SOCIO-ECONOMIC ASPECTS OF IRRIGATED AGRICULTURE

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FOREWORD

The present paper was written as a broad introduction to the general topic of socio-economic aspects of irrigated agriculture. It is not presented as a comprehensive argumentation of all socio-economic dimensions. It is intended more as a background exposition and general cognitive map of the topic and as a basis for further discussion and elaboration. Being part of a number of works in the seminar on the prospects for irrigation in West Africa it should be read in conjunction of all other papers, especially those presenting the physical parameters of irrigation systems. Finally, the sociological background of the present author can explain the relative shorter discussion on economic and political considerations, as contrasted to a major emphasis in analyzing the socio-cultural dimensions of irrigation systems.

The support of the Agency for International Development is gratefully acknowledged in providing funds through the 211(d) Institutional Grant Program at Colorado State University (AID/csd-2460) and in the strengthening of activities leading to a better understanding of water management problems in developing countries.
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I. WATER, AGRICULTURE, AND SOCIETY

The relationship between natural resources and development has always been recognized as an important element in all attempts for modernization and economic growth. Together with human resources, they comprise the important ingredients for concerted efforts of planned change. In many respects, the economic life of a nation revolves around the availability, use, and exploitation of natural resources, especially as expressed in the pursuit of concerted natural resources' policies.

It has been widely accepted that natural resources include essentially all the elements of the natural environment needed for the production of certain basic commodities. What is important to notice is that the resource has real value only if the effort invested in its use is more than compensated for by returns to people. Thus, an important task in many developing nations is the determination of the availability of natural resources, the inventorying of potential uses, and the establishment of integrated long-range planning. Rational utilization of natural resources and proper management become key elements for utilizing science and technology in such a way as to accrue long-range benefits.

Despite the large strides in increasing agricultural production in the last two decades, there is a continuous challenge for more food production. This challenge is also recently accentuated by the apparent concern with the depletion and/or despoilation of natural resources. Such problems can be particularly acute in developing nations where both economic and manpower constraints compound difficulties in the process of development. In many developing countries where capital is scarce,
manpower unskilled, and entrepreneurship rather weak, the appraisal of
natural resources and the rational utilization become essential ingredients
for national plans on development. Similarly, in developing nations where
science and technology are recently introduced nature becomes a major
constraining factor in their effort for development and economic growth.
Natural resources, however, their development and utilization as well as
their effective allocation are not only important ingredients of the pro-
cess of economic growth. They can also be of much larger social process
of nation-building and of the continuous quest for social justice.

Before we introduce the topic of the role of irrigated agriculture and
the socio-economic environment within which irrigated agriculture takes
place, we need to provide some more general remarks on the role of water
and agriculture as basic ingredients in developmental policies. It has
become apparent by now that the task of future agricultural development
raise some very serious questions in all efforts for planned change and
modernization. Dwindling uncommitted lands, negative environmental
effects, increasing demand for food from rapidly growing populations make
it imperative to examine also the wise use of water resources as a vital
component of an improved condition of the population. Thus, irrigated
agriculture and the wise investment of limited financial resources become
part of the quest for the development of a major policy for achieving
important social and economic objectives. Thus, in trying to provide some
general directives for water development and agricultural growth, we need
to emphasize the importance of the proper mix of resources, the organiza-
tional and institutional frameworks for intervention, and the establishment
of priorities within the context of a national development plan. In addi-
tion, increasing urbanization and the demands for industrialization are
expected also to increase the need for a rational, multi-purpose use of available water supplies.

By establishing a much larger framework of national development efforts where natural resources play a key role, we can discuss irrigated agriculture in a sequence of questions and interlocking propositions. These can be summarily stated as:

1. What are the affected "environments" usually associated with an effort of introducing or improving irrigated agriculture in a given region?

2. Affected "environments" contribute to an understanding of facilitators and/or constraints, i.e., a whole host of circumstances that make more or less possible the establishment or operation of a well-designed scheme of irrigated agriculture.

3. Facilitators and/or constraints are incorporated in attempts of comprehensive planning. Such planning incorporates the standards of performance as well as criteria for evaluating the effectiveness of a proposed system.

4. Planning is formulated with the ultimate purpose of meeting regional or national goals or objectives through short- or long-range policies of development.

Such points will be raised throughout the following exposition in order to underline the major premise, namely that an understanding of irrigated agriculture requires also sensitivity to larger questions of social policy and delineation of broader concerns of national development. Irrigated agriculture, like any other major public project and technological intervention, requires knowledge of all the interlocking phases of conceptualization, design, evaluation, and implementation.
It should be noted from the beginning that in any attempt towards development, economic growth and material progress can be achieved not only by an effective use of given resources but also by a general economic tendency, orientation and capacity of responding to what Wiener has labelled "a growth environment" (Wiener, 1971). This growth environment incorporates the capacity of a socioeconomic system to modify its structure and to respond with greater variety and greater coordination and control to improved conditions. Thus, in the case of irrigated agriculture, increased production becomes part of a well-coordinated effort of improving incentives, allocating goods, and channelizing growth to desirable directions, including cumulative growth and equitable distribution throughout society. To meet such harmonization of economic and social goals, strong political mechanisms must exist that can translate directives into action and bridge discrepancies between social intentions and actual performance.

Thus, since the outcome of many programs depend both on the political decision-making process as well as on the availability and effective utilization of resources, every major development program should be characterized by both an improvement of this political decision process and the resources-outcome ratios. This implies an understanding of the integration of both physical and non-physical dimensions in long-range development strategies aimed at maximizing resource-outcome considerations. Climatic constraints, physiographic features, engineering potentialities, the general social context, and multi-objective multi-level planning are essential ingredients of efforts attempting to integrate physical and social goals and of shaping a socio-economic system which will facilitate increased production and provide diversified mechanisms of coordination and control leading to conductivity for a growth environment.
Towards the end of the 1960's, a number of books and works have brought forward a recurring discussion concerning the disappointing results in Third World development efforts. Many writers emphasized the structural inadequacies, the faulty planning methods, and a host of irrelevant evaluation procedures which did not permit many of the countries of the Third World to achieve or even take advantage of a growth environment characterizing developed nations. In agricultural development, in particular, there seems to be agreement that the apparent inadequacies center around the following points:

1. Incompatibility between development planning and the political decision process, especially because of the limited time span of planning and unstable organizational environments.

2. Lack of goal orientation and weak normative or "teleological" thinking. What we find here is a preoccupation with short-term production objectives as contrasted with long-term capacity orientation important for a growth environment in many developing countries.

3. Ignorance, and many times failure, to realize the differential process of development in various countries of the Third World, including a failure of incorporating principles of complex interdisciplinary approaches in the transformation process.

4. Narrow development alternatives, preoccupation with mega-structures and, often, blind transference of knowledge from developed to developing countries with little understanding of the socio-cultural context within which change takes place.
and of the need for a flexible framework of technological conditions suited to each specific country.

5. Preoccupation with sectoral planning and reductionistic analysis rather than systemic thinking orientation and multi-objective, multi-disciplinary considerations.

6. Failure in properly evaluating agricultural development in the context of a long-term national policy of resource allocation, system of priorities, trade-offs and time constraints in the implementation process.

What needs to be emphasized from the above brief remarks is that technologically speaking, the development of water resources of a given country can be achieved with the existing level of scientific and technical knowledge. However, development is not a matter of technology alone. We cannot simply transplant the technological apparatus of a given country into another social structure expecting the same benefits. Technology, in the absence of relevant data, organization, planning, institutions, human skills, available capital, and more than anything else, a clear understanding of the motivation of the people who are to employ it can become a futile task of mimicry with no organic connection to the life of the region. The question that we must raise is not technology per se but the social uses of technology and the purposeful articulation of human effort and institutions required to apply the technology in order to obtain effective results (Cantor, 1967).

Given these larger considerations, one can understand why most nations have attempted to develop much more comprehensive policies of water resources rather than concentrating in specific natural resources use. This can be seen, e.g. by the U.S. Senate Document No. 97
approved in 1962) which still defines official United States policy on water resources. The basic objectives of planning emphasized:

1. Development

Water and related land resources development and management are considered essential to economic development and growth through concurrent provision for adequate supplies, water quality facilities, power, flood control or prevention, land stabilization measures, drainage measures, watershed protection and management, outdoor recreation, and any other means by which development of water can contribute to the achievement of satisfactory levels of living.

2. Preservation

These include protection and rehabilitation of resources to insure availability for their best use when needed, open spaces for recreational purposes, the preservation of areas of unique natural beauty and of historic and scientific value, and generally the efficient employment, inspiration, enjoyment, and education of the people.

3. Well-being of People

This is the overriding determinant in considering the best use of water and related land resources. More than anything else, water resource development should not be directed towards the benefit of a few, but, like all other natural resources, it should safeguard the interest of all the people of the nation.

What becomes apparent, then, in discussing the interconnection of water, agriculture, and society is that they are all part of a larger national policy which aims in achieving not only economic development and growth, but
also in providing the basis for social reform and social change. This can
be done by integrating technological changes with parallel efforts for
social intervention and through political action guaranteeing efficient
employment of resources. Three major criteria emerge, therefore, in any
resource planning: physical, economic and social. The physical criterion
is perhaps the simplest to apply because relatively few factors affect it.
The economic criterion becomes more difficult because it is not self­
evident and can be affected by quite a number of factors. What is the
most difficult consideration is the delineation of the social criterion.
Social considerations, although repeatedly referred to in any general
statement of national policy of development, are at their best general
statements of intent, rather than well-clarified criteria of policy. In
many public projects (and in our case large-scale irrigated agriculture),
although physically and economically feasible, ultimate success seems to
depend on the third dimension, social feasibility, which incorporates a
host of constraints that are very difficult to define, almost impossible
to measure and part of the general counter-intuitive character of social
systems.

