition for that scarce resource exists. The competition results in conflict that ultimately can lead the participants to engage in mutually destructive behavior. Two groups of farmers, for example, may be in conflict over the amount of irrigation water they receive, leading to one of the groups destroying a section of the watercourse channel. Such action actually could reduce the degree of water control for both groups of farmers. At other times, however, the conflict can be managed in a mutually beneficial way where no parties are hurt. For example, a conflict over water delivery schedules perhaps could be resolved if the farmers collectively help to establish the schedule.

The task of conflict management refers to containing and channeling these disputes and disagreements into non-destructive forms of behavior. This is not to say that conflict must be or can be totally resolved; that may be an impossible task in some irrigation systems. To operate efficiently, however, the conflict in a system must be managed to some degree.

Three Organizational Levels

As Figure 26 also demonstrates, each one of these three universal tasks must be performed at three organizational levels. Each of these fundamental irrigation activities must be addressed at the individual farm level, the local command area organizational level, and the central organizational level. Except for small-scale, communal systems, these three levels of analysis are encountered in irrigation systems throughout the world. In Diagnostic Analysis, we want to examine the relations within and among those different levels.

91

For our purposes, the farm level refers to that part of the irrigation system which passes through an individual farmer's field(s). It is commonly thought of as that part of the irrigation system below the outlet. Here the farmer usually has direct control over the irrigation water and personal responsibility for the maintenance of the field channels.

Individual farmers, however, rarely act in total isolation. They usually are participants in local formal or informal organizations which help to manage the irrigation water. The level of the local command area organization refers to the local farmer organizations based along the watercourse or in the village. Here collective decisions are made concerning water management. Though in some irrigation systems a formal organization may not exist, in all systems at least an informal organization of water users operates. This is an extremely important level of analysis as it is the link between the central bureaucracy, which often controls the capture and delivery of water, and the individual farmer who uses the water.

These local organizations often must interact with large governmental organizations. The level of the central organization refers to the irrigation bureaucracy which usually has control over the main system and large quantities of water. This central bureaucracy is normally a part of a country's irrigation department and customarily is responsible for the operation of a system's dams, canals, and main structures. Agricultural departments, extension services, and other governmental bureaucracies also are a part of this level. A field sociologist in Diagnostic Analysis needs to examine this higher organizational level, the individual farm, and local command area level to determine where the organizational problems lie.

Different Objectives and Priorities

It is important to realize that the personnel managing water and performing the fundamental irrigation tasks at each of these three organizational levels may have different objectives and priorities. What is important to an irrigation water official may not be so important to a farmer and vice versa. The primary concern of the central irrigation bureaucracy is to divide large quantities of water in main canals into smaller shares of water at the watercourse and farm level. During this division process, the managers at the central organization may simply desire an efficient and smooth running system.

The farmers at the individual farm level, however, may have an entirely different set of objectives and expectations. As the farmer receives his shares of water, he requires certain flexibility in the quantity and timing of water delivered. Depending on the weather, soil condition, variety of crops grown, and many other factors, the individual farmer will decide when to irrigate his crops. It is often difficult for the farmer himself to predict exactly when he will need the water, so he quite rationally desires some degree of adaptability and flexibility at the individual farm level.

As the central irrigation organization and individual farmer may have competing objectives in managing the irrigation water, the middle level of local command area organization becomes very important in mediating between the different priorities. The local command area organization must act as a bridge between the farmers and the central irrigation organization.

In a Diagnostic Analysis of an irrigation system then, these three different organizational levels need to be matched with the critical tasks or actions which are outlined in Figure 26. When examining an irrigation system, the sociologist can look down and across the tasks and levels displayed in Figure 26. The water distribution, system maintenance, and conflict management procedures need to be examined at all three levels. For instance, at the mid-level local organization, how does the formal or informal organization distribute the water? Who, if anyone, performs maintenance tasks along the watercourse? How are these tasks organized? How is conflict managed within the local command area organization? At the central organizational level, how are decisions made about distributing large quantities of water throughout the canal system and how are maintenance activities carried out?

In addition to studying each of the nine divisions displayed in Figure 26, the sociologist in Diagnostic Analysis also can analyze the quantity and quality of linkages among the various tasks and levels. For instance, what is the relationship between water distribution at the farm level, at the local command level, and the central organization level? Where does control of the water pass from the government bureaucracy into the hands of the farmers? At the local command area level? At the individual farm level? Alternatively, is the efficiency of water distribution practices at the central organization level affected by the system maintenance or conflict management procedures? If so, how? What are the relationships among these three tasks at the other levels?

By using the framework displayed in Figure 26, the sociologist not only can detail the existing social arrangements for irrigation but also can begin to identify the social and organizational changes that may be necessary for system improvement. If, for instance, there are problems regarding the distribution of water from the main system to the individual farm level, a potential solution might involve the establishment or strengthening of the local level irrigation organization. Filling in each of the divisions with information concerning the relevant rules, roles, and relationships will give the sociologist a focused picture of the social organization of any irrigation system.

FOUR BASIC QUESTIONS FOR ANALYSIS

While the field sociologist conducting a Diagnostic Analysis might begin the study with an examination of farmer decision-making or with the scheme presented in Figure 1, there are other areas of the social organization which need examination. The local level organization itself is a subject that should be examined during a Diagnostic Analysis. Though the organization may be informal with no written rules or procedures, an analysis of this level of organization is both feasible and desirable. The sociologist also needs to look at the organizational structure, formal or informal, of the local command area. To conduct such a study, four basic questions need to be addressed.

1. Who is eligible for membership? Though it is often assumed that a farmer who farms in the command area is automatically a member of the local organization, this is not always the case. Are tenant farmers eligible for membership, and if so, is their voice in the decision-making process heeded less because they own no land? If the association is formal, dues may be required; some farmers may choose not to pay these dues. Regardless of dues, other farmers may see no benefit in becoming involved in the organization and choose not to participate. Conversely, the organization itself may simply declare that any farmer who receives irrigation water is a member. Who is eligible for membership in the local command area organization then is a question which needs to be studied in some detail.

2. Is the staff composed of local persons or outside government officials? The staff of these local level organizations are typically either local inhabitants or outside government officials. The locals live in the immediate community and usually have their career within

97

the local organization. The outside government officials have only a temporary presence in the local irrigation community, and they spend their career within the centralized irrigation bureaucracy.

The composition of the staff can have a great bearing on the management of the system. If the staff of a local association is composed of outside government officials, it is likely that their objectives are the smooth functioning of the system. If the staff contains primarily locals, the adaptability of the system to specific circumstances might be their primary concern. In other words, whereas the outside government officials might have their loyalty to the government bureaucracy, staff from the local community could retain their loyalty to the agricultural needs of the farmers. The composition of the local organization staff is a question that needs to be addressed when studying the social organization of irrigation.

3. <u>To whom is the organizational staff responsible</u>? This same staff is responsible to someone or some group of people. To whom the organizational staff is responsible also has a direct bearing on the management of the irrigation system. The staff might be responsible to a higher central authority such as a civil service system. Other local level irrigation organizations may have their staff responsible to the local farmer members themselves. In these cases, the staff or water authorities may be the same as the water users themselves. These staff people might be hired on the local labor market as opposed to assigned to the particular system by the central irrigation bureaucracy.

To whom the leadership of this staff is accountable is a particularly critical issue. If the leadership is directly accountable to the membership, how will their behavior differ from those staff members who are accountable only to the central governmental organization?

4. <u>How will resources mobilize to sustain the organization</u>? The resources used to maintain the organization can come from a variety of sources. They simply could be provided by a higher authority with very little participation by the farmers. Conversely, the resources could be supplied by the farmers themselves. If supplied by the local community, the resources could be

provided either by a direct labor mobilization or by mobilizing cash to hire a special staff.

The different types of resource mobilization would have a bearing on the operation of the irrigation system. Do resources provided by the local irrigation community give the local farmers a greater sense of ownership and control over the irrigation system? Under these conditions, do the irrigators consider the irrigation network "our" system as opposed to the government's or "their" system? The sociologist in the interdisciplinary team could study whether a closer identification with the irrigation system prompts the farmers to take better care of the system and become more involved in overall water management activities.

All four of the above questions involve important issues in the study of the social organization of irrigation. During a Diagnostic Analysis, however, the field sociologist may wish not only to answer these questions for a particular irrigation system but also to test some specific hypotheses concerning the structure of irrigation organization. Figure 27 displays the type of hypothesis testing which is possible by using the four questions described above.

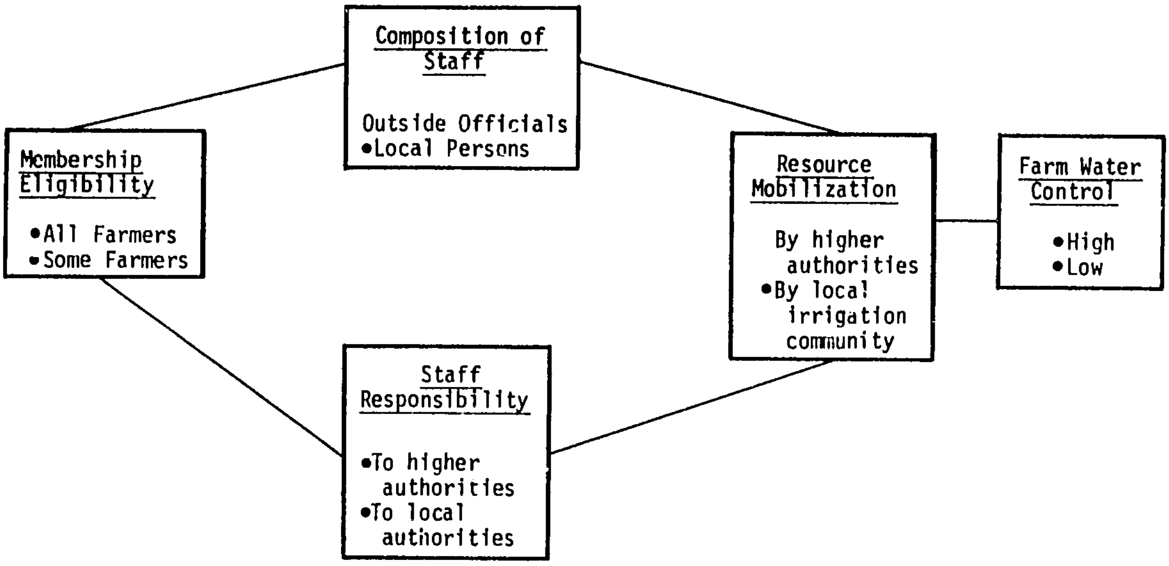


Figure 27. Possible Hypotheses for Social Organization of Irrigation

If, in a particular irrigation system, the sociologist discovers that only those farmers who pay dues are formal members of a local level organization, that the staff is composed of locals responsible only to local authorities, and that the resources are mobilized by the local irrigation community, then how do these conditions affect the degree of water control exercised by the farmer? Under a totally different set of circumstances, (for example, all farmers are eligible for membership, the staff is made up of outside government officials accountable only to a higher irrigation authority, and the resources are mobilized by the irrigation bureaucracy), we might reach a very different conclusion regarding farmer water control. There are obviously a number of potentially different conditions displayed in Figure 27. An important element in the study of irrigation's social organization would be to see how these diverse circumstances affect the farmer's water control and water management.