The main thrust of the previous short notes was the often repeated
argument that natural resources need always to be understood within the
context and in relation to a surrounding socio-economic environment.
Water, therefore, has meaning and importance where socially used for
the achievement of certain objectives. Its physical availability and
natural characteristics are certainly constraining factors, but it is
its eventual social use that makes it a valuable resource.

As part, then, of an integrated social system the use of water in
any irrigated agricultural society must be socially controlled through
a set of institutions known as an irrigation system. This means that the way in which water supplies, patterns of water distribution and water reclamation practices are regulated in a given agricultural society will depend largely on the nature, structure, and evolution of its irrigation system which in turn is essentially dependent on the larger socio-cultural environment and the specific ecological circumstances of a given region.

Historically, agricultural economics have always flourished in areas and regions with favorable ecological conditions for plant growth. Therefore, location and immediate ecology were key factors for agricultural production. The locational importance, however, has receded because control over the environment, technological innovations, transportation of water, etc., have provided greater flexibility for agricultural production in otherwise relatively hostile physical environments.

Yet, despite innovations and continuous promises of further physical breakthroughs (including futuristic alternatives of aquaculture, hydroponic potentialities, synthetic foods, and others) soil, water, and climate as given in the ecological configuration of a given region are prime physical constraints in consideration in agricultural production.

We propose to begin our discussion through a progressive unfolding of the general environments, the subsystems and broad conditions affecting irrigated agriculture. Such an argumentation will enable us to concentrate on the non-physical subsystems of the irrigation system, being cognizant, however, of the systemic links and of the interlocking character of physical and non-physical dimensions.

The physical or natural environment includes the watershed, airshed, minerals and land and it is often referred to as the geosphere. As important as the physical environment is also the social environment or what
we may call the sociosphere. This environment contains the common patterns of interaction between people in the physical environment, historical and community values, and all aspects of human resources as well as knowledge and skills. These two major environments or major resource systems are only descriptive categories of a complex set of interdependent relationships subsumed under the broader rubric of total environment, that is, all conceivable systems affecting man as an individual and his community as a whole. Once again, we need to argue against a misleading artificial distinction between natural environment and social environment, since what is usually called natural environment has meaning and utility only in the context of a social setting in which man interacts with nature. The man-centered system is the heart of a total environment approach and of the society-technology-nature symbiosis. In other words, in any attempt of technological innovation and in all efforts of environmental intervention, we want to insure that the conditions we impose on the natural environment and ourselves are reasonable, non-hazardous and beneficial as interacting systems.

We have introduced so far the two major environments affecting irrigated agriculture. There are many ways of classifying the surrounding environments within which irrigated agriculture operates. The two major categories established above are obvious divisions. Other classifications may be made with such criteria as size, structure and degree of social relationship. Most important here is the introduction of a scale of environment (physical and non-physical). We may speak of a continuum from micro-environment, i.e., basic smaller units of immediate space and personal contact, to macro-environments, i.e., the larger social units
and the more comprehensive interaction of spatial, cultural, and institutional configurations. To illustrate the point of differentiating between various "environmental levels" we may utilize the descriptive categories of Figure 1.

(Figure 1 about here)

What this figure indicates is that as the scale of the particular project increases there are different requirements for planning from the micro- to the macro-environment and, therefore, the level of analysis provides us with different considerations of social and technological principles depending on the level or environment of concern (we may think of the analogy of using a microscope vs. a telescope depending on the kind of environment we want to study). Thus, there are different principles to be introduced when we talk about irrigation within a given valley as contrasted to a basin, a whole river system or an inter-basin exchange. These remarks will become more relevant when later on we will discuss the importance of the level of analysis and the specific requirements for water resource planning under conditions of differential size of socio-ecological environments.

One additional remark on the general topic of level of analysis. The various units or different size environments as presented in Figure 1, in referring to both physical and non-physical dimensions, point also to the importance of inter- and intra-system relationships. A farm is part of a community, belonging to an irrigation system which falls within an irrigation area, and part of a larger basin, which is connected to other basins, etc. Each subsystem is then an open system affecting and being affected by other systems. Ultimately, whatever the level of
Figure 1: Levels of Analysis and Complexity of Design
analysis or unit, it will be impossible to avoid the restrictions or constraints from linkages with other systems and subsystems. In discussing irrigated agriculture we need to recognize and always keep in mind the three distinct elements or dimensions affecting establishment, performance, and effective evaluation of an irrigation system: physical and non-physical environments, level of analysis or scale of environment under consideration, and, finally, inter- and intra-subsystem and system linkages and exchanges.

We have provided so far some general remarks concerning water resources problems, the connection between natural resources and development, and some broad distinctions between physical and non-physical dimensions and levels of analysis in any cogent discussion of irrigated agriculture. It will be equally important at the same time to provide some cursory introductory remarks on the geographical perspective of water resources. Far from providing a regional geography of irrigation (a task which is done adequately in many general descriptive works, or such succinct expositions as Cantor's handy little book, *A World Geography of Irrigation*), we only need to indicate how unequal geographic distribution of water poses the major water-supply problem.

It has been observed that in more than one third of the land area of the earth, water is the chief limiting factor on human activity. About 21 percent of the land area has arid climate, another 15 percent is semi-arid, and an additional sizeable area has an uncertain water supply. There are some 25 billion acres of land on the earth, of which something less than 3 billion or about 12 percent are devoted to cultivated crops. Of this total, about 400 million acres are included under irrigation
systems, and an additional 200 million acres are served by artificial
drainage or protective works. The expansion of total food output in the
form of cultivated crops can be brought about generally in two ways: by
increasing the yield per acre of already cultivated lands, and by opening
new lands to cultivation. The development of new water supplies and
improved water use practices can contribute to greater food output in
both situations. Overall, two conditions converge in order to increase
the problematic situation of water. First, varying water supplies in
both time and space. And, second, diversity in water uses and water
requirements. Thus, not only the variability in distribution of water
provides us with a major difficulty in our quest for increasing agri­
cultural production, but, at the same time agriculture, as a major consumer
of water, has to compete with increasing demands arising from municipal
and industrial uses.

More important in discussing the general global look at water manage­
ment are a number of substantive problems that emerge in the discussion of
water use. First of all, it is generally recognized that there is an
increasing problem of scarcity of water in many lands particularly in an
arid and semi-arid belt that seems to comprise a large segment of the
inhabited earth. Second, while scarcity of water seems to be a major
problem, equally important for a number of countries is also the problem
of excess water and the assorted floods that seem to plague countries who
cannot regulate their supply of water. Thirdly, transcending the condi­
tions of either scarcity or excess are problems of water quality degrada­
tion due to either natural or human practices. The poor quality of water
is many times associated with a fourth problem in water management, namely,
misuse, and bad agricultural practices which accentuate complex problems of natural degradation. A fifth problem has to do with organizational ineffectiveness and the non-rational use of water supply. Even though water may be abundant, in many cases there do not exist the proper institutional mechanisms or the organizations that could effectively maximize allocation and use of existing natural resources. Finally, a persistent problem has to do in many cases with what one may describe as trans-national interdependencies, and the fact that many water supply systems do not confine themselves within arbitrary national boundaries or artificial political divisions. Problems of jurisdiction can become major handicaps for total environmental planning.
II. IRRIGATED AGRICULTURE AND SOCIO-ECONOMIC SUBSYSTEMS

A. The Irrigation System: A General Overview

Irrigation enterprises are associated from early historical times with every civilized society. The first known irrigation took place in Mesopotamia and other areas of the Old World. The type of irrigation which took place in these early times was primarily one of river flooding which would cover the lowlands of the delta. The flood waters would prepare the soil for the forthcoming agricultural time, and would supply the early agriculture users with a new layer of fertile and productive silt. A good crop could be grown with a minimum of expertise on the part of the early agrarian people.

Today almost seven thousand years after the beginning of irrigated agriculture in Mesopotamia, irrigation systems continue to be built and provide the basis for national wealth and power for many countries. In all countries, complex irrigation systems are associated with larger social political changes of the economy and culture of a given region. Irrigation projects, as well as other types of water resources development, have been associated with efforts for local growth and stability and with regional and national impacts by providing a diversified basis for choice commodities and solutions to the basic problems of community survival.

Irrigation developments were the product of complex civilizations which have progressed beyond the subsistence stage of agriculture. These civilizations required the construction of enormous public works in order to control water supply for irrigation with an inevitable development of complex bureaucracies and of elaborate systems of social organization. Throughout history the undermining of the delicate, complex irrigation
systems either through war, conquest, or the silting up of reservoirs and canals have been associated not only with the collapse of the physical infrastructure but also with the decline of the particular civilization (Cantor, 1967: 13).

Thus, irrigation has played throughout history a strategic role in the continuous course of agricultural development. Irrigated agriculture provided, and continues to provide, the agrarian basis of society. An important point always to be discussed with an historical overview of irrigated agriculture is that after the basic or central productive goal of an irrigation system is achieved, i.e., sufficient production for survival and economic growth, other social goals also appear which greatly complicate the institutional arrangements of an irrigation system. Such developments and goals, however, carry with them both benefits and disadvantages. On the one hand, the control of water resources and the establishment of an irrigated system of agriculture in places where rainfall is inadequate or unreliable permit the establishment of highly productive agricultural practices, followed by an expansion of human population and economic growth. On the other hand, an irrigation system carries with it not only certain technological imperatives which cannot be ignored, but also important social constraints for the operation of what will eventually become a highly complex system. The imperative of efficient organizational structure and of strong supportive institutional mechanisms for the operation of an irrigation system have been strongly associated throughout history not only with the success of the irrigation system but with the whole rise and fall of many civilizations.
As societies become much more complex and diversified and demands continuously increase and expand in scope and intensity, the use of scarce water resources and the preservation of the natural environment become much more important concerns in the planning and evaluation of development efforts. In any water resource development, three major problematic situations give rise to a continuous re-examination of the parameters of any water use system:

1. Continuously changing economic and social conditions, such as increasing population, demands for more food, urbanization, and industrialization.

2. The strong presence of institutional constraints, result of long historical and cultural practices, embodied in laws and judicial doctrines and in traditions reflecting the norms and practices of a given society and community.

3. Increasing concern with adverse environmental impacts and consequences. This concern stems either from an already ecologically fragile environment (natural sources of pollution), or from man-made perturbations, such as the misuse of the land and the various forms of the despoliation of the water supply.

Irrigated agriculture has to be seen as an integral part of these larger socio-economic trends and of increasing awareness of new equations between technological intervention and ultimate ecological balance. Suffice to indicate here, that there is already enough consensus and shared concern all over the world as to the consequences of the technological imperative and increasing efforts towards the protection of man's habitats.

One may start the discussion of irrigated agriculture by providing some key definitions and concepts associated with the view that irrigation
should be treated as a system with component parts and functions, operating within a larger sociocultural milieu. A concise definition of irrigation could be that of the artificial application of water to overcome the deficiencies in rainfall for the growing of crops. An irrigation system may, then, be understood as both the physical facilities and the institutions by which the acquisition, distribution, use, and reclamation of water contribute to increased agricultural production in a given enterprise setting. The practice of irrigated agriculture occurs today under three main conditions:

1. When water supply is inadequate. In the arid and semi-arid regions of the world the use of irrigation has been most extensive and practiced for thousands of years. Such areas as Egypt, West Pakistan, Southwest Asia, and a great part of the United States, could have never prospered unless cultivation took place under conditions of irrigated agriculture. In all such regions the water supply is derived partly from rivers and partly from underground sources.

2. When water supply is unreliable. In those geographical areas which are characterized by a marked seasonal shortage of rain, as, e.g., Monsoon Asia and circum-Mediterranean lands, irrigation is widely used when circumstances of rainless months and favorable temperatures make possible the promotion of plant growth.

3. When water supply may be used as a supplemental means of control and regulation. Generally, humid areas where the rainfall is normally sufficient to promote plant growth, irrigation may be used as a safeguard against drought and in order to promote higher
yields. This form of supplemental irrigation is increasingly used in order to improve an already existing system of irrigation rather than in creating an altogether new type of agricultural production. This type of supplemental irrigation is most widely used at the present in the eastern half of the United States, in the Soviet Union, and in western Europe and we may even think that increasingly may be used in various parts of sub-Saharan Africa.

While irrigation has usually been associated with regions of the world that have inadequate or unreliable water supplies, as a result of technological changes and increasing demands, irrigation is becoming a significant factor also for humid areas. Irrigation is an important quality control device in the production of many crops. Specialty crops are often produced by using irrigation as a production and quality control practice.

New conditions have also come to fore in terms of using water for irrigated agriculture. Increasingly in many countries, both developed and developing, the concern with limited water supplies and a realization of technological limitations in existing schemes of managing water quality and quantity have made imperative the considerations of alternative uses for a given water supply. Even areas of unquestioned abundance of water will have to face soon growing demands and increasing competition for water both between the different categories of users (agricultural, municipal, industrial) between geographical areas, including trans-national demands. There is a pressing need for a greater understanding of the physical nature and limitations of water and of the relative importance and value of the several uses to which it can be put. Thus, no region in the world independent of the available supplies of water will avoid a future pressing demand for
educating people as to the true character of the water problems and as to the needs for an integrated approach incorporating multiplicity of uses and multi-objective planning.

In many regions of the world, particularly in arid or semi-arid areas, the very existence of irrigated agriculture has been called into question. Recent writings both in the United States and in other nations have been raising questions about the constant hunt for water, especially for all those big projects designed to bring more of it to arid lands. As a matter of fact, the point has been raised that perhaps we should redistribute population towards more productive lands, and in order to save water practice agriculture only in regions that seem to be much more amenable to agricultural production. In the United States a question has been repeatedly raised as to why should the government pay farmers not to till the soil in States with high rainfall while it subsidizes farm irrigation in rainfall poor States. Despite all such remarks, it seems that barring a global catastrophe it is virtually certain that irrigation will increase in the years ahead.

When irrigation is introduced into an established agricultural area, the existing pattern of agriculture will be greatly altered. Changes will take place in the types of crops raised, the kinds of cultural practices, the intensity of use of labor and machinery and credit, and the kind of work skills that are required for any farmer in order to succeed in an irrigation agricultural economy. Many existing organizations and institutional patterns will be subject to pressure to change and adjustment to the needs of new irrigation projects. Pressures for adjustment of individuals, groups, organizations and institutions will also lead to
the establishment of new and appropriate structures. These new forms may produce a counter-reaction on the part of those in established roles and positions of power, influence or authority. Two contending forces seem to emerge in established agricultural areas with the introduction of irrigation projects. On the one hand, there must be a mobilization of the people, their organizations, and their resources to protect old goals and established traditional procedures. On the other, innovative schemes are required in order to meet the changing conditions of agricultural production, as well as new institutional forms for adopting to changing socio-economic conditions. It has been observed that in many projects not only of irrigation but of other forms of innovation and change opposition and resistance to changes seems to come from the following elements or conditions of the social structure (see Brower, 1968):

1. Beliefs, feelings, values. Those people who live and share certain beliefs and feelings about the present ways and the appropriate way of life unless persuaded by a new rationale or a new set of knowledge and beliefs, they will block the acceptance of the change.

2. A new irrigation project may produce goals which are incompatible with pre-existing objectives and goals of people in a given agricultural area. Unless aspirations of both individuals and groups can be redefined or adjusted as to be supportive of the new irrigation project, we may expect opposition in the implementation of the particular project.

3. Normative structure. Rules, expected behavior, and laws are inherent in any social structure, groups or organizations. The normative structure includes not only the definitions of
appropriate behavior in relation to farming practices, but also laws or specific rules regulating the distribution, use, and control of water. Such long-established practices and legal requirements are important forces of resistance to an irrigation project. Therefore, a whole new series of norms regulating the relationship among water users plus definition of the means for the systematic distribution of the water to serve the needs of all the people in the project must also emerge in order to insure control and regulation and absorption of a particular irrigation project in the community.

4. Roles, statuses, and power. It should also be realized that the establishment of any new irrigation project in already established agricultural areas clashes with ongoing social situations of individual members of the group and of communal groups. New irrigation practices not only produce a new set of goals but additional roles and positions as well as new sources of authority and influence. In many instances existing roles and positions of power become inappropriate and in many respects dysfunctional. Thus, those who are to lose from the introduction of a new irrigation project unless they become part of needed new roles and positions, they are expected to provide resistance to a new irrigation project. Any new program, therefore, needs to introduce new power arrangements which will not be suspected and resisted, but well defined and understood as part of a well-thought plan of water use and control.

These problems that appear with the coming and the establishment of an irrigation project in an already established agriculture area are not any
easier for irrigation projects in new or virgin lands. Even in these lands where previously few, if any, people have lived additional socio-economic problems can be encountered. People need to be enticed to move into new areas from other areas, facing the uprooting from traditional surroundings and the building of new institutions and organizations aiming at the creation of new patterns of life. When people have been enticed to move from barren, rocky villages to more or less fertile but hotter, more humid low lands, resistance has always appeared because of existing strong family ties, perceived relative deprivation, the fear of disease, and other conditions of fear towards a new situation (Brower, 1968: 459). As it is also true in the introduction of irrigated agriculture in established systems, here also in new areas not only problems of physical adaptation arise but also tremendous educational problems of needed new skills and abilities in order to manage a new and different kind of farming operation.

While we have been discussing so far the general human problems involved with the introduction of a new system of social life in either established agricultural areas or in new lands we need to elaborate a little bit more some of the problems associated with irrigated agriculture. A variety of reasons have been cited throughout the literature as associated with the fact that despite heavy investments in irrigation and drainage in recent years, the derived benefits often have been short of expectation. An underlying important reason that repeatedly comes throughout the literature is a lack of an awareness of the need for integrating engineering measures with agricultural practices which is essential for achieving a high and rapid rate of economic returns. As it has been stated in many studies, often the engineering undertaking and the assorted socio-economic
Agriculture activities seem to operate in isolation to the detriment of the development objectives.

Second, it should be noted that in addition to the lack of an integrated approach and the demands for comprehensive development incorporating physical and non-physical dimensions irrigated agriculture is characterized by the fact that it is the biggest consumer of water and as a matter of fact, one of the most inefficient. Irrigation accounts for more than 85 percent of the total consumption of water controlled by man. It has been estimated that while most industrial processes use less than 100 tons of water for one ton of end product, agriculture generally requires several thousand tons. Other estimates show that both the application efficiency of most of the irrigation methods, and as a matter of fact the overall project efficiency, seem to sometimes be as low as twenty to thirty percent in the less developed countries where management of water use is virtually neglected (Lim, 1971: 2). This inefficient use of water application together with the high consumptive character of irrigated agriculture becomes particularly important and increasingly so in recent years where competing demands will required reexamination of the role of irrigated agriculture in the context of total development.

A third problem associated with irrigated agriculture is the fact that generally irrigation schemes are very costly undertakings and the experience with many of them so far has proved to be both slow and low yielding. While we can understand the reasons for the slow flow of returns inherent in such irrigation projects, still in a number of cases their long, so called gestation periods are many times related to the inadequacies in engineering design criteria. This particular difficulty is also coupled with the lack of proper overall technical administration of project
development and operation. As a result, irrigation and drainage facilities are seldom provided to make possible the practice of proper water management at the farm level (Lim, 1971: 2).