ANALYSIS OF ORGANIZATIONAL RULES

Another component in the analysis of the social organization of irrigation involves the rules of the formal or informal organization. These rules may be either written and specific or simply implied and unwritten, depending on the type of irrigation organization. These may be rules specifying the particular water distribution or system maintenance procedures or they may be other rules specifying behavior within the organization itself, such as rules for membership or dates of irrigators' meetings.

The rules governing irrigation water management need to be examined objectively. In Diagnostic Analysis, we need to examine how these rules or laws operate as incentives or discentives to improved farm water management. The field sociologist needs to compare the specific laws and rules with the actual behavior of the farmers in the field. Is there a difference between what the laws and rules state, and what is actually taking place in the field? What the formal rules and regulations call for is often found not to exist in the real world of the farmer.

Such an analysis does not mean that a participant in Diagnostic Analysis is to be a policeman. Rather, the social scientist is simply trying to discover if there is a difference between what the law states and what actually takes place. If there is a large difference between the two, it might be an indication of inefficient water management codes. For example, some farmers might be forced to break an old and inflexible law to obtain more water control in their irrigation operations.

Regardless of the particular details of these codes of behavior, there are certain questions which can be asked about these rules. These questions will help not only the sociologist to identify the rules of the organization, but also will allow him to evaluate the organization.

1. <u>Are the rules known by all?</u> Are all the irrigators who are a part of the organization aware of the rules or codes? If some farmers know the rules but others do not, those who do not know them can be placed at a disadvantage. These hidden regulations could easily be used to the detriment of those farmers who are unaware of them.

2. <u>Are the rules clear and consistent?</u> Even if the organization's rules are known by all,

problems still can develop if these rules are not clear and consistent. Contradictory or confusing codes can lead to poor water management practices or farmers ignoring the rules altogether.

3. Do farmers perceive the rules as unbiased toward their group? In any irrigation system, there are various groups based on family ties, political factions, religious beliefs, settlement status, or any number of other factors. Often these groups will be competing with one another for scarce irrigation water; they will attempt to use the rules to gain access to that water. If these groups believe that the regulations are biased in favor of another competing group, a great deal of unmanageable conflict can result.

4. Do the rules reward those members who follow them? Often penalties are imposed against those farmers who break the rules of the organization. While some form of penalty is frequently effective, farmers could be rewarded to gain compliance. If some small reward is given, it might be an incentive for the farmer to adhere to the rules.

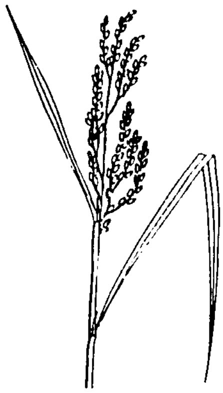
5. Are the irrigation rules supported by the norms of the local groups? Each culture and group contains certain norms or rules for behavior. While analyzing the rules of an irrigation organization, it would be helpful to determine if the organization's rules are supported by these norms. For instance, if a norm of the group is that older people are highly respected, then a possible rule for the local irrigation organization might be to give a village elder an advisor's role within the organization. If the rules of the organization violate many of the norms of the local group, serious water management problems could soon develop.

The five questions mentioned above are another way to analyze the social organization of irrigation. By examining the rules, either written or merely informal, that govern the operation and maintenance of an irrigation system, much can be learned about possible social and organizational constraints. If the system is not operating efficiently, a breakdown in organizational rules is one possible cause to be investigated.

POINTS TO REMEMBER

What has been presented in this section is a series of strategies which a field sociologist can use to study an irrigation system. The questions try to evaluate the behavior of the water users and water authorities as well as the coordination between them. The results from each of these strategies--farmers' decision making, irrigation tasks at various organizational levels, the study of local irrigation organization, an analysis of the organization's rules--need to be used in conjunction with the results from the other disciplines. It is important to keep in mind that the social and bureaucratic rules and organizations in an irrigation system need to be tied closely to the technical tools and structures that physically manage the system. Organizational arrangements must be developed together with physical arrangements. The sociologist in Diagnostic Analysis must always keep in mind the links between the irrigation system's "rules" and "tools."

107



Chapter 4

THE SYSTEM'S MANAGER

Management is the decisive factor that ultimately influences all components of an irrigation system. As pointed out in Chapter 1, water management is not the individual components of a system nor even their collective functioning. Rather, water management is the process by which the irrigation system is manipulated and used in the production of food and fiber.

No component of the system, therefore, can function without being managed; at the farm level, the farmer is that manager. For this reason, Diagnostic Analysis recognizes the importance of the farmer and incorporates his knowledge into the investigative process. An extensive examination of management practices are included to understand how water, the environment, and all inputs and services are manipulated within the system. By understanding management at the farm level--that is, decisions made by the farmers for their own farms--you can expand your understanding to the distribution system and indeed, the total irrigation system.

The managerial importance of the farmer can be expressed in many ways. As seen in Figure 28 we can place the farmer graphically within the system with its interrelated components. He is symbolized here as being the pivotal center of the system. In many ways, however, this representation lacks the actual impact, knowingly or unknowingly, which the farmer has upon the system. It also does not reveal the constraints under which the farmer must function. It would be more effective to transform our graphic symbol into a fictional but working farmer. We then can observe how the farmer must balance himself, often precariously, within the total system.

104

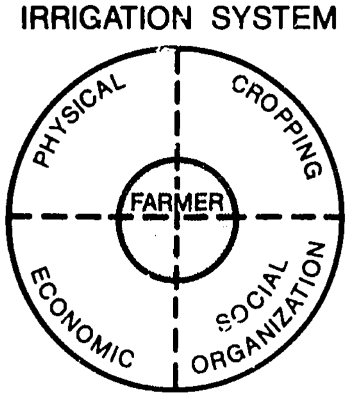


Figure 28. The Pivotal Role of the Farmer

ADAN THE FARMER

Allow me to introduce you to Adan, a farmer as was his father before him. I cannot tell you from which particular country he comes, for it could be any, perhaps your own. Adan is not simply a drawn symbol in the middle of a diagram, rather he is the working center of a large family and an even larger community (Figure 29).

You probably would like Adan for he is said to be a generally pleasant fellow with a good sense of humor. Not yet middle age, Adan is physically strong and works long hours on his farm. His two sons are too young to work all day in the fields, but Adan boasts that some day they will be stronger than he is. He also likes to say that his three daughters are the most beautiful in the village. You can understand then why Adan is such a likeable man!

Figure 29. A Fictional Farmer Called Adan

Unlike his parents, Adan is literate and keeps all his own records. He has been educated to the 6th grade and anticipates that his children will be also. He is a member of the local cooperative although not an influential member.

Adan, unlike some of his neighbors, owns his farm from which he derives his entire income. He is neither very poor, nor very wealthy: he earns enough to maintain his family.

His farm is located along a distribution channel that is operated on a rotational system of four days on and eight days off. Water is conveyed to the farm level through earthen channels. Luckily, there is a sufficient water supply throughout the entire year. Adan levels his fields based on his own judgment and experience. Drainage water flows out into a field drain and eventually into a main drain.

Adan's farm consists of some two hectares located midway within the command area. The average fields in the area, however, are 0.5 hectares within which are irrigation basins of approximately 5 meters by 10 meters. Like his neighbors, Adan grows wheat in the winter, corn in the summer months, and miscellaneous local vegetables year round for both home consumption and for market.

A PRIMARY DECISION MAKER

At the farm level, Adan is the primary decision maker. Yet, each and every decision he makes is influenced by various components of the system over which he has little control. Adan is simply an individual farmer involved in an extensive network of relationships and interactions that include remote governmental agencies and officials, local authorities and institutions, and his neighboring farmers and extended family.

In addition to the influences of various social and institutional factors, Adan's decision-making role is limited by norms and rules that are often informal and implied. For example, although no one in the community might ever say so, it is possible that water is viewed common property and, therefore, to be shared equally. If Adan should break this unspoken norm, his neighbors would not only be upset, but might enforce some form of punishment or sanction either officially or unofficially.

Adan also can claim little control over formal policies, laws, services, and decisions about water supplies, canal closures, or the maintenance and operation of channels which serve his area. The local gatekeeper is his most immediate representative of the main authorities who establish such policies and services. Adan therefore must keep on good terms with the gatekeeper which is no easy job since the fellow is very cranky and uncooperative most days.

Adan, with a smile, always tells his neighbors that there is little good in complaining, but even he admits that water supplies often are erratic and at times insufficient. His neighbors at the tail end of the system have even a greater problem. Adan realizes this and, on occasion, he has helped his immediate neighbors to install illegal pipe intakes so as to supplement their regular irrigation water supply.

An area which Adan cannot correct, even illegally, is the supply and regularity of inputs needed for crop production. These inputs include such items as seed, fertilizers, pesticides, credit, and access to extension services. The local cooperative to which he belongs is in charge of supplying the majority of these items. Again, one does not like to complain, least of all Adan, but one must be realistic and admit that necessary inputs are often limited in quantity, quality, and timing. In addition, Adan's wealthiest neighbor, a powerful man called Wazzar, often has first claim to many of the items. Adan must maintain a good relationship with Wazzar as well as other leaders in the village. These men, through the cooperative, regulate some of the crops he grows and the various inputs which are to be assigned to him.

Even remote officials influence much of Adan's decision making. This year the Irrigation Department simply came in and assessed him for maintenance of the watercourses even though everyone in the village knows that Adan has been attempting to organize a communal maintenance plan for at least two years. Yet, when he requested assistance to do so, no one from the appropriate agency ever showed up. Yes, it surely is a difficult job juggling all these formiable personalities and institutions not to mention Adan's own frustration.

UNDERSTANDING A PROBLEM

As we have seen, Adan is not an ignorant man. Not only does he do a rather successful job of balancing all the conflicting elements of his life, but he also is well aware that his crop yields are decreasing. Certain fields are producing

107

crop stands and growth far from optimum. After pondering the matter for some time, Adan decides to contact the local extension worker who, in turn, brings in an agronomist to look over Adan's fields. The agronomist sees visual evidence of possible nitrogen deficiency. Subsequent laboratory analysis of both plant tissue and soil samples confirm the agronomist's visual observation: only about half the recommended amount of nitrogen is being made available to the plant.