A fourth problem in irrigated agriculture arises from the observation that there has been an overemphasis on engineering structures with little consideration as to the rate of return. Ignored many times in the classical engineering approach are considerations of rational and timely application of water for increased crop production through the provision of "software" organizational facilities and procedures. It is only recently that concern has arisen as to the problems of organizational deficiencies and timing as important factors in breaching the gap between the irrigation potential created by major engineering structures and on-farm development with supporting water management. Such organizational constraints are not only the result of historically established inadequate organizational procedures and administrative infrastructures for on-farm application, but also due to a continuous lack of funds or adequately trained personnel.

A fifth problematic situation is associated with the fact that irrigation structures and irrigated water management are only part of a larger story: the eventual success of an irrigation project depends on the capability of individual farmers in adopting and utilizing a growth environment for agricultural production. Thus, well-conceived irrigation projects and appropriate physical structures can produce fruitful results only if the farmers make full use of them. Motivation, strategic initiative in utilizing a growth environment, and improved capability for sustained production are perennial problems appearing in any discussion of developmental efforts in agriculture. In various parts of the literature it has
been indicated that farmers in various regions of the world work only on a subsistence basis. In the absence of modern irrigation facilities, they have developed practices and forms of cultural adaptation characterized by traditional beliefs and cultural habits as to what may be considered optimum production. Problems, then, arise as how to break away from this traditional system and introduce innovative schemes of modern farm management. The response to that is usually education through the extension service, which may provide the basis for improved capability for sustained production.

A final problem in irrigated agriculture has to do with the availability and accessibility of a general market where the increased product could be distributed. Problematic situations arise when schemes of improved irrigated agriculture lack the dependability of the market and of institutional supports or price incentives. Such considerations are part of broader governmental decisions beyond the narrow scope of improved agriculture within a given region or locality. Thus, while new levels of technology, improved organizational efficiency and receptivity to a new growth environment may produce an abundant product, the farmer may be handicapped by low conditions of market dependability and by adverse regional or national circumstances affecting the absorption and circulation of the increased product (see also later at the Conclusion on the requirements for increased agricultural production).

We have underlined above quite a number of problems associated with irrigated agriculture. We should not forget of course that there are quite a number of social and economic benefits to be derived from irrigation development. Increased food production and its importance in alleviating
population pressures need no further discussion. While in most cases the expenditures of public funds for irrigation projects are still made with the old historical intent of increasing wealth, there are also growing considerations of larger, broader social goals concerning a balanced attempt for the welfare of the nation as well as the welfare of the farmer and of the region in which he lives. Thus, the preoccupation with increasing wealth is now accentuated by an understanding of the larger effects of investments in irrigation projects in terms of their impact on local growth and stability. Indeed, when the initial period of heavy capital expenditures and growth are achieved, the economy is then able to reach a level of stability based on a continuing intensive application of land and water resources. The source of stability of a given region derives from a generally accepted principle that the more diverse the pattern of cropping in irrigation areas, the more the economic stability through a diversified product capable of withstanding wide price fluctuations (Marr, 1967: 17).

Not only wealth and local and regional stability are the larger benefits of irrigated agriculture, but other ancillary features are adjunct to irrigation development. These include the facilities for hydroelectric power, flood control, municipal and industrial water supplies, fish and wildlife conservation and recreation. Thus, the construction of any of these facilities alone would usually entail prohibitive expenses but they become feasible and parts of the larger developmental planning of social welfare with rational impact as a part of a multiple-purpose water project. Of course, we should not also ignore the important benefits to local, state, and federal governments
from revenue. Also the construction phase of an irrigation system provides increased employment and demand for construction material, therefore resulting in the expansion or introduction of new industries. Last, but not least, the larger socio-economic benefits to be derived from an irrigation project is the fact that in addition to the provision of efficiently produced food supplies, the products of new irrigation projects may favorably increase the nation's balance of payment by decreasing a need for imported foodstuffs or by providing new products for export.

In comparing the advantages and disadvantages from introducing irrigated agriculture, we need to underline the concern that the important factor for the ultimate success of irrigated agriculture is systematic planning with sufficient flexibility to account for the changing economic and social structures of an area. This means that in order to mitigate the problematic situations narrated above and in order to accelerate the advantages expected from an irrigation program, we need to take into account schemes of integrated planning incorporating physical and non-physical dimensions of an irrigation system. By having a better understanding of the local conditions we may be able to utilize a well-designed irrigation system by well-trained and equipped farmers. Thus, the so-called "human factor" becomes the important catalyst for change and an assurance that the investment in physical resources will be managed properly and will become part of an overall scheme of individual and communal development.

This last remark brings us therefore to the essence of the argument in this presentation. While we realize the existence of problems of irrigated agriculture and the potential benefits from new schemes of
expanding agricultural production, we need now to turn our attention to
the more specific ways of understanding irrigation systems, to ways of
modelling our particular socio-economic subsystems, and to more concrete
details for our understanding of the irrigation system functions and
dynamic processes.

B. Irrigation System Functions and Dynamic Processes

The central questions of the sociological part of the discussion of
irrigated agriculture is how to theoretically and methodologically
approach the social dimensions of natural resources. The core argument
centers around the proposition that although water supply and water quality
themselves are vital in any discussion of resource utilization, a key
element will be the specific mechanics of organizational structures which
will determine and secure the volume of water supply, adequate distribution
operations, and the meeting of local, regional, and eventually national
water use demands or goals.

The discussion of appropriate organizational structures and processes
in order to meet present and future water demands requires recognition of
both physical and social dimensions of a projected irrigated agricultural
system. In adopting a systems analysis we view water management as a
system operating in a given environment where inputs (physical and social)
processed through the "organization" (through) result in outputs or goals
established for the functioning of the system.

If one is to look at any organizational unit, including water use
systems, one must take into account some systematic format which brings
together component parts. To start with, there are two major environments
within which component systems or subsystems operate:
a) the external environment which is both natural and man-made; and

b) the internal environment encompassing all subsystems operating primarily inside the boundaries of the external environment.

Any model then would integrate external and internal environment, where inputs (resources), through the system or thruput (organization) will contribute to outputs (objectives or goals). As any other system, an irrigation system implies a collection of people, devices, and procedures intended to perform certain functions. Thus, a systems model is a working model of a social unit which is capable of achieving a goal and involves the systematic exploration, analysis and evaluation of all the possible consequences of proposed alternatives to an on-going system.

The general orientation with the systems approach is part of the overall effort of integrating physical and non-physical dimensions of irrigation systems. At the same time, such a systemic approach includes not only the conditions (facilitators and constraints) under which particular irrigation organizations are maintained, but also the conditions or circumstances under which processes and activities contribute effectively in the achievement of given water resources goals. We may use the following simplistic Figure in order to establish an initial understanding of the proposed systems approach in irrigated agriculture.

(Figure 2 about here)

In the above input-thruput-output model we attempt to utilize a dynamic systems analysis approach which requires:

1. Delineation of our objectives and goals as well as of alternatives.
2. Description of the system (boundaries).
3. Constraints of the system (inputs).
Figure 2: Conceptual Design of a Systems Model
4. Time constraints and diachronic considerations (short vs. long-range).

5. Techniques for systems analysis.


The specific variables required to analyze a given system are innumerable, and dependent on a great variety of spatial and aspatial circumstances. For a general irrigation systems model, however, the elementary component parts can be broadly summarized in the three major categories of input, thruput and output. Input considerations include such variables as the physical environment, population characteristics, normative resources, economic viability, political networks, and technological development. System or thruput considerations (incorporating internal variables) are various structures and processes identified with organizational arrangements, such as personnel, facilities, and procedures. Finally, output considerations are variables referring to the established goals or objectives of an irrigation system, revolving around such goods or services as the total volume of water supply, water quality, flow and distribution, enhancement of life, and long range water resource development.

We have indicated that a system may be perceived as an array of elements or functions structured to facilitate the accomplishment of an objective. Indeed, the simplest form under which we can perceive a proposed irrigation system is a three-component arrangement of elements described briefly as input, thruput, and output. More complicated systems can be structured using such triadic distinction as the basic units. These complicated systems, in addition to more detailed considerations of subsystem parts involve also other dimensions, such as their degree of openness or closure, their dimensionality, and the hierarchy of
objectives. Moving beyond the simplistic elements of Figure 2 we may see the increasing complexity of systems analysis in Figure 3, which incorporates further elements, component subsystems, and hierarchy of objectives.

(Figure 3 about here)

In line with our major argument in delineating the factors facilitating or hindering irrigated agriculture, our primary focus is on the following inputs or constraints of an irrigation system:

1. **Engineering** inputs (part of natural resources inputs) having two major dimensions:
   a) hydrology or water supply problems, such as time history, diversions and crop water demands;
   b) network requirements (water facilities), such as canals, pumps, delivery systems, and irrigation return flows.

2. **Social inputs**, such as ecological and demographic characteristics and the normative resources of communities within which irrigation systems are located.

3. **Legal inputs**, such as the substantive water law, legal aspects of surface and ground water, duty of water, administrative aspects of law, requirements and limitations, and the specific allocations of individual water rights.

4. **Economic inputs**, such as conditions of production and processing, markets and marketing, forms of capital formation, credit, employment and labor, and diversified aspects of capital resource allocation.
Figure 3: Input-Thruput-Output Model for Diversified Subsystems (Vlachos, forthcoming)
What we are essentially saying is that the external environment, i.e., the ecological configurations and the conditions of an existing social structure provide the constraints (and the facilitators) for the inputs characterizing our irrigation system. These input constraints include natural resources (available water, land configurations, etc.), demographic characteristics (total population, age, sex composition, vital rates, etc.), normative and legal constraints (values of the community, legal water doctrines, etc.), the economic viability and potentialities of the area, the administrative apparatus (sources of local government, degree of autonomy, etc.), and state of technology (degree of automation, technological innovations, etc.).

The inputs are then processed through institutional mechanisms, or the concrete organizational systems devised for maximizing desired goals. Thruput involves physical structures (buildings, canals, etc.), and organizational infrastructures, such as rules of operation, patterns of leadership and command, efforts for control, integration, information, and communication, and ways of interacting with other organizational environments.

The crucial point in our discussion of an irrigation system is that the construction of such a project is closely associated with all major components of a social system: with its inputs (as expressions of the conditions of the external environment), with the organizational arrangements devised to meet performance requirements (thruput or "system"), and of course, with desired objectives or goals and social policies for introducing an irrigation project in a given locality.

Perhaps another figure can summarize the above remarks by providing a simplified version of water resources problems and of water management.
leading towards a more complex presentation of an irrigation system model.

(Figure 4 about here)

We have established so far some general framework of water resources problems in order to facilitate the discussion of the non-physical parameters of irrigated agriculture. Social scientists have traditionally included the environment in their theoretical frameworks, but the interconnection between physical and social parameters has not only been clearly stated. In order to be able to examine any kind of a physical system, it becomes imperative to provide a much broader view of natural resources, and a more careful analysis and delineation of individual and aggregate levels involved in the presentation of a system. This is particularly true in irrigated agriculture which has to be examined within a complex socio-technical framework that is operating with varying degrees of success in relationship to an encompassing natural environment.

Our particular concern and attention will be focused on four subsystems that are of importance for a socio-economic understanding of irrigated agriculture. These are the socio-cultural subsystem, the economic subsystem, the political subsystem, and the legal subsystem. However, before we proceed with a more detailed analysis of these important socio-economic subsystems, we need to provide the larger map of an irrigation systems model and its submodels. The following figure summarizes the engineering or physical parameters that comprise the general irrigation model and the natural environment conditions that need to be taken into account before we proceed with any further analysis of socio-economic aspects.

(Figure 5 about here)
Figure 4: A Simplified Version of Water Resources Problems and of Water Management (Vlachos, 1972a)
The submodels of the irrigation system described in Figure 5 are also key elements for a later delineation of the socio-economic dimension. At every submodel and throughout the total irrigation system the use of water must be socially controlled through sets of appropriate institutions. Rules in the use of water and special operational agencies are required not only because of conflicting demands emanating from a pervasive scarcity of water, but also from more general requirements of utilizing natural resources as part of cooperative action and communal living.

There is a great variety of irrigation systems because of different geographical conditions, cultural circumstances and above all because of the general character of the water supply, namely whether inadequate, unreliable, or supplemental. Yet, despite great variations in scope, extent and organizational form, they all encompass common elements and parallel institutional mechanisms which result from the following crucial questions:

1. How will the water resources be used in the productive process?
2. Who will plan and how will the production facilities be installed and organized?
3. Which individuals shall exercise control over the acquisition, distribution, use, and reclamation of water resources?
4. What will be the distribution and marketing of goods and services produced, including also the installation and operation of distribution facilities?

More specifically an efficient irrigation system should be designed in such a way as to be able to perform the following functions:

1. Store water so that it will become available in sufficient quantities whenever required.
Figure 5: Irrigation Systems Model and Physical Submodels
2. Deliver water to all parts of the cultivated area in amounts needed to meet crop demands during peak use periods.

3. Provide complete control of water.

4. Measure the amount of water at entry into farm irrigation system.

5. Divide water into required amounts for use in different fields.

6. Dispose of waste water after use.

7. Provide for the reuse of water on the farm.

8. Allow for the free movement of farm machinery.

9. Distribute water evenly into the soil of the field

(Cantor, 1967: 38).

Institutions need to be devised, therefore, which will allow for proper utilization of such a system through efficient use of water, making irrigation possible without soil erosion, saline or alkaline accumulation, or waterlogging.

Needless to say, such a system demands both capital investments to cover the high cost of installation and a considerable degree of technical expertise to use it to its best advantage. While this may be true in quite a number of technologically advanced countries, in developing nations where knowledge is lacking and capital is limited modern irrigation techniques become difficult to introduce.

What should concern us from now on, assuming that we are able to use technological innovations and expertise gained from irrigation enterprises in developed countries, is the question of understanding and organizing the socio-economic dimensions of a water management system for irrigated agriculture. Once again, water management is perceived as a system operating in a given environment where inputs (physical and social) processed through
the "organization" result in outputs or goals established for the functioning of the system. We have described above the elementary parameters of such a system by indicating the external environment as well as the component parts and subsystems of what has been described as an internal (predominantly physical) environment. Using the previous descriptive figures as a springboard, we may proceed in delineating the socio-economic dimensions of an irrigation system. Figure 6 presents a simplified version of a local irrigation system designed to achieve maximum agricultural productivity through the application of water by human agencies in order to assist the growth of crops and grass.

(Figure 6 about here)

This figure indicates that four major environments provide the necessary inputs for the operating of a system or organization. These are the physical environment with the particular ecological constraints, the existing socio-demographic conditions and spatial arrangements, the economic potentialities, and the normative milieu (which includes not only norms, values, and institutions, but also legal constraints and cultural resources). There are also additional inputs into an irrigation system, arising from constraints and/or facilitators of the larger system or external environment, such as the state of technology and technical innovations, the larger political network and the linkages with other administrative units, and the constraints from broader (national or regional) resource policies affecting the operation of the irrigation subsystem.

As figure 6 indicates and as repeatedly stated previously, the inputs from a variety of environments are processed through structures and procedures which attempt to maximize desired goals. These organizational
Constraints / Needs
[Inputs]

Socio-Demographic
(Population,
Distribution)

Economic
(Capital Resource
Allocation)

Physical
(Natural Resources,
Ecological Limitations)

Normative
(Values, Institutions,
Laws)

Feedback and Changes in Inputs
(More Capital, Population
Growth, New Values, etc.)

Processing Mechanisms
[Thruput, "System"]

Institutionalized Organization

Physical Infrastructures

Rules of Operation

Objectives:
- Increased Productivity
- Enhancement of Land
- Quality Product
- Individual, Collective Betterment

Feedback to the Organization
(Participation, Morale)

Desired Goals
[Output]

Additional Constraints from External Environment
- Technology
- Political Network and Administrative Apparatus
- State, Regional, Federal Policies

Figure 6: Simplified Version of a Local Irrigation System (Vlachos, 1972a)
structures or throughs, varying in size, scope, integration, and complexity from region to region, from basin to basin, and from country to country include both physical facilities developed for meeting the need of increased productivity and various dimensions of infrastructure, such as rules of operation, patterns of leadership and command, efforts for control, integration, information, and communication and ways of interacting with other organizational environments.

The desired goals or objectives in an irrigation system denote the output part and revolve around a variety of goods and services for individuals, communities, regions, and the nation as a whole. Recently, in addition to such obvious objectives as increased productivity, wealth, land enhancement, security, etc., increased mention is made of such qualitative goals as enhancement of quality of life, aesthetic satisfaction, regional balance, and others which provide us with infinitely more difficult problems of evaluating the effectiveness and performance of any proposed irrigation system.

In trying to understand an irrigation system, we need also to emphasize the feedback loops that connect the various component parts and processes of the system. One feedback loop leads from output to the "organization" through increased participation of individuals, organizational morale, and direct interaction between, e.g. users and/or officials and members of the organizational units. Another feedback loop connects output with input. Thus, the achievement of stated objectives may provide the impetus for the commitment of more capital, increase population, and contribute to changing attitudes and values as a result of the successful meeting of stated goals. Ideally, feedback processes can serve as
corrective mechanisms, monitoring devices, and additional inputs which could increase the organizational effectiveness and thus the achievement of desired and continuously expanding objectives. The above rather complicated remarks are nothing more but a continuous extension of the core argument introduced early in the simplified representation of the connection between inputs, throughput, and output. The systemic linkages and component parts incorporated in Figure 6 can become much more complicated if we try to develop a more comprehensive analysis of a large array of irrigation systems (rather than the local irrigation system depicted in the above figure) and their intra- and inter-system dependencies. As it will become apparent later on, these major categories and dimensions describing the irrigation system will eventually provide us with more specific variables and parameters in organizing, understanding, and finally evaluating the effectiveness of any proposed irrigation system.

While Figure 6 shows the overall structure of an irrigation system, and the more or less static considerations in terms of the constraints of the natural and socio-cultural environments, the following figure attempts to provide another view of the dynamic aspects in the operation of a given irrigation system.

(Figure 7 about here)

Figure 7 is based on an understanding that three subsystems, namely the water delivery, cropland, and water removal subsystems, are the major dimensions characterizing an integrated irrigation system. From these major dimensions, an irrigation system's functions can be broken down into the following dynamic processes, each of which requires a vast array of organizational structures and complex rules and procedures affecting crucial considerations of decision-making and policy guidelines:
Trnspiration from Crops and Irrigated Land
Poor Quality Wtr Cloud Supply, Precipitation, Recycled-Seeding, Desalination, Non-Irrigated Surface Runoff, etc.

Water Water Distribution (Canals, Laterals, Distributions) Water Utilization (Irrigation) Water Reclamation (Surface and Subsurface)

Irrigation Return Flow

Figure 7: Irrigation Water System Functions and Dynamic Processes (Vlachos, 1972a)
1. Water supply and water source considerations including new or potential sources of supply.

2. Water control aspects and characteristics of diversion, storage, reservoirs, and wells, and the assorted institutional forms of regulation.

3. Water distribution systems, the means of transmission and patterns of water flow.

4. Water utilization, the system of irrigation and crop operation, as well as cultural practices and scheduling programs.

5. Water reclamation and aspects of drainage, including field outlets, release of full water, and irrigation return flow (Vlachos, 1972: 297).