Adan finds this amazing as he insists that the correct amount of nitrogen has been applied and that records at the cooperative where he purchased the fertilizer will confirm this fact--which they do. Adan is worried and annoyed for neither the extension worker nor the agronomist appear to believe him. Shoulders are shrugged and Adan is left with his unsolved problem of inadequate yields.

Some months later, an engineer visited the area; Adan, as casually as possible, mentions his on-going problem. The engineer, a competent official, notes the nitrogen deficiency; however, he also spots weeds blocking the drainage system which is functioning inadequately.

The engineer goes away and returns a few weeks later with permission to make measurements of the water supplied to each farm field and the groundwater levels. The measurements taken over time reveal that an adequate amount of water is being delivered to the field, but that groundwater levels are within 1 meter of the ground surface. The engineer concludes that Adan's problem involves drainage. The engineer suggests that Adan clean the drain: this he willingly does. There is some change in the plant population and growth of crops, but it is obvious that a problem still exists. The engineer is now gone, but Adan and the problem remain.

After repeated enquiries by Adan through the gatekeeper, the Irrigation Department finally decides that a tile drainage system is needed. Adan, though he has little choice in the matter, gives this idea much thought. He then approaches the necessary official to arrange a twenty year loan with which to install the expensive solution to his problem!

Two cropping seasons now pass. Adan observes only minimal improvement in crop production levels and the visible signs of nitrogen deficiency remain as if to mock all his efforts. Like most farmers, Adan is a patient man, but he is rapidly losing his good humor. His farming practices have been called to task, he is in debt, and even his wife is belaboring him. It is then he remembers that his cousin has a relative in

108

the Irrigation Department in a position of some power. The first free moments he finds, he is into the village and confronts the official who arranged the loan, "If something is not done soon to help me," he demands, "I will talk to my cousin who will report this whole costly affair to your superiors!"

Now this official, a much harrassed young man, may not know what is causing Adan's problem, but he does know that he wants no problems from his superiors. Therefore, in a final effort to both solve Adan's problem and protect himself, he arranges through another department for an economist and a rural sociologist, to conduct a collective examination of Adan's farm.

These two gentlemen, highly regarded in their respective disciplines, document everything known about Adan's problem, beginning with the initial recommendation of insufficient nitrogen application, through drainage channel maintenance, to the eventual replacement of the drains. They recorded that Adan did use the recommended amount of seed, fertilizer and insecticides: as a result, he should have had greater crop yields. In addition, it clearly was evident to them that Adan was not only losing money but would soon be in an unmanageable debt situation.

During the interviews, Adan displayed a limited knowledge of the soil-plant-water relationship. Therefore, they recommended that an extension worker supply Adan with appropriate information. They particularly suggested information dealing with the furrow system of cropping. Always respectful of education, Adan reads everything that the extension worker gives him and even asks relevant questions when allowed. Our tale grows weary now with frustration for nothing changed--or at least enough that Adan could see a marked improvement.

THE UNSOLVED PROBLEM

We could leave Adan, sitting by the side of his house, mumbling to one and all about the injustice of the world. He would continue working the land, but with ever-increasing frustration, knowing full well that he is not reaping a just reward for all his efforts. Adan clearly is in the middle of the system, making decisions day by day, regulating those parts of the system over which he has responsibility yet little control. We have seen him patiently working through all the interactions with irrigation officials, fellow farmers, extension workers, outside experts, and a remote beaucracy.

A BETTER TYPE OF ENDING

Our tale need not end here though. Adan is still sitting by the side of his house when a member of a Diagnostic Analysis team wanders over and, in a friendly tone, asks what he is mumbling about. Adan wants nothing to do with any more so-called experts so his reply is clipped, even rude--which simply shows how frustrated our fellow has become. But the Diagnostic Analysis team member is not so easily put off, and after a while, Adan relates the entire tale.

Although he guarantees nothing, the team member explains that Adan's farm is part of the command area in which an interdisciplinary study is being conducted. He asks Adan if he might be willing to talk with different team members about his farm, how he manages it, and the history of his problem. Adan, though not hopeful, figures why not? At least talking does not cost money, he tells his wife.

What Adan did not know--though he cooperated throughout the Diagnostic Analysis--was that team members themselves could not agree initially on the cause of his problem. The team, however, began detailed studies and after a number of weeks of data collection and analysis, they were ready to synthesize their information and conclusions. As a result, the team is satisfied that they had identified the primary constraint limiting Adan's yields.

It appears that although Adan thought he was applying the proper amount of water, he actually was over-irrigating. Roughly a third of the applied nitrogen was leaching into the groundwater. During the summer season, the groundwater levels were so high that salinity was a problem.

Studies of water advance time and water patterns across the fields indicated unleveled fields. This critical discovery was confirmed later by a topographical survey of the fields. The level varied from 4 to 10 centimeters over the basin.

This variation in levelness created high spots in which some plants seldom received adequate water despite the over-irrigation. Excessive salinity in these high areas was inhibiting seed germination and plant growth. In the correspondingly low spots, plants were receiving excess water thereby raising the already dangerously high water table and causing the leaching of costly nitrates.

110

Now, all along Adan had assumed that his fields were level. No one else had questioned this fact. He, of course, had neither the equipment, nor the technical expertise to have done a better job even if he thought he should.

The primary constraint or problem was thus identified. The implementation of that solution was yet to be undertaken, but one of the team members made a point of explaining it to Adan and his neighbors who were experiencing similar problems. He also showed them all the various individual symptoms of the problem with which Adan had wrestled over a long period of time. A quickly drawn diagram (Figure 30) made it all the more clear.

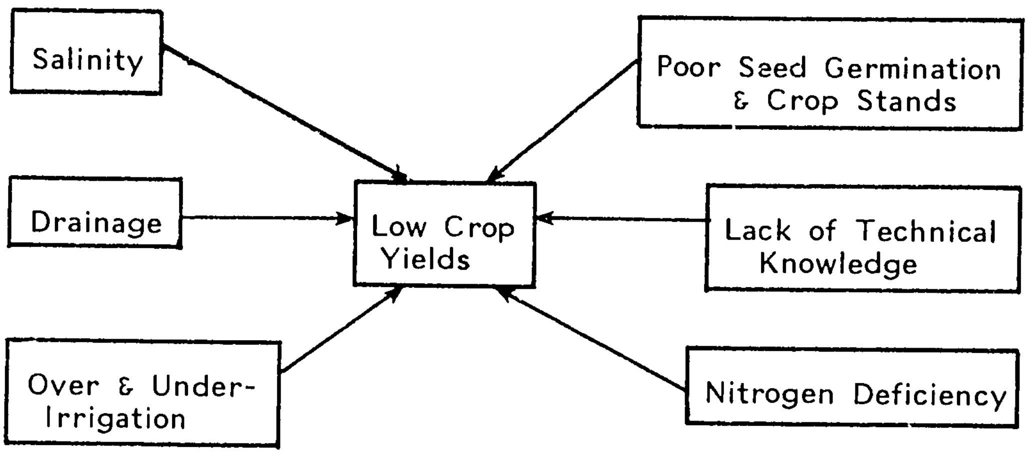


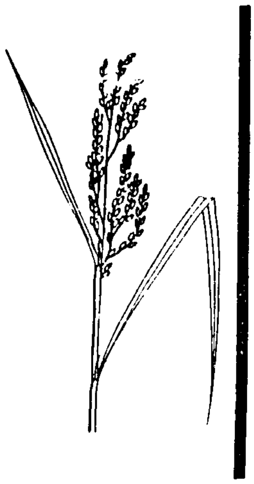
Figure 30. Constraints to Productivity of Adan's Fields

All of the previous experts who had attempted to help were not wrong--only they had focused more on the symptoms of the problem rather than discovering the problem itself. Because Adan's fields were less than level, he unknowingly overirrigated in an attempt to deliver water to the high areas within the fields. The overirrigation resulted in a high groundwater level, i.e., waterlogging, which in turn created high salinity levels, poor seed germination, and so forth. The final result was low crop yield. Appropriate leveling of his fields then is the solution to Adan's problem. With adequate leveling, not only will Adan see an increase in his crop productivity but a corresponding decrease in all the other symptoms with which he has contended.

We leave Adan a happier man; his good humor has returned. He tells his neighbors that only a patient man like himself could have been so long suffering, but at last now he has solved his problem! His wife smiles from the doorway.

POINTS TO REMEMBER

The farmer as manager is at the center of the irrigation system: he is the primary decision maker at the farm level. To investigators conducting a Diagnostic Analysis, he is also the primary source of information concerning the system as it is functioning. It is important to note, however, that nearly all of a farmer's decisions are restricted or influenced by his relationships with other individuals, institutions, and/or the governmental bureaucracy. The complexity of the irrigation system with its interrelated components as well as relationships, often causes investigators to concentrate on the symptoms of a problem rather than the problem itself. By recognizing that water management is the process of how the system's interdependent components are manipulated and by employing a Diagnostic Analysis approach, actual problems or constraints to the system will be identified and not simply their symptoms.



Chapter 5

SUMMATION

An idea often begins with an insignificant thought--even as a plant comes forth from a seed. The thought may be nothing more than a new way of seeing something which is very familiar. From the very beginning, however, an idea continues to stretch and grow as it evolves into maturity. The development model presented in this manual began as an attempt to look at the operating irrigation system in its entirety so as to improve its effectiveness and productivity.

DEVELOPMENT MODEL

The need for such a model and the insights it might allow investigators grew out of a different understanding of what exactly is meant by water management. Traditionally, water management has been approached at the physical level--the delivery, application, use, and removal of water. Today, that approach is considered inadequate. Water management is defined now as the process by which the irrigation system with all its component parts is manipulated and used for the production of food and fiber. Any investigative approach to it, therefore, must acknowledge this more complex and dynamic definition.

The development model uses its three distinct phases--Diagnostic Analysis, development and assessment of solutions, and program implementation--to directly address the complexity inherent in any operating irrigation system. It does so by incorporating a systems perspective, an interdisciplinary approach, and the farmer's involvement throughout its interrelated phases. This manual has concentrated particularly on the first phase of the development model--Diagnostic Analysis.