What both the previous two figures try to emphasize is the multiplicity of levels of analysis and the multiplicity of functions in an irrigation system. Most important, at each level and for each subsystem component part and function, problems of institutional order arise, difficulties of organizational arrangements, and need for specific understanding of the normative rules involved at each stage or phase of a dynamically operating irrigation system.

What are then the major sociological remarks to be made concerning each of the above five functions? The essential argument underlining our concern with the functions and institutions related with these five dynamic processes is that each system function is associated with important organizational and institutional considerations and aspects of decision making. Independent of their essential connection with the physical or engineering aspects of any irrigation project, each dynamic function
presented in Figure 7 requires considerations emanating from the larger socio-economic context. More specifically, in each of these functions we can make the following observations:

a) **Water supply and water source considerations**

The success of every irrigation system rests largely on the adequacy and dependability of its water supply. Indeed, the watershed component is a key element for the eventual success of any irrigation project. The natural sources, watershed and underground, provide the principal sources of irrigation supply. There are additional sources such as rain-making or cloud-seeding and saline-water conversion, but these techniques have not advanced sufficiently to make them important and inexpensive sources of irrigation water supplies.

Whenever water supply is considered the first element which should come to mind is the very dependability of the water supply. The engineers can build the structures, they can impound the water, but is that water a dependable element for the individual user? Will there be water at the end of the season? If there is water and it is not adequate for the year, the types of crops which would be grown are necessarily limited. A water poor situation would be characterized by fairly low yield crops and probably very meager results for the agricultural water users. These crops would primarily be small grains and hay. On the other hand, if the water supplies were quite adequate and dependable toward the end of the agricultural year, the crops which would be grown would be different. The yield from the latter crops are very high and the margin of profit is considerably higher than the margin of profit from the low yield crops. As a result, the dependability of the supply of water becomes very significant in the eyes of the water user. If the supply is somewhat
erratic, the desirability of the land clearly drops because the probability of success would not be as high as if the supply of the water were much more dependable.

The institutional arrangements for the management of the water supply are not adequately understood or effectively organized. Part of the reason is a consequence of the inadequate knowledge and technology to manage this resource base. Little is known about changing ecology of watershed areas and on the flows of surface as well as underground water. At the same time, it has been recognized that little has been done, even in developed nations, to systematically and constructively manage underground resources. The institutional arrangement has been essentially inadequate and subject to rapid obsolescence. With the introduction and increased development of irrigated agriculture it becomes more and more necessary to exploit underground water reservoirs and problems of conjunctive use of water complicate the situation.

b) Water control, storage, regulation

The regime of most great rivers is irregular. Frequently, they carry their greatest volumes of water following torrential thaws of spring, which fill the river and which without conservation would rush heedlessly to the sea.

Therefore, one of the first considerations which must be made when a water project is being considered is the controlling of the water during low times as well as high. The construction of water control facilities in an irrigation system allow for dependable supply of water. That is to say the ability to store water provides the irrigation water users with a series of impoundments which allows them to be sure that the water will be
available to them throughout the year. Once the impoundments themselves have been constructed the element of dependability then shifts to the construction of such things as diversion structures so that the appropriate amount of water can be diverted.

c) Water distribution and patterns of transmission

The primary purpose of the water transmission system is to make irrigation water available to the common irrigator in accordance with crop and soil needs. Formally organized irrigation systems are set up in order to deliver water to a certain point where traditional institutions largely take over one of the most important functions, namely the allocation of water between the farmers and for the crops planted.

Speaking of distribution, a major project requires a complex network of dams, pumping stations, and canals. In addition to the main dam, whose reservoir is the main storage unit, smaller diversion dams are needed to direct the water into an intricate canal system. The water is led from the dams into broad canals by gravity and in cases where because of physical conditions water cannot be transmitted by gravity, pumping stations may be installed. From the main canals, water is diverted into a system which will distribute it throughout the farm. The most common means by which this is done is by open ditches or laterals, and the flow of water into them is controlled by headgates or regulators. The ditches are generally permanent ditches and commonly follow property boundary lines, fences and edges of fields. Leading from the permanent open ditches are secondary or field ditches. Water is delivered from these ditches to the area to be irrigated by means of check structures or turnouts.

There are three different types of distribution which are commonly used. The first method of water distribution is continuous flow. A
continuous flow situation is one in which the irrigator is entitled to a specified amount of water on a continuous basis. Typically this amount of water is very small and it is measured in second inches or in minors inches. This is generally a small flow, or head, of water. This does not necessarily mean the irrigator will use this water all of the time, it only means that he is entitled to that water on a continuous basis. The advantage of having a continuous flow of water available is that the irrigator feels that when water is needed it is always there and he is entitled to it. Perhaps the major disadvantage of a continuous flow of water is the small head, and it is fairly difficult to do an adequate job of irrigating when the head of water is small. It is also very time-consuming because the individual irrigator is compelled to go out and change the water quite frequently, a rather undesirable practice in the eyes of many agricultural water users.

The second form of irrigation water distribution is rotation. Rotation is nothing more than delivering water on a fixed schedule every so many days or every so many hours. For example, a rotation could be every seventh day or every fourteenth day at the twelfth hour and then the water user would receive that water for a fixed number of hours during that particular time period. Rotation is generally implemented in cases where the irrigation system is not large enough to supply the water at any particular time or in cases of high land fragmentation. The advantage of rotation is one in which the irrigation water user receives a fairly large head of water at a specified time and it then can be used by another irrigator at another specified time. Thus, the agricultural water user knows exactly when he has to be ready for his water and for a fairly short time period he is extremely busy watering. After that, he can address himself
to other tasks which need to be taken care of after his water turn has come and gone. The disadvantage of a rotation system is one in which, during hot days of the year, the rotation may be slow enough so that the crops will begin to burn before the individual's water turn arrives. The converse can also occur, and the water turn can come too frequently or early and the agricultural water user finds himself in a situation where he is actually overwatering his land with assorted damages from water application.

The third type of water delivery is by demand. Demand is perhaps the best method for delivering water from the agricultural water user point of view because he can ask for a specified amount at a certain time and have the water delivered for as many hours as he wishes to receive it. The water user can decide how much water he needs, he can have that water delivered at a time when he feels his land needs it most, and he can generally save water because he can apply it according to the needs of the particular piece of land or crop which is in that land. The major disadvantage of demand is that at certain times of the year all farmers want the water at the same time and no matter how large the irrigation system it simply is not capable of delivering all the water at the same time. As a result some farmers will find themselves not able to receive the water at the time they request a delivery of water.

All the above lengthy remarks on water distribution have as common denominator for a successful operation of a distribution system a highly knowledgeable water user and appropriate organizations and procedures for meeting the diversified circumstances of water transmission. In addition, to insure that irrigation water is used economically and
efficiently, the irrigator must know the size of the stream he is using and the amount of the water that he takes from it, so that he can divert the water from the ditch to the field and lower water safely from one elevation to another. In a modern irrigation system, the measurement and control of water are efficient and highly developed procedures. This then becomes the next crucial junction of an irrigation system, namely, the patterns of water utilization and application.

d) Water utilization, application, crop practices and scheduling programs

The above primarily physical elements of an irrigation system represent already quite a complex situation which an efficient farmer has to consider. Indeed, the crucial element in any irrigation system is the performance of the farmer or the common irrigator. In a well designed irrigation system, the farmer becomes the central and responsible force for the success of the irrigation enterprise. He is the one who ultimately decides to what uses he wishes to put his land and selects the methods of irrigation best suited to them. He usually determines what crops are planted, when irrigated, how much water applied, and makes related decisions that significantly determine the extent of success or failure of the irrigation undertaking (Jones, undated: 11).

However, additional considerations have to be taken into account during this phase of an irrigation water system. Many times the farm equipment may have some bearing on the methods of irrigation under consideration. Also, the amount of available labor must be taken into account since a system which may be installed cheaply may be very expensive to operate because of the amount of labor required. Also, on a larger level, it should be understood that some schemes of irrigation are
considerably more expensive to set up than others and in some countries, lack of capital is the decisive factor in determining the nature of water utilization in a given irrigation system.

What should be stressed at this point is that the farmer becomes the important but so often neglected factor in the development of irrigation systems. At the same time it should be recognized that a farmer is very much a product of his socio-cultural environment. Much of his performance, degrees of success or failure, depend upon the composition of the institutions that are set up to support his farming activity. This implies that except for extremely small scale irrigation operations, successful irrigation systems require strong and well organized water user or shareholder associations. Irrigators are effective in their plans of water utilization, crop practices, and scheduling programs to the extent that they operate within well designed organizational systems. Irrigated agriculture at the level which counts more, i.e., the farm level, requires coordinated and cooperative action on the part of a number of institutions and individuals (Jones, undated: 12).

This part of water utilization and scheduling programs becomes an important consideration in our systems analysis because it is the throughput or the "organization" that ultimately will determine the efficiency and operation of our system. On-farm operations become crucial elements in comparing inputs against some reference or output level and in being able to evaluate the results in such a way as to be able to correct practices in order to maximize performance. What we are essentially then saying is that the wise application of irrigation involves a considerable degree of expertise, based on the principle that enough water should be provided
to satisfy the needs of the plants without causing waste or damage to plants or the land.

The methods of irrigation in current use, which vary enormously in complexity all over the world, are most highly developed in technologically advanced nations. The four general methods of applying water are: (a) by flooding, thus wetting all the land surface; (b) by furrows, thus wetting only part of the ground surface; (c) by sprinkling, in which the soil is wetted with a spray; (d) by subirrigation, in which the soil is wetted only a little if at all, but in which the subsoil is saturated. In any one farm of sufficient size and with a variety of crops, soil, and landscape features, a number of these methods of irrigation may be in use.