DIAGNOSTIC ANALYSIS

Much like an agronomist takes a plant apart to observe its various parts, we have examined Diagnostic Analysis in a step by step manner moving through its six activity phases: 1) Preliminary Objectives, 2) Reconnaissance, 3) Revised Objectives and Plans, 4) Detailed Studies, 5) Interdisciplinary Analysis and Synthesis, and 6) Report Writing. We saw that the fifth step, Interdisciplinary Analysis and Synthesis, was the most important activity around which the other activities revolved. We now are at a point in this manual where rather than merely feeding back the various segments of Diagnostic Analysis, we can rearrange what we have examined and combine it (synthesis) to obtain possibly fresh insights to the entire procedure.

OBJECTIVES OF DIAGNOSTIC ANALYSIS

Three distinct objectives have been repeated throughout this manual to define the purpose of Diagnostic Analysis. These objectives are:

- Understanding the irrigation system as it actually operates with both its strengths as well as its constraints;
- Identifying the major physical, biological, economical, and social-organizational constraints to the system; and,
- Listing the identified constraints, their causes and magnitude in an order of priority and based on stated criteria so as to assist the development and assessment of solutions.

These general objectives form the foundation of all Diagnostic Analysis investigations and support each activity phase within the investigative process.

OBJECTIVE: UNDERSTANDING THE SYSTEM

To understand any system, you first must understand its component parts; a system is the sum of all its interdependent parts. The irrigation system, as we have reviewed it, is composed of four related components: the physical, the

114

cropping, the economic, and the social-organizational systems. Because they also are made up of mutually dependent parts, these components are systems in themselves. Each component system has its own boundaries and specific characteristics. Collectively, however, they combine to create the irrigation system as we understand it here.

The Physical System

The physical component of an irrigation system is defined by its subsystems: water delivery, water application, water use, and water removal. The water use subsystem, however, is the critical area which governs the entire physical system. Both the design and management of the physical system must be based on the crop's water requirements as determined within the water use subsystem.

The Cropping System

All those elements necessary for the production of specific crop(s) and the interrelationship between the crop(s) and the natural, chemical, and biological environment constitute the cropping system. Because of its complexity, the system is classified by cropping and rotational patterns--that is, the variety of crops planted and the pattern in which they are planted. Climate, soil, biological constraints, and management are the four primary influences within the plant's environment.

The Economic System

The economic component of an irrigation system involves productivity and allocation of resources. Land, labor, capital, and management are the principal productive resources. Allocation of resources is based on identifying and verifying economic efficiency--that is, the optimal allocation of resources so as to maximize profit. A comparison between economic efficiency and physical efficiency is necessary when making any decisions affecting an irrigation system.

The Social-Organizational System

The relationships among people, organizations, and the environment are the primary focus of the social-organizational system. Individual and collective behavior, the patterned interactions which make human actions predictable, and the decision making process are the areas of most importance within this component system. These areas can be examined at three separate levels--farm, command, and central organizational.

Mutually Dependent Component Systems

All the component systems--physical, cropping, economic, and social-organizational--are mutually dependent. To make changes within one component automatically affects the others. If you look back, you also will see that each and every component, in some manner or other, includes management and decision making. Your understanding of an irrigation system is incomplete, therefore, if you do not recognize that it is not the components themselves which create the system, but rather, it is how those components are used or manipulated that ultimately describes and defines an irrigation system.

It also follows that if an irrigation system is manipulated, in order to fully understand the system, you must identify those persons who do the manipulation. At the farm level, the farmer is the manager, the manipulator, the primary user. It is, therefore, necessary to understand both his behavior and his decision-making rationale including the constraints under which he must act.

Finally, an often over-looked goal within this first objective is the understanding of the system's strengths as well. It is true that it is the constraints which occupy our greatest attention; however, when we observe the strengths of a system, we complete our understanding of the entire system as it is operating. Additionally, recognizing a system's strengths allows you to capitalize on them--that is, build upon them--as well as to use those strengths in improving the effectiveness of other irrigation systems.

If, in fact, you do combine knowledge of the physical, cropping, economic, and social-organizational components with an accurate perception of a system as it is being managed, you will have achieved the first objective of Diagnostic Analysis: understanding the irrigation system as it actually operates with both its strengths and constraints.

OBJECTIVE: IDENTIFYING CONSTRAINTS

To understand something does not always involve an ability to identify its separate parts, as any teacher will inform us. A student holding a nondescript plant in his hand may understand that it is a rice plant while being totally unable to identify its characteristic parts! More importantly, because he cannot identify the parts of the plant, he lacks the comprehension that the parts are internally related and are externally subjected to numerous variables. Therefore, to say that we want to understand a system's constraints involves more than mere recognition: it involves their identification, their relationship to one another, and, above all, their causes and magnitude.

An Interdisciplinary Undertaking

The second objective of Diagnostic Analysis then is the identification of major physical, biological, economical, and social-organizational constraints to the irrigation system. Neither the components of an irrigation system nor its examination can be divided along purely disciplinary lines. To do so would result simply in what is known as a multidisciplinary approach to investigation.

A Diagnostic Analysis is always an interdisciplinary undertaking, that is, every activity involves not only a collaboration among experts but a mutually informed sensitivity to the interdependency of data and analysis. The success of an interdisciplinary team often is revealed when they approach the synthesis phase of Diagnostic Analysis. It is at this point that the team's collective knowledge must be ordered so that relationships within the system, including its constraints, can be penetrated without regard to discipline or individual bias.

A Systematic Undertaking

Diagnostic Analysis is a structured interdisciplinary investigation which maintains the unity of an irrigation system while examining its interrelated parts. Its primary focus is at the farm level, but the boundaries of the system are ultimately determined by the constraints under consideration. A Diagnostic Analysis team could trace the causes of a constraint all the way back to the main water source if need be. What is important is that the procedure used within Diagnostic Analysis offers a repeatable and orderly method in which to observe the operating system.

The six activity phases of Diagnostic Analysis overlap or may even take place at the same time. Often the objectives set forth at one point of process become the objectives for another part of the investigation. The six distinct phases of Diagnostic Analysis we have studied are: 1) preliminary objectives, 2) reconnaissance, 3) revised objectives and plans, 4) detailed studies, 5) interdisciplinary analysis and synthesis, and 6) report writing.

The preliminary objectives of any Diagnostic Analysis need to be based on the specific investigation

\\'17

taking place; however, each Diagnostic Analysis undertaken must fulfill the three general objectives put forth in this manual. Understanding the system's strengths and constraints, identifying those constraints, and ordering their causes and magnitude are not simply abstract goals, but concrete guidelines.

Diagnostic Analysis assumes that if you wish to understand an operating irrigation system, you will go out into the fields and observe just that--the operating irrigation system. Therefore, both the reconnaissance and detailed studies phase of Diagnostic Analysis are field oriented and field conducted.

Reconnaissance and detailed studies are the workhorses of the investigative process. Reconnaissance, by definition, calls for a sweeping overview of the system so that perimeters to investigation can be established--that is, the team's working hypothesis. Detailed studies, on the other hand, demand an in-depth examination of the system to prove or disprove earlier observations. Throughout both phases, objectives constantly will undergo revision in light of field findings. This revision of objectives and plans is also a formal activity step which links reconnaissance and detailed studies.

Reconnaissance and detailed studies share many similar activities. As mentioned, objectives must be constantly defined and refined; responsibilities are assigned and monitored; data collection involves both interviewing techniques and field investigation and measurement; analysis and synthesis must take place; and reports must be written in order to present the findings of the team. Intelligent observation, however, is the most valuable tool an investigator can possess throughout both activities. Additionally, the most valuable characteristic that the team can possess is its interdisciplinary mind-set which is expressed in joint planning, execution, and completion of all activity phases.

The differences between the reconnaissance and detailed studies phases are primarily ones of time and depth. All the steps of a reconnaissance are deliberately quick and comprehensive. The field observation normally takes only one day; the entire process, including report writing, seldom lasts more than a week. Detailed studies, however, can span two cropping seasons if the investigation warrants it.

Furthermore, the nature of analysis and synthesis also vary as far as breadth, and even as far as depth is concerned. During the reconnaissance phase, analysis must necessarily be rapid and synthesis sufficient only to establish a hypothesis. The detailed studies phase demands an analytical procedure of far greater depth so as to result in a greater degree of synthesis. Following the detailed studies, constraints are identified and ordered according to stated criteria.

An Analytical Undertaking

All activities within Diagnostic Analysis are directed towards the analytical process of examining the collected data in order to synthesize it into a conceptual whole. You cannot do something until you know what you have to do it with! The collected data will include all of the preliminary information which was assembled: the literature surveys, guest speakers at workshops, interviews with relevant officials, reconnaissance observations, and of course, all of the information collected and verified throughout the detailed studies.

It will be within the process of analysis and synthesis that the team will use that information, observations, and data to explore all components of the operating system. A hypothesis will have been established; investigative perimeters will have been set: analysis and synthesis now will either substantiate that hypothesis, or disprove it; it will either confirm the perimeters of investigation or indicate a need to expand them. Analysis and synthesis when successfully conducted not only indicate the major constraints to an irrigation, but also their primary causes and the magnitude of their influence.

A Reported Undertaking

It is as important to communicate ideas as it is to have them! Diagnostic Analysis is a method which includes both disciplinary and interdisciplinary report writing. These reports, whether of a technical or non-technical nature, are the vehicles through which the team's findings and recommendations are communicated. Furthermore, it is these reports--and in particular, the final, interdisciplinary report--which will serve as the basis for the next step of the development model: development and assessment of solutions. If your report does not clearly present an interdisciplinary insight into the system along with the supportive data, further action may be hampered and perhaps even inappropriate.

\19

OBJECTIVE: ORDERING THE CONSTRAINTS

The final distinct objective of each Diagnostic Analysis is to order the verified constraints based on stated criteria, so as to assist the future development and assessment of solutions. Throughout the investigative process we have noted the need to list verified constraints according to an order of priority. Any priority, however, is based on some criterion, or criteria. There will be specific criteria which will influence the final ordering of the team's findings and recommendations. That criteria often will be dictated by the nature of the investigation and the findings of the team. The criteria by which constraints initially were selected for study, however, should be evident right from the beginning of the study.

Diagnostic Analysis is not intended to tackle all the problems of a particular irrigation system. Rather, there are certain problems that are appropriate for this method of investigation and others that are not. The Diagnostic Analysis team at the beginning of the study will need to answer two specific questions to establish their criteria for problem selection. First, what is the magnitude of the constraints being suggested for investigation? Second, what measure of success can be anticipated for correcting or removing a constraint? These questions must be asked of any problem which may be examined during a Diagnostic Analysis.