The above considerations on water utilization and crop practices are not discussed here in order to underline again the importance of engineering and physical considerations. The fact should be stressed, however, that all these complex conditions associated with the application of water in a given farm or area depend ultimately on the expertise and continuous education of local irrigators who not only themselves know the ideal conditions for increasing agricultural production, but also are members of strong organizational units which in their collective presence and effective procedures permit maximization of individual efforts.

e) Water drainage, reclamation, water quality

Getting the water onto the land is only part of the problem that faces the farmer. Of equal importance is also the disposal of water after use. Too much water in the soil can be worse than not enough, while inadequate planning and improper irrigation frequently result in salination and waterlogging.
Drainage can become a large problem in an agricultural area where irrigation has been implemented because if the water is not being removed or is not capable of removing itself from the land, the land will become waterlogged and sour very quickly. Once land is waterlogged and soured, it is unproductive and in some cases it is necessary to simply abandon the land and move on to another plot of property. Traditional practices in many parts of the world have already brought about desolation by year-round irrigation. Efficient use of water is among the most important means of insuring that in the future further despoliation will be avoided. All the efforts for introducing technological innovations for avoiding problems of drainage seem to require more and more technological expertise (including even in the future large canals systems controlled by computers). This means that once a system in the irrigator as well as his water use organizations will be required to provide not only capital for major technological breakthroughs but also procedures and organizational rules that will permit judicious decisions as to problems of water drainage.

There are presently some common practices for reducing waterlogging problems. The first and most common method is one of using open drains. These are nothing more than very deep ditches running through the land which drain the water away. This water can be carried to any point which the irrigation company or the irrigator feels is appropriate. The second way of dealing with waterlogging is to put tile drains in the land. The tile drains then can be covered with gravel and soil and the land immediately above the tile drains may be used for agricultural purposes or any other purposes which the water users feel is appropriate. The last way which is perhaps the most costly way is pumping the land. When water reaches such high levels that the land is being damaged it is possible to put wells
in the land and pump the water from the land. This water can once again be used in any way which is deemed appropriate by the water users or by the irrigation company. But pumping is very expensive and it will very quickly lower the water table if enough large pumps are placed over the wells.

Water reclamation for an irrigation system of any scale or level is also an extremely complicated problem and in many respects much bigger than that of drainage. Increasingly, it is becoming necessary to not only remove excess water to avoid the problem of waterlogging, but also to recycle the water in a systematic fashion (Jones, undated: 13).

Because of the diffused nature of the underground water resource, the reclaiming of water, the removing of excess water, and the exploitation of underground aquifers, has largely been on an individual farmer basis. As repeatedly indicated throughout the presentation of the dynamic functions of an irrigation system, this individual basis is becoming inadequate as an institutional approach when increasing demands for water and the need for large capital outlay require much larger organizational units and more complex administrative procedures.

Given these major component parts of the physical dimensions of an integrated system of irrigated agriculture, we need to re-emphasize some major points of concern to the social scientist that should be derived from the above brief presentation.

1. Successful development and management of water resources requires much larger institutional and organizational arrangements, quite succinct from the presently prevailing highly segmentalized and individualized approaches in agriculture in various parts of the world.
2. Norms and cultural values concerning water use must be coordinated within a larger social planning domain, especially with regard to water rights.

3. Each proposed irrigation system, independent of its level of intervention or analysis, must develop unique patterns much more responsive to the specific people and cultural conditions found in a given region, rather than simply blindly transmitting generalized information from other nations.

4. The larger scope of the irrigation system and the greater the scale of analysis, the more complicated the organizational arrangements and, therefore, the more the need for coordinating powers and comprehensive planning.

At this point it is important that we summarize the argument so far. We have introduced two major dimensions characterizing our attempts to understand an irrigation system, namely, physical and non-physical. At the same time, a general introduction was provided on the major categories of the major irrigation water system functions and dynamic processes. Finally, throughout the previous discussion there was also a continuous recognition of different levels of analysis, namely micro- and macro-environments or levels, which require different variables, consideration of scale, scope, and extent of approach and intervention. Essentially, our argument so far can be summarized in the following descriptive figure.

(Figure 8 about here)

We need to turn our attention now to some key questions and problems associated with the description, understanding, and analysis of the non-physical subsystems.
<table>
<thead>
<tr>
<th>Physical</th>
<th>MICRO-ENVIRONMENT</th>
<th>MACRO-ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUPPLY</td>
<td>Precipitation, River Flow, Underground, Surface, Recycled, etc.</td>
<td></td>
</tr>
<tr>
<td>CONTROL</td>
<td>Reservoirs, Dams, Wells, Seepage</td>
<td></td>
</tr>
<tr>
<td>DISTRIBUTION</td>
<td>Canals, Pipelines, Measurement, Seepage</td>
<td></td>
</tr>
<tr>
<td>UTILIZATION</td>
<td>Agronomic considerations, time and amount, yield</td>
<td></td>
</tr>
<tr>
<td>RECLAMATION</td>
<td>Runoff, deep seepage, return flow</td>
<td></td>
</tr>
<tr>
<td>Non-Physical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOCIOCULTURAL</td>
<td>Population, Community organization, values, institutions, etc.</td>
<td></td>
</tr>
<tr>
<td>ECONOMIC</td>
<td>Capital resources, Manpower, reimbursement policies, etc.</td>
<td></td>
</tr>
<tr>
<td>POLITICAL</td>
<td>Organizations, political network, administrative apparatus, etc.</td>
<td></td>
</tr>
<tr>
<td>LEGAL</td>
<td>Substantive law, administrative law, judicial guidelines</td>
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</table>

**Figure 5**: Physical and Non-Physical Environments in Irrigated Agriculture
C. **Non-Physical Subsystems**

What are some general considerations that will enable us to understand the human landscape? We have been so far largely concerned with the technical aspects of irrigation. Yet, at the same time, irrigation is as much an expression of human organization as it is a technical achievement. The human and social dimensions of irrigation are particularly dramatic in arid and semi-arid regions of the world, where human adaptation to the physical environment has produced striking forms of geographical and communal arrangements.

There are four subsystems, which although non-exhaustive of the range of non-physical subsystems, are central in any discussion and understanding of irrigated agriculture.

1. **The socio-cultural subsystem**

Cultural institutions usually evolve slowly and are shaped by religion, history, language and the surrounding natural environment. The shared values about the relationships among individuals and between the individual and the group, assumptions about motivation and initiative, concepts about justice, attitudes toward the environment, policies regarding water, and many other cultural precepts will determine whether any given institutional arrangement vis-a-vis irrigated agriculture will succeed or fail. By understanding these cultural institutions as well as in studying the general community system we are also able to provide clues as to institutional support for water development.

There are perennial difficulties in the social sciences concerning the terminological variations of key concepts on human community, socio-cultural environment, etc. Both community and society are among the more ambiguous concepts. Although sometimes they are used interchangeably
with reference to a group of people living together and sharing a common culture, it is important to keep them distinct by reserving the term society for the most inclusive, complex, and self-efficient type of social grouping.

There is little agreement upon how best to describe a community as a sociological entity. Although multiple usages of the term may be unavoidable and part of the elusive character of social phenomena, nevertheless they make things difficult for those who seek to study communities and understand their importance, crucial mechanisms of social organization in any project. The problem is accentuated by the overlapping between such concepts as "community," "social structure," "social system," "society," and "social organization." A major definition in the field is that of a community as a "combination of social units and systems which perform the major social functions having locality relevance," with the emphasis placed on a firm territorial base. Above all, communities represent an organizational pattern through which persons meet their daily needs in a local area.

At the same time, although there is disagreement concerning the best way of describing community as a unit of social organization, there seems to be an underlying agreement that one of the best ways of presenting such an entity is in terms of a social system, or as a network of social interaction.

We may adopt the term "social environment" as a more relevant definition involving three key variables, namely the territorial variable (physical environment), a sociological variable (social interaction and organizational and institutional networks), and a cultural variable (common ties and normative system).

The social environment leads us to a definition of the social system as a collection of people, devises, and procedures intended to perform
some function. A social systems model is a working model of a social organization which is capable of achieving a goal and involves the systematic exploration, analysis and evaluation of all of the possible consequences of proposed alternatives to an on-going set of interdependent role components surrounded by a boundary of social norms (Vlachos, 1972b: 13).

The formidable, if not obscure, definition given above is not intended as a means of confusing the issue of a systematic exploration and accounting of the structuring of human behavior in a social environment. What we are aiming at is to describe the minimal conditions, or basic variables of the human community that must be taken into account when an irrigation project is being introduced in a surrounding social system. Of course, such variables will vary from situation to situation and from time to time, given also the type, scope, intensity, and extent of the irrigation project.

There are certain basic variables within a spatial/temporal location which indicate the essential arena within which social interaction takes place. These clusters of variables and their dimensions are important in planning and in considering irrigation projects effects. Such variables may appear on all levels of possible irrigation planning with different degrees of intensity between micro- and macro-environments. These basic variables of the socio-cultural environment can be clustered in the following categories:

1. Demographic variables. These involve the population characteristics and population composition or the basic demographic conditions essential in the operation of any human community. Thus, the total number of people involved, population density, vital
rates, and patterns of mobility, are among the first units to be taken into account in considering potential effects and the general character of an irrigation project. In addition, we need to know not only the number and composition of people involved in an irrigation area, but also infer from the given demographic profile the ability of any human community to be able to accommodate shocks induced by an irrigation project.

2. **Normative resources.** These include a number of social and cultural resources, the attitudes, values and sentiments, ideological orientations and goals, as well as historical antecedents and cultural practices of a local population of a given community. The general community culture, the degree or extent of communal consensus, and the patterns of normative behavior are among the conditions to be considered when estimating the effects of a new irrigation project.