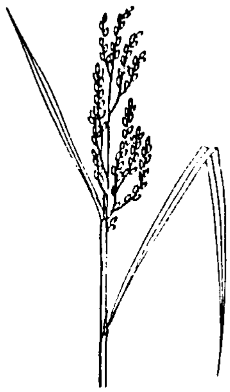
For example, an irrigation system within its physical boundaries may have a population that is predominately illiterate. Irrigation officials suspect that the illiteracy is the major factor hindering extension activities and, in turn, limiting agricultural productivity. However, it would take possibly a generation before an improvement in the literacy level would have any measurable impact upon the command area. Therefore, although this is a completely valid area for concern and attention, this particular constraint is not an appropriate one for a Diagnostic Analysis investigation. A constraint that is appropriate would be of such an anticipated magnitude that the field-oriented method could adequately evaluate it; the time frame typical of Diagnostic Analysis would be sufficient; and it would have the potential to be successfully corrected or removed within a reasonable time span. In other words, any solution to the constraint would have a measurable impact--whether technical, social, or economical--upon the irrigation system either in the short or long term.

Therefore, the use of criteria both in the selection of areas to be investigated and in the ordering of the final recommendations is a distinctive mark of the Diagnostic

Analysis method. Such criteria structures Diagnostic Analysis while directing its efforts in those directions where it will prove most beneficial.

POINTS TO REMEMBER

The ultimate objective of Diagnostic Analysis and the development model to which it belongs is the recognizable increase in crop productivity and the improved well-being of the farmer and his family. Diagnostic Analysis accomplishes this objective by examining those aspects of an irrigation system appropriate to the method in an interdisciplinary, structured manner. The success or failure of the method ultimately rests upon the ability of the team, regardless of its disciplinary make-up, to perceive the system as a unified, interdependent whole and to recognize the major constraints, their causes and magnitude which are restricting the effectiveness of that system.



Chapter 6

BIBLIOGRAPHY

The following bibliography has been compiled for two purposes: 1) to identify those published works which were used to produce this manual; and 2) to list additional material that may facilitate one's understanding and use of the development model and Diagnostic Analysis in particular.

Each chapter has at least one reference listed which should be widely available. The section on teamwork is more extensive than the others. Participants in Diagnostic Analysis often have limited familiarity with the nature and workings of a team. The final bibliographical section offers a listing of materials available presently through the Water Management Synthesis Project. Particular emphasis has been placed on audio-visual material. The address of the project is noted at the end of that section.

CHAPTER ONE: THE DEVELOPMENT MODEL

Clyma, W., M.K. Lowdermilk, and G.L. Corey. 1977. A research-development process for improvement of on-farm water management. Water Management Technical Report No. 47, Engineering Research Center, Colorado State University, Fort Collins, CO.

Clyma, W., M.K. Lowdermilk, E.V. Richardson, W.R. Schmehl, M.D. Skold, and D. K. Sunada. 1981. An agricultural development model for Egypt. American Society of Agricultural Engineering, Paper No. 81-5025, St. Joseph, MI.

122

Lowdermilk, M.K., W. Clyma, J.J. Layton, A.G. Madsen, D.J. Redgrave, F.A. Santopolo, D.K. Sunada, and D.L. Lattimore. 1979. Problem identification manual for on-farm irrigation systems. Two Volumes. Egypt Water Use and Management Project, Colorado State University, Fort Collins, CO.

Lowdermilk, M.K., W.T. Franklin, J.J. Layton, G.E. Radosevich, G.V. Skogerboe, E.W. Sparling, and W.G. Stewart. Problem identification manual. Water Management Technical Report No. 65B, Engineering Research Center, Colorado State University, Fort Collins, CO.

Lowdermilk, M.K., W. Clyma, M. Haider, D.L. Lattimore, J.J. Layton, D.W. Lybecker, A.G. Madsen, L.J. Nelson, D.J. Redgrave, F.A. Santopolo, and D.K. Sunada. 1981. Draft. Monitoring and Evaluation Manual, Two Volumes. Water Management Synthesis Project, Colorado State University, Fort Collins, CO.

Skogerboe, G.V., M.K. Lowdermilk, E.W. Sparling and J.E. Hautaluoma. 1980. Development process for improving irrigation water management on farm. Water Management Technical Report No. 65A, Engineering Research Center, Colorado State University, Fort Collins, CO.

Svendsen, M., D. Merrey, and W. Fitzgerald. 1983. Meeting the challenge for better irrigation management. In: Horizon, March.

Swanson, E.R. 1979. Working with other disciplines. American Journal of Agricultural Economics. pp. 850-859.

CHAPTER TWO: DIAGNOSTIC ANALYSIS

All of the above citations also deal with Diagnostic Analysis as an investigative method. In addition, the reader is referred to the bibliographic section which list other materials presently available through the Water Management Synthesis Project.

Report Writing

Day, R.A. 1979. How to write and publish a scientific paper. ISI Press, Philadelphia, PA.

Chandler, H.E. 1978. The "how to write what" book. American Society for Metals, Metals Park, OH.

Lannon, J.M. 1982. Technical writing. Little, Brown and Company, Boston, MA.

Michaelson, H.B. 1982. How to write and publish engineering papers and reports. ISI Press, Philadelphia, PA.

Strunk, W., Jr. and E.B. White. 1979. The elements of style. Macmillan Publishing Co., New York, NY.

CHAPTER THREE: THE SYSTEM

Physical

Robinson, A.R. 1983. Farm irrigation structures. HandbookNo. 2, Water Management Synthesis Project, Colorado State University, Fort Collins, CO.

Trout, T.J., I.G. Garcia-Castillas, and W.E. Hart. 1982. Soil-water engineering. Field Manual. Department of Agricultural and Chemical Engineering, Colorado State University, Fort Collins, CO.

Cropping

Shaner, W.W., P.F. Philipp, and W.R. Schemhl. 1982. Farming systems research and development: guidelines for developing countries. Westview Press, Boulder, CO.

Thorne, D.W. and M.D. Thorne. 1979. Soil, water and crop production. AVI Publishing Company, Inc., Westport, CT.

Economic

Biggs, H.H. and R.L. Tinnermeier (Eds). 1974. Small farm agricultural development problems. Colorado State University, Fort Collins, CO.

Murphy, J. and L. Sprey. 1982. Monitoring and evaluation of agricultural change. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands.

Murphy, J. and L. Sprey. 1983. Introduction to farm surveys. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands.

Osburn, D. and K.C. Schneeberger. 1978. Modern agriculture management. Reston Publishing, Reston, VA.

Upton, M. 1973. Farm management in Africa: the principle of production and planning. Oxford University Press, London, England.

Social-Organizational

Coward, E. Walter (Ed). 1980. Irrigation and agricultural development in Asia. Cornell University Press, Ithaca, NY.

Freeman, D.M. and M.K. Lowdermilk. Forthcoming 1984. The sociological analysis of middle level organizational linkages in irrigated projects. In: Putting People First: Sociological Variables in Development Projects, M.M. Cernea (Ed). Oxford University Press, London.

CHAPTER FOUR: THE SYSTEM'S MANAGER

Popkin, S.L. 1979. The rational peasant: The political economy of rural society in Viet Nam. University of California Press, Berkeley, CA.

APPENDICES: TEAMWORK

Team Development

Argyris, C. 1971. The path from Xa to Yb. Management and Organizational Development. McGraw-Hill, NY.

Bradford, L.P., J.R. Gibb, and K.P. Benne. 1964. The group theory and laboratory method. Wiley, NY.

Dunn, L.E. 1982. Teamwork: a training module. Colorado State University Cooperative Extension Service, Fort Collins, CO.

Dyer, W.G. Team Building: Issues and Alternatives. Addison Wesley Publishing Co., Reading, MA.

Gordon, T. 1955. Group-centered leadership. Houghton Mifflin, Boston, MA.

125

Jameson, D.A., M.A. Moore, and P.J. Case. 1982. Principles of land and resources management planning. U.S. Government Printing Office, Washington, D.C.

Likert, R. 1961. New patterns of management. McGraw-Hill, NY.

McGregor, D. 1960. The human side of enterprise. McGraw-Hill, NY.

Communications

Berkman, H.W. 1974. The human relations of management. Dickerson Publishing Co., Inc.

Robinson, J.W. and R.A. Clifford. 1972. Process skills in organizational development. University of Illinois, Board of Trustees.

Conflict Management

Blake, R.R., H.H. Shepard, and J.S. Mouton. Managing inter-group conflict in industry. Foundation for Research on Human Behavior, Ann Arbor, MI.

Filley, A.C. 1975. Interpersonal conflict resolution. Scoll, Foresman and Co., Glenview, IL.

Nielsen, E.H. 1972. Understanding and managing intergroup conflict. In: Managing Group and Intergroup Relations. J.W. Lorsch and P.R. Lawrence (Eds). Irwin-Dorsey, Homewood, IL.

Management by Objectives

Beck, C., and E.D. Hillmar. 1976. Making MBO/R work. Addison-Wesley Publishing Co.

Beck, C. and E.D. Hillmar. 1972. A practical approach to organization development through MBO. Addison-Wesley Publishing Co.

Drucker, P.F. 1954. The practice of management. Harper and Rowe, NY.

McGregor, D. 1960. The human side of enterprise. McGraw-Hill, NY.

WATER MANAGEMENT SYNTHESIS MATERIAL

Articles

Designing Furrow Irrigation Systems for Improved Seasonal Performance. T.K. Gates and W. Clyma. Winter ASAE Meeting. 1980.

Furrow Irrigation Practices in Northern Colorado. T.W. Ley and W. Clyma. Transactions of ASAE (24:3). 1981.

On-Farm Water Management for Rural Development. W. Clyma, M.K. Lowdermilk and D.L. Lattimore. Agricultural Engineering (62:2). February, 1981.

Optimal Design of Surface Irrigation Runoff Recovery Systems. J.M. Reddy and W. Clyma. Summer ASAE Meeting. 1982.

Systems Analysis for Improvement of Surface Irrigation. T.K. Gates, W. Clyma and T.W. Ley. Summer ASAE Meeting. 1981.

Irrigation Water Management Problems Around the World. W. Clyma, D.L. Lattimore, and J.M. Reddy. Paper presented at the Ninth Technical Conference on Irrigation Drainage and Flood Control. October, 1982.

Optimizing Furrow Irrigation Runoff Recovery Systems. J.M. Reddy and W. Clyma. Transactions of the ASAE (26:4). 1983.

Brochures

Diagnostic Analysis Workshop Videotapes

Interdisciplinary Water Management: A Videotape Package

Water Management Synthesis I Project

Handbooks

Circular Concrete Irrigation Turnout: Design and Construction. T. Trout, W.D. Kemper and H.S. Hasan. April, 1982.

Farm Irrigation Structures. A.R. Robinson. March, 1983.

Pumps and Water Lifters for Irrigation. R.E. Griffin, et al. July, 1983.

127

Manuals

Diagnostic Analysis of Irrigation Systems, Volume 1: Concepts and Methodology. M.K. Lowdermilk. December, 1983.

Diagnostic Analysis of Irrigation Systems, Volume 2: Evaluation Techniques. Editors: C.A. Podmore and D.G. Eynon. October, 1983.

Field Study of Level Basin Irrigation: A Manual for Engineers. T.K. Gates and W. Clyma. September, 1980 (draft).

Soil-Water Engineering Field and Laboratory Manual No. 1. T. Trout, I.G. Garcia-Castillas and W.E. Hart. March, 1982.

Water Management on Small Farms: A Training Manual for Farmers in Hill Areas. L.J. Salazar. August, 1983.

Water Management on Small Farms: A Training Manual for Farmers in Hill Areas, Instructor's Guide. L.J. Salazar. November, 1983.

Planning Guides

Land Leveling, Planning Guide No. 1. D.L. Lattimore. July, 1981.

Farmer Involvement, Planning Guide No. 2. M.K. Lowdermilk and D.L. Lattimore. December, 1981.

Irrigation Pumping, Planning Guide No. 3. R.E. Griffin and G.H. Hargreaves. June, 1982.

Farm Irrigation Structures, Planning Guide No. 4. A.R. Robinson. October, 1982.

Small Farm, Self-Help Irrigation Projects. Planning Guide No. 5. B.L. Embry and N.L. Adams. September, 1983.

Other Publications

Rice Irrigation Water Management. R.N. Oad and D.A. Fowler. December, 1983.

An Analysis of Traditional Level Basin and Graded Border Irrigation. J.M. Reddy, W. Clyma, and D.A. Fowler. December, 1983.

128

Slide-Shows*

Farmer Organization in Minipe, Sri Lanka. Nine-minute slide show indicating the success of one irrigation scheme's success in farmer organization.

Diagnostic Analysis Workshop. Eleven-minute slide show about the five-week workshop that the Project has presented in several countries.

Water Management on Small Farms: Training for Farmers in Hill Areas. A series of five slide-tapes that explain water management for farmers in hill areas: a companion to Water Management on Small Farms: A Training Manual for Farmers in Hill Areas.

Plant-Nutrient Deficiencies. Discusses major nutrient deficiencies and their symptoms.

*(Also available on videotape.)

Videotape Guides

Diagnostic Problems with Irrigation Conveyance Channels. T. Trout. June, 1982.

Videotapes

Measuring Conveyance Losses in Watercourses. T. Trout. Discusses how to measure and evaluate water losses.

Farmer Involvement. Investigates the need and benefits of involving farmers in all phases of the development process.

Diagnostic Analysis Workshop. Shows the process used in the five-week project workshop.

Research-Development Process. Discusses the development model used by Water Management Synthesis Project.

Diagnostic Analysis Process. Outlines the first phase of the development model. This phase is divided into reconnaissance and detailed studies. Flow charts describe the sequence of activities.

\29

Pakistan: Investments in Water Management. Discusses the Pakistan Project with slide show of the project included.

Diagnostic Analysis in Gujarat, India. Examines training program in Gujarat, India.

Diagnostic Analysis in Sri Lanka. Summarizes the Diagnostic Analysis Workshop conducted in Sri Lanka in July, 1983.

The Minipe Project. Looks at how a group of religious leaders organized farmer groups in Minipe, Sri Lanka.

The Agronomy Series. Examines soil moisture measurements, salt-affected soils, and plant/soil water relationships.

The Role of Economics in Diagnostic Analysis. Discusses the major economic considerations in diagnostic analysis of a system.

Diagnostic Analysis Phase I. Opportunity cost concept.

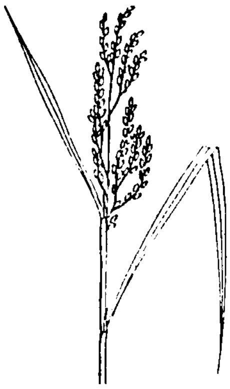
Diagnostic Analysis Phase II. Capitalization, discounting.

Farmer Organization. Describes the necessity of organizing farmers into groups for more efficient water management.

All of the material cited in this section is available from:

Water Management Synthesis Project
University Services Center
Colorado State University
Fort Collins, CO 80523 USA
Phone: (303)491-6991

130



A: INTERDISCIPLINARY TEAM BUILDING

In the mid-1800's the Industrial Revolution began in England and later spread to other Western Hemisphere countries. This historical phenomenon marked the shift from the handicraft production of goods to machine and factory production. It was characterized by the then prevelant directive style of personnel management: a rigid hierarchical structure of authority existed in which the individual labored. This style remained virtually unchanged to the present day. With greater societal penetration by democratic principles, however, there has been a corresponding expansion of individual freedom. In recent years a participatory style of management has emerged in which personnel work together as a team for a specific purpose or task. A simple diagram (Figure 1.1) illustrates the difference between the two approaches, particularly regarding the flow of information among individuals.

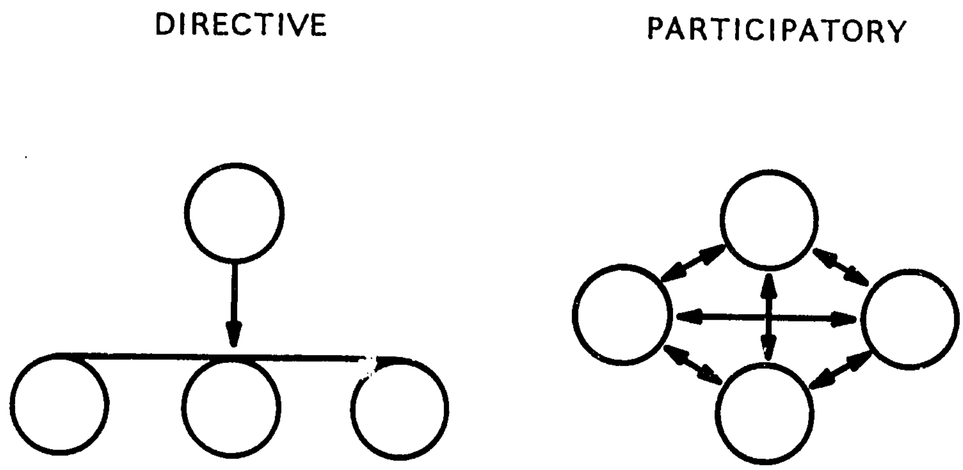


Figure 1.1 Management Styles and Information Distribution

Behavioral scientists have indicated that the participatory style affects human energy, creating changes in the way people view themselves, their work, and their fellow workers. It also has been suggested that human creativity is stimulated by the greater freedom found within the participatory style.*

Diagnostic Analysis use the participatory style of management. It does so because the basic characteristics of the style--individual freedom, creative flow of information, and task orientation--lend themselves to the interdisciplinary analytical process.

INSIGHTS AND GUIDELINES

The "team" is the mode through which the participatory style operates; in our case, it is an interdisciplinary team. Because limited attention has been focused on the function of an interdisciplinary team, you could assume that it

---

* The Bibliography chapter of this volume contains references for the reader who wishes to explore this topic more fully.

was a natural or simple mode of operation for the professional. This is not the case, as anyone who has participated in an interdisciplinary team would assure you! This appendix, therefore, provides insights and guidelines for dealing with the organization and maintenance of such a team.

We will examine first the attributes of an effective team member as well as the diverse roles that members might assume within the group. We also will look at the specific role of the team's leader(s). Having established the characteristics of the individuals, we then will focus our attention on the cylical nature of the group itself. This will be followed by a section on the development of appropriate skills. Finally, we will review the subject of conflict management, an often misunderstood facet of the participatory style. It is anticipated that a greater understanding of the team building process will lead to a greater appreciation of the participatory approach to personnel management.

ATTRIBUTES OF AN EFFECTIVE TEAM MEMBER

There are many general qualities which are desirable when people work with each other. Respect, trust, cooperation, and commitment are words that readily spring to mind. These qualities are ideal for many work situations not just for an interdisciplinary team member. Therefore, it would be worthwhile to examine how such qualities should develop into the inherent attributes of a team member.

RESPECT. To assure a sense of mutual respect among team members, a solid disciplinary foundation is desirable. A firm grasp of an individual specialty area increases the tendency for one to be open and tolerant of other points of view. It is important to remember, however, that all positions are equally important and deserve equal respect. This is true whether your team members are engineers, sociologists, economists, agronomists, farmers, or auxiliary personnel. Mutual respect will manifest itself also in a willingness to learn and grow professionally. Each team member must be willing, even eager, to learn about other disciplines, the knowledge they represent, and new methods of analysis and synthesis.

TRUST. Team members must be able to confidently rely on each other. Trust allows communications to be open and productive. It also allows team members to accept criticism, suggestions, and/or challenges to one's professional position. At times of stress when disciplines must develop an interdisciplinary perspective, trust, coupled with respect, eases the processes of compromise and collaboration.

COOPERATION. A team effort, by its nature, is always characterized by working together for a specific purpose. It involves sharing both the challenges and frustration of an undertaking despite inefficiencies and criticism. It also implies a willingness to be flexible. At one moment a team member speaks as an authority, and the next moment--as other expert opinions are presented--he must become a student or learner. This role flexibility, a natural product of cooperation, is often the most difficult for the specialist to assume and practice. Tolerance and humility, however, are additional qualities that assist the undertaking. A team member who is accepting, humble, and tolerant of different viewpoints, work styles, and disciplinary jargon makes a major contribution aside from their individual expertise. As one team member once offered, "This kind of individual is always part of the solution process and not part of the problem."

COMMITMENT. Finally, and perhaps most importantly, an effective team member must be committed to his fellow workers and to their common effort. In the early stages, it is tempting often to discard the team concept especially if results appear meager. To persevere through the common frustrations, inefficiencies, and even external criticisms requires a mature, on-going dedication. Success in doing so, however, will allow and even stimulate the team to develop its full potential and to accomplish the task at hand.

Respect, trust, cooperation, and commitment, therefore, are not simply words to reel off without thought. Rather, they are attributes so woven into the very texture of an interdisciplinary team that any attempt to separate or ignore them weakens the team's structure and unravels its effectiveness.

TEAM MEMBER'S ROLES

The need for role flexibility has been mentioned previously--the movement from being a teacher to that of being a student. There are other roles that effective team members assume at one time or another. These roles have two purposes: 1) the building up of a harmonious group, and 2) coordinating the completion of the designated task. Consultants who have worked with developed cohesive teams cite the following as the major role expectations of team members:

INVOLVING ROLE. A team member may initiate action by motivating others to become involved in an idea or problem. The involving role consists of asking questions of other members to "bring out" or stimulate each team member.

LISTENING ROLE. A team member who listens actively (nodding, leaning forward) expresses that he really is hearing what is being said. Active listeners encourage group members to express their opinions and ideas.

COMPROMISING ROLE. Compromise requires concession on the part of a team member. Compromising can lead to team productivity and is a necessary element of problem solving, cooperation, and collaboration.

SUPPORTING ROLE. Team members give added dimension to the good ideas of others when they extend their support and encouragement. Mutual confidence and trust are strengthened as a result.

THE LEADERSHIP ROLE

The role of team leader is unique. The person (or persons) who assume this role must fulfill specific responsibilities while remaining a viable member of the team--of the participatory process. In other words, a team leader is not a leader or manager in the traditional sense of the word; rather, he or she is the designated team member who provides structural and organizational support for the entire team. Four specific areas of responsibility would be guidance, group stimulation, coaching, and coordinating.

Guidance is the process of directing the efforts of the team to accomplish objectives and providing structure in which planning and action can take place. Stimulation involves subtle methods of reinforcing productive team efforts. There is a need to determine constantly if all team members are involved actively. Coaching is done both formally and informally by asking team members if they are having problems, recommending outside resources that may be helpful, and generally offering helpful suggestions. Coordinating is a major responsibility and involves improving communication and feedback among team members. This can be accomplished by improving the work environment, controlling the operational climate, and indirectly doing such things that produce a cohesive working team.

Despite these specific responsibilities, the leader must be viewed by others as a peer and not as a management figure. Therefore, the leader will possess all the previously discussed attributes of an effective team member.

FROM ATTRIBUTES TO ACCOMPLISHMENTS

It is all very well to understand the specific attributes and roles of an effective team member, but how do you use such knowledge? How do you develop the necessary skills?

We first need to add some additional knowledge to our collection to date. All of us spend much of our lives participating in groups, but rarely do we take the time to observe what is really happening in these groups. When you observe what a group is talking about, you are focusing on the <u>content</u>. When you examine how the group is functioning, you are focusing on <u>process</u>. It is important to understand that as team members we are required to deal with these two very separate entities.

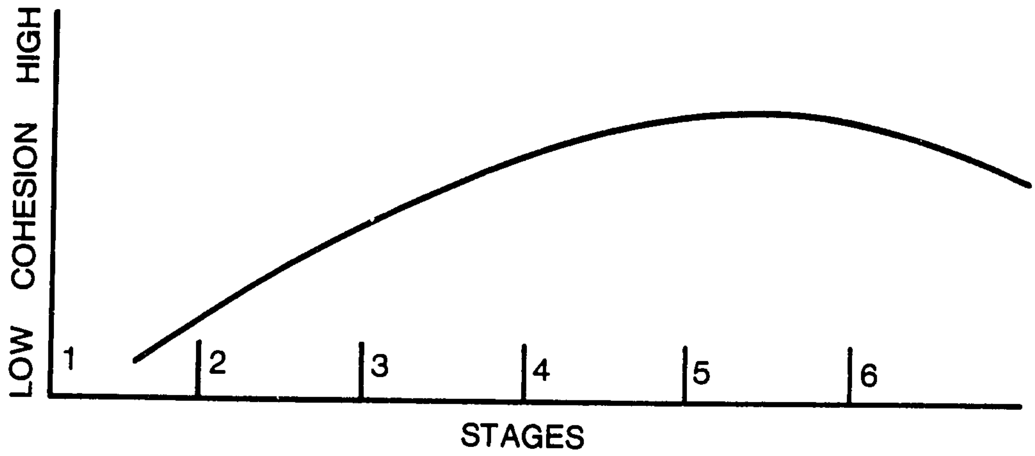
The main body of this manual discussed the content material that concerns you as a team member. The following sections therefore will concentrate on the process, the functioning of the group.

LIFE CYCLE OF A TEAM

Researchers involved in the study of team building note that the developmental pattern of a team closely resembles a life cycle, i.e., birth, growth, and decline. This cyclical nature is more fully illustrated in Figure 1.2.

This "group cohesion model" shows the relationship between group cohesion, i.e. the ability to stick

136



Stages	Activities
1. Assembly	Individuals are assembled to do a task.
2. Organizing	Assembly is named; mission is explained; the goal is proposed; and members are assigned to various tasks.
3. Learning	Through interaction with and observation of one another, members develop perceptions of their likely performance as a group, begin developing interpersonal ties, group norms, camaraderie, specialized roles, and goal commitment.
4. Gaining Momentum	Early successes and development of interpersonal relationships encouraged the group and build its confidence--increase desire for success; performance standards emerge; norms and values solidify; task expertise develops; teamwork and willingness to help each other develop; a clear idea emerges of "who we are and where we are going".
5. Peak Performance	Group becomes strongly focused on the goal; conformity pressures develop; deviants, if any, are disciplined; members make personal sacrifices on behalf of the group's welfare.
6. Decline	a. Conformity becomes dysfunctional--group becomes inflexible, unresponsive to its environment; some individuals rebel, others leave, performance declines, and internal bickering increases; or b. repeated success reduces challenge; members become complacent; members pursue other interests; group loses its momentum.

Figure 1.2 The Developmental Cycle of Team Cohesion

131

together on the vertical axis and the passage of time on the horizontal axis. As can be seen reading the chart from left to right, this is a model of a successful group. The group started as a mere assembly of individual members, became highly cohesive and successful, reached its peak, and then went into a gradual decline. Knowledge of this developmental cycle is important in understanding the development of cohesion within a team. It is a continuous process, one in which you are a contributing member.

Your contribution to the cohesion process will depend first of all on your attitude, i.e., the previously discussed qualities you bring to the team, and second, on the skills you develop that foster team development. Remember, team members are those individuals who must accomplish their objectives through group consensus. It is likewise important to remember that as with all skills, results will not be instantaneous. The amount of practice, reinforcement, and evaluation undertaken by the team member usually will determine his or her effectiveness.

COMMUNICATING: SAYING WHAT YOU MEAN

Being knowledgeable is different from being able to communicate that knowledge. The team meeting is a particularly important time for group communication. Following are some suggestions for improving communications, both verbal and nonverbal. Preparation is always the first step.

1. Know what you want to say. This involves not only compiling good research data, but also outlining that material in an easy-to-understand manner. Technical jargon and elaborate diagrams should be avoided. They often require much precious time for explanation and open the way for needless misunderstandings.

2. Think before you speak. Any communication, no matter how informal, requires your full attention. Careful organization of your material and thoughts before team meetings can greatly enhance your communication skills. Before the team meeting, take time to seriously consider the following questions:

   a. What topics are going to be discussed?
   b. What is the most valuable contribution I could make in the discussion?
   c. What problems or needs may be expressed by other team members?
   d. How can I help them meet their needs?

3. Verbal communication. The way in which you express your ideas will determine how the message will be interpreted by other team members. It is important to speak in a manner that is concise and clear. Choose words that are easy to understand, forming them into complete descriptive sentences. If a sentence is too long to be stated in one breath, it is too long for your listeners to understand. The language barriers that often exist in multicultural teams further reinforce this principle. Rehearse what you are going to say. This will enhance your oral presentation skills while reducing nervous tension which comes when speaking unprepared. Finally, master voice control. Soft, quiet tones tend to make people listen more intensely; speaking too loudly causes listeners to concentrate on your voice rather than your message. A change in volume is useful for emphasis of certain points.

4. Nonverbal communication. This type of communication consists of responses that one person gives to another by use of the eyes, head movement, and postural changes. Such responses are interpreted as support or nonsupport for what has been said. We are not usually aware of our own body gestures, but other team members observe them and form their own opinions on how we are receiving their communication. Both the listening and supportive roles mentioned earlier involve the use of nonverbal communication. You can improve nonverbal skills by carefully observing the nonverbal skills of others. If feasible, seek ways of getting feedback relating to your own nonverbal communication techniques. Such feedback can come directly from other team members or through use of a videotape camera.

COMMUNICATION FEEDBACK

Feedback is a method of evaluating how a team member is communicating to other members, both verbally and nonverbally. Appropriate feedback can provide the corrective mechanism for evaluating how well one's behavior matches one's intention. Whether you are giving the evaluation or receiving it, there are certain principles which improve the feedback procedure.

-- Good feedback is descriptive and specific, not evaluative or general.

-- Productive feedback is offered only about that behavior the team member can do something about.

-- Within the team situation, feedback is concerned with both the needs of the individual and the team goals.

To offer constructive feedback, you need to carefully listen and observe the actions of other members when they are communicating as well as evaluate its effect on individuals and on the group cohesion.

ORGANIZATION AND OPERATION OF TEAM MEETINGS

Everything that we have discussed so far--attributes, roles, cyclical development, skills--are brought into focus at the team meeting, the nucleus of the participatory style of management. It is here that the team by collective action and consensus determines goals, reviews behaviorial objectives, makes evaluation, and carries out any number of specified activities. In a relatively formal setting, properly conducted team meetings facilitate all aspects of project management. Team meetings also strengthen group unity and enhance the professional development of members.

A method for conducting team meetings is given in Appendix B. It provides a structure that facilitates decision processes while assisting in the development of a cohesive team. The format, agenda items, officers, agenda management, and working environment are all given. These suggestions should be used by a team to improve the effectiveness of its meetings.

CONFLICT MANAGEMENT

By its very nature, teamwork involves conflict. Conflict can arise from disruptive behavior on the part of one or more team members, from differences in social or ethnic values, from dissimilar evaluations, or even because of the team's goals. Therefore, understanding certain basic facts about conflict and how to handle it is essential.

Organizational leaders, indeed most humans, have a bias against conflict; it is perceived as a negative activity. Such persons would describe progress and conflict as being mutually exclusive. This, however, is not always a valid perception. Conflict also can be viewed as "creative tension" which, when properly managed, leads to constructive action. Listed below are positive effects that conflict can have on the team building process.

Conflict can help:

-- Define issues;

-- Stimulate ideas;

-- Increase quality of work accomplished;

-- Create group cohesion; and

-- Keep members alert and reduce stagnation.

How conflict is managed is, of course, the key to whether it produces such benefits. This requires a great deal of skill and practice. Emotions can obscure rational problem solving. Therefore, a primary challenge in a conflict situation involves handling obstructive behavior--whether our own or others. Such behavior needs to be recognized, expressed, and resolved. Five basic methods for doing so are listed in the following chart.

The term "win/lose" used in that chart means that in a conflict resolution some members benefit (win) while others do not (lose). A "win/win" situation, as found in the collaboration method, indicates that all members benefit, which is always desirable regardless of the method used. Within a team situation compromise or collaboration are the two methods with the greatest potential to achieve this beneficial resolution.

The following step-by-step procedure is given to illustrate how the collaboration method can be applied to conflict situations.

1. The problem must be clearly defined to understand the origin of the conflict. If the conflict is a product of disruptive behavior on the part of one or more team members, the source of the disruption should be made clear. It should be spelled out in a supportive manner since often the person distracting the group may be unaware of the negative effects of his/her

\ҷ\

FIVE BASIC METHODS FOR RESOLVING CONFLICT

Methods	Description	Appropriate When:	Inappropriate When:
Denial or withdrawal	Person tries to solve problem by denying its existence. Results in win/lose.	Issue is relatively unimportant; timing is wrong; cooling off period is needed; short-term use.	Issue is important; issue will not disappear, but build.
Suppression or smoothing over	Differences are played down; surface harmony exists. Results in win/lose in forms of resentment, defensiveness, and possible sabotage if issue remains suppressed.	Same as above; preservation of relationship is more important than issue at that time.	Reluctance to deal with conflict leads to evasion of an important issue; others are ready and willing to deal with issue.
Power or dominance	One's authority, position, majority rule, or a persuasive minority settles the conflict. Results in win/lose if the dominated party sees no hope for self.	Power comes with position of authority; this method has been agreed upon in advance.	Losers have no way to express needs; it could result in future disruptions.
Compromise or negotiation	Each party gives up something in order to meet midway. Results in win/lose if "middle of the road" position ignores the real diversity of the issue.	Both parties have enough leeway to give; resources are limited; win/lose stance is undesirable.	Original inflated position is unrealistic; solution is watered down to be effective; commitment is doubted by parties involved.
Collaboration	Abilities, values, and expertise of all are recognized; each person's position is clear, but emphasis is on group solution. Results in win/win for all.	Time is available to complete the process; parties are committed and trained in use of process.	The conditions of time, abilities, and commitment are not present.

his/her behavior. In addition, the team also must recognize the effects that this conflict is having on the team process.

2. The team then should brainstorm possible solutions. To brainstorm is to find as many ways as possible to resolve the conflict.

3. A solution or combination of solutions should be selected and acted on that will meet the needs of all team members. If the conflict is stemming from behavior problems, alternative behavior should be suggested.

4. Finally, the collaboration process itself should be evaluated along with its results. This step will help in the future resolution of conflicts as well as in the evaluation of present solution(s).

POINTS TO REMEMBER

This appendix has dealt with the participatory style of personnel management. We have examined the attributes of an effective team member, the need for flexibility, the nature of group cohesion, and the basic methods of conflict management. It is intended that such knowledge not remain in the theoretical realm. It is the application of knowledge that proves its ultimate worth. In the end, the effectiveness of a team is determined largely by the effectiveness of its individual members.

B: CONDUCTING A TEAM MEETING

A. Suggested Format for the Team Meeting

1. Presentation of the previous meeting's minutes
2. Development of an agenda (use a blackboard)
    a. Listing agenda items as suggested by team members
    b. Classification of each agenda item
    c. Establishing the time required for each agenda item
    d. Establishing the order in which agenda items are to be presented
3. Presentation of the agenda items in the established order
4. Listing of preliminary agenda for the next meeting
5. Evaluation of the meeting and its operation
    a. General comments
    b. Suggestions for improvement
    c. Evaluation of the team leader

B. Classification of Agenda Items

1. Informational: Questions are limited to those which clarify the presentation. Discussions are not allowed and decisions are not required. Informational items

144

usually require a short time frame, i.e., five minutes or less.

2. Discussional: Information is presented to elicit comments or discussion. Decisions are not required. Discussional items have variable time frames according to the complexity of the issues involved.

3. Decisional: Information is presented in order to reach decisions. Discussion of decisional items are limited, however, and the time-frame normally is limited to 10 minutes or less.

C. Team Meeting Officers

1. Team leader: The role of the team leader is described in Appendix A.

2. Secretary: The role of the secretary is to record notes during the meeting. The secretary also may be a participating team member.

3. Time Keeper: The time keeper assists the team leader with the enforcement of time frames which have been established for each agenda item.

D. Agenda Management

1. The time frame established for agenda items should be adhered to <u>rigidly</u>. A two-minute overtime may be allowed for those agenda items not completed in the allotted time; however, during this overtime period the item should either be completed or assigned as an agenda item for the next meeting.

2. Team meeting officers should rotate on a regular basis. This procedure aids the development of the participatory skills needed in a team approach and improves each member's understanding of the project.

E. Environment of Meeting

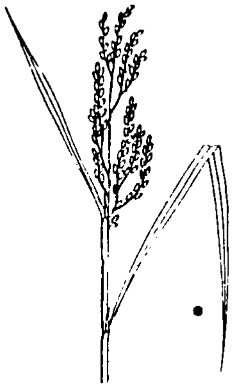
1. The meeting room should be comfortable and well lighted.

2. Chairs should be arranged closely together, preferably in a circular arrangement where it is obvious that information will flow in all directions. One word of caution: over-stuffed chairs, couches, and lounge

145

chairs should be avoided as team members may relax too much forgetting that they are gathered to accomplish a particular task.

3. Audio-visual equipment to be used should be tested and arranged prior to the team meeting. A blackboard is the minimal audio-visual equipment required.



C: TEAM BUILDING EXERCISES

An interdisciplinary team does not just happen; a great deal of effort is required by team members both individually and collectively. Structured exercises often are beneficial in developing the potential of any group. Synergism is an English word used to describe a cooperative action in which the total effect is greater than the sum of the effects taken independently. In other words, a unified, cooperative effort can be more productive than individual effort. The following exercises are offered so that a team can experience synergism, that is, the productivity of collective effort, and in doing so, more fully understand it and use it.

147

Exercise Number One:

WHAT IS IN THE BAG?

Number of People: 8 or more
Time: 1 hour
Material: A small bag and a few everday items

Procedure

1. An object, such as a shoe, pencil, notebook, is placed in a small bag. Participants generally are asked to attempt to identify the hidden object. They may ask questions of the leader which only can be answered with "yes" or "no".

2. On a blackboard, the leader keeps track of the number of questions it takes before the participants identify the object.

3. During this first round of questioning, participants ask the questions as individuals.

4. After the object has been identified, the leader talks about asking broad questions first, and then gradually asking more specific questions so as to narrow the possibilities. He or she also points out that the efficiency of teamwork is usually greater than individual effort. The leader also would note that the time used for performing tasks often will be reduced through team effort.

5. Participants are then divided into teams consisting of 4 to 5 persons. A new object is hidden in the bag, and the team members discuss various possibilities before asking the "yes" and "no" questions. It is the teams which now ask the questions. The leader once

142

again records how many questions are asked until the item is identified. The new number is compared to the number of questions it took when everyone was working at the task individually. (The number of team questions usually is much less than the number of individual questions.).

Exercise Number Two:

WHO DID IT?

Number of People: 8 or more
Time: 25 minutes as a minimum
Materials: Pencils, story sheet, and worksheets

Procedure:

Participants read the story and answer questions twice in this exercise: the first time individually, the second time as a team.

1. Hand exercise and worksheets to individual participants.

2. Allow three to four minutes for reading the story three times. Then ask that the paper be turned face down.

3. Allow five minutes for marking answers on worksheets and then collect them for tabulation.

4. Participants then form into teams of 4 to 6 persons. One answer sheet per team is handed out.

5. After reading the text again, the team should formulate team answers during discussion without referring to text. Allow 10-15 minutes.

6. Tabulate the team scores and compare them with individual scores.

7. Discuss the comparison of answers, changes in responses, and advantages of teamwork.

150

STORY:

A businessman had just turned off the lights in his store when a man appeared and demanded money. The owner opened the cash register. The contents of the cash register were scooped up, and the man sped away. A member of the police force was notified promptly.

Answers:

1)?; 2)?; 3)F; 4)?; 5)?; 6)T; 7)?; 8)?; 9)?; 10)?; 11)?.

Teams	Team Score	Average Indv.Score	Best Indv.Score	Group Over Ave.	Group Over Best	Range Indv.Scores
1.						
2.						
3.						
4.						
5.						

Exercise 2:
Statements About the Story

1. A man appeared after the owner had turned off his store lights. T F ?

2. The robber was a <u>man</u>. T F ?

3. A man did not demand money. T F ?

4. The man who opened the cash register was the owner. T F ?

5. The store owner scooped up the contents of the cash register; he ran away. T F ?

6. Someone opened the cash register. T F ?

7. After the man who demanded the money scooped up the contents of the cash register, he ran away. T F ?

8. While the cash register contained money, the story does <u>not</u> state <u>how much</u>. T F ?

9. The robber demanded money of the owner. T F ?

10. The story concerns a series of events in which only three persons are referred to: the owner of the store, a man who demanded money, and a member of the police force. T F ?

11. The following events in the story are true: someone demanded money, a cash register was opened, its contents were scooped up, and a man dashed out of the store. T F ?

157

Exercise Number Three:

ROLE CLARIFICATION

Number of People: Groups of no more than 12 persons
Time: 3 hours
Materials: Paper and pencil for each participant; newsprint, felt-tipped markers, and masking tape for leader.

Procedure:

1. The leader discusses the four aspects of role:

   a. Role Expectation: what others think a person is responsible for and how he should do it,

   b. Role Conception: what the person thinks his job is and how he has been taught to do it,

   c. Role Acceptance: what the person is willing to do, and

   d. Role Behavior: what the person actually does.

   The leader explains the goals of the exercise and the fact that participants will have to write several sets of notes and be willing to talk about them.

2. Team members are asked to make notes about their own jobs in terms of the four previously discussed aspects of role. (20 minutes)

153

3. The leader ask for a volunteer who is willing to clarify his role within a team. Other team members make notes on their understanding of the volunteer's responsibilities. Meanwhile, the leader informs the volunteer of the activities which will follow. (10 minutes)

4. The volunteer then shares what he thinks the other members' "role expectation" for him are. The leader will list key items on the newsprint for the entire group to follow. At this point, only questions of clarification are allowed from the other team members.

5. The volunteer then questions the other team members about their actual expectations of him. These responses are listed on the newsprint by the volunteer. The leader will intervene only to keep the volunteer listening accurately and nondefensively.

6. The leader now leads a discussion comparing the volunteer's perceptions to the team's expectations.

7. The volunteer discusses his own "role conception" and the leader once more lists key items on the newsprint. Once again, only questions of clarification are accepted.

8. The leader then can conduct a session in which the volunteer and the other team members mutually agree as to the volunteer's role within the project.

These steps are then repeated with other members of the team on a volunteer basis. The leader will need to lead a discussion on the role clarification process and the need for team members to periodically reevaluate their roles and the team's expectations. Step 2 could be assigned prior to the session, and the entire procedure could take place within smaller groups in which the volunteer has an interdependent relationship.