3. **Community organization and institutional networks.** This general category of variables includes the whole network of special social organizational arrangements in a given community and reflects our concern with an understanding of the types of specific social relationships and institutions within a given social structure. The degree of integration or conflict, social power distribution and influence, housing conditions, types of various institutional facilities, and existing types and patterns of voluntary and non-voluntary associations are all important dimensions in the examination of the socio-cultural environment and its relation to an irrigation project. Some communities have
better organized facilities and institutional arrangements that seem to be able to handle more effectively the presence of a proposed irrigation system. Others lack both the organizational background and the institutional structures to be able to absorb with minimal social perturbations the presence and continuous operation of an irrigation system. We also need to take into account in any discussion of community organization the presence and extent of larger social aggregates such as social class, categories of social rank, religious groups, etc.

4. **Organizational procedures and institutional mechanisms.** Cross-cutting the general parameters of a community are the procedural details involved in the conception, maintenance, completion, and operation of an irrigation project. Potential effects and advantages of a newly established irrigation project can be alleviated or increased by strong or weak procedural mechanisms in organizational handling, by the different networks of communication and by established patterns of intergroup relations. Water is only one of a myriad of elements which are flowing into the community. In terms of the organization of the irrigation company and its relationship to other organizations, water has to be readily accessible to individual users or groups. Because of differential demands in various months of the year, patterns of communication and institutional arrangements must be established in order to insure communication of needs, monitoring of use, and feedback information for a more effective operation of the system.
Organizational procedures need not only be the formal institutional mechanisms for carrying out a particular project, but also a number of informal procedures and operations affecting responses of an irrigation system. Informal procedures and mechanisms of intergroup relations include provisions for public participation and community cooperation and communicable awareness of probable and plausible consequences or effects of an irrigation project. Finally, as it will be related later on in the much larger area of political environments, the mechanisms of support and coordination (which include the political network and existing administrative apparatus) are crucial in achieving the diversified goals attempted through an irrigation project. Such general elements of organizational procedures influence significantly the policy making and the various agencies in a given community and can be better understood under the concrete dimensions of administrative structure and organizational functioning. This simply means that communities which have developed mechanisms of support and coordination are better able to perceive and effectively organize themselves in meeting both the challenge and the potential consequences of an irrigation project. Their successful integration of an irrigation project will, thus, depend on the content and clarity of the functional objectives of the organization, on the comprehensiveness of the geographic and economic scale of operation, and on the social characteristics of the organizational style and pervasive political philosophy.

The above remarks and major subcategories of the socio-cultural sub-system emphasized what one may summarily call structural or background
characteristics of human aggregations. Communities as a whole, as well as parts of a community, are primarily characterized by populations of differential social, educational, cultural, occupational, or institutional composition. Therefore, an irrigation project has also differential potential for success and variegated impacts given the socio-economic and cultural background of the surrounding communal environment.

2. The economic subsystem

A number of economic and financial considerations are involved in selecting and planning any water development project. These considerations may be grouped under various headings such as economic policy, reimbursement policy, and project economic evaluation. At the same time, individual irrigation programs cannot be examined in isolation from the more general national efforts of economic planning and from a total economic perspective of regional policy and resource allocation.

Economic programming and considerations of resources-outcome ratios are part of multidimensional efforts that require numerous material and nonmaterial inputs and specific sequential events for the maximization of the investments. Following Wiener's analysis, these inputs can be grouped under two principal headings and each further subdivided as follows (Wiener, 1972: 36):

1. Material inputs
   a. Basic investments, i.e., creation of new means of production.
   b. Supplemental investments, or investments necessary for the improvement of existing resources.
   c. Current production inputs, as e.g., seeds and fertilizers.
2. Nonmaterial inputs
   a. Technological inputs (know-how skills).
   b. Motivational resources.
   c. Structural resources or what were discussed above as organizational and institutional imperatives.

Together with the material and nonmaterial input, the economic analysis will also consider the developmental sequence for a maximization of available resources. Thus, a first pre-investment groundwork phase (essentially the exploitation of available resources and investments) is usually followed by the main investment phase, i.e., transformation of institutional structure, emergence of growth environment, and overall capital-intensive investment.

In conducting economic investigations determination is made of how proposed agricultural projects would contribute towards the primary objective of promoting and sustaining social and economic growth. Ordinarily, this overall objective cannot be reached by a single agricultural project. Complementary projects have to be designed in order to meet specific problems and needs through new or improved use of available resources.

The economic investigation and understanding of the economic environment revolves around the identification and comparison of the costs and benefits associated with a particular course of action, purpose or project. These costs and benefits are measured by the difference in conditions which would prevail with and without the project. Usually such an economic investigation is closely related to a sociological study of the area and involves the following time landmarks: historical and present conditions, probable future conditions without the proposed project, and probable future conditions with the project in operation. It should be stressed
then that time is a vital element in any comparison and economic evaluation. Equal costs and equal benefits occurring at different times are not necessarily of equal value. In addition, any good economic analysis should also be supplemented by a recognition of the difference between primary and secondary effects, between tangible and intangible consequences (always hard to measure in purely economic terms), direct and indirect impacts and, finally, between desirable and undesirable side-effects or negative spill-overs after the system operates for a long period.

The data needed for an economic analysis is characterized by a long list of items that serve as a basis for estimates of future conditions. A very comprehensive list of such economic consideration has been provided by the United Nations Manual of Standards and Criteria for Planning Water Resource Projects (1964: 23) and includes such items as:

- Land ownership and tenure.
- Patterns of land use.
- Number, type, and size of farms.
- Organization of typical farms including number of persons per farm and workers per farm.
- Farm investment.
- Number and kinds of livestock.
- Farming methods.
- Farming costs.
- Crops and crop yields.
- Marketing facilities and consumer demands.
- Relation of agriculture to general economy of the area.
- General financial or economic status of the farmer.
- Necessity and opportunity for off-farm employment.
- Standard of living and on-farm consumption of farm products.
- Skill of farmers and ability and suitability of equipment.

All these essential categories are of course supplemented by the general analysis and understanding of the socio-cultural data presented above, of the population basis and of other general characteristics of socio-economic composition.

In estimating the potential irrigation benefits, the literature makes a particular point in distinguishing between direct irrigation benefits as contrasted to indirect irrigation benefits. The first are the increases in net farm income resulting from the application of project water. The increase in net farm income is derived from the differences in total net farm income for the project area with and without the project. Indirect irrigation benefits, on the other hand, are usually labelled as public benefits and cannot readily be expressed in monetary terms. Nevertheless, they are always considered as vital factors in the justification of the project. Among benefits of this type are: settlement opportunities (new family-size irrigated farms), employment opportunities in industry or commerce resulting from increase in the processing of farm production, and improved standard of living resulting from increased and more varied food production. Finally, another indirect irrigation benefit characterizing the overall emphasis of introducing a new irrigation project is the security of the farmer as a result of a more reliable water supply (U.N., 1964: 24).

There are many specialized studies exploring the aspects of the economics of farm irrigation. What we need to indicate in the present general introduction of the economic subsystem is that all these specialized studies, formulas, or other highly technical understandings of the economic
dimension of irrigation projects and water resources planning revolve around in-depth analysis of a basic expression. This expression is essentially understood in terms of an input-output function which relates physical output \( Y \) to inputs of variable resources or resource factors. The latter are stated in general as \( X_1 \) (land), \( X_2 \) (labor), \( X_3 \) (capital), and \( X_4 \) (management). In further analysis, the general land variable can be expanded into its areal, soil, and soil moisture standpoints, each of which can be set out as subvariables. Similarly, subvariables can be set out for the other major variables of labor, capital, and management, the last usually being treated as a residual factor.

Output \( Y \), then, may be stated explicitly in various ways, ranging from the lineal function \( Y = a + bX_1 + cX_2 \ldots nX_n \), to more complicated exponentials \( Y = aX_1^bX_2^c \ldots X_n^n \) (Steele and Pavelis, 1967: 175).

Quite a number of mathematical and economic properties and many alternative functions have been investigated throughout the literature, essentially resulting from such simple equations as the one described above, expressed as a function of \( Y = f(X_1, X_2, X_3, X_4) \) or other parameters of an irrigation regime, such as \( E = f(S, T, D) \), where \( E = \) economic parameter, \( S = \) soil characteristics, \( D = \) drainage characteristics, and \( T = \) topographic characteristics. The last equation concentrates more on physical characteristics as the independent variables whose interaction under an irrigation regime may be equated to an economic parameter.

It is not our purpose here to explicate either the specific means of financing irrigation, how economies of scale can be achieved, the mathematics of economic analysis, price theory, conditions of project optimality, or general principles of engineering economics (for a thorough discussion of all such topics one should consult the massive work of James and Lee,
An important part of this discussion, however, centers around the role and importance of welfare economics and the move beyond pure economic analysis to normative or prescriptive criteria of a social optimum. Thus, rather than using traditional descriptive economics, new indices and formulas can be used, computed as a mathematical formula incorporating all social goals of a type as:

$$SWI = a_1 G_1 + a_2 G_2 + \ldots + a_n G_n$$

where SWI, social welfare index measures in some form the achievement of each goal (G), through a progressive weighting factor (a) indicating the relative influence of the goal in achieving general social welfare.

The difficult part in such operations is the construction of a social welfare index or function requires a series of value judgments, which in turn depend on clear policies, consensus of goals and non-conflicting objectives. Such requirements make it extremely difficult to develop sensitive indices in that usually in water resources conflicting goals are sought, and overt and covert considerations may be in basic disagreement. Such lofty goals as maximum national income, equitable income distribution, environmental quality, institutional stability, regional development, aesthetic opportunity, individual freedom and variety, etc., have a most obscure definitional domain, high subjectivity, relative importance, and above all transcended by considerations of political expediency.

All in all, the conclusion of this brief discussion is to indicate once again the crucial role of the economic subsystem as a parallel constraining non-physical environment affecting the establishment and successful operation of irrigated agriculture.
3. The political subsystem

A major concern in the implementation of an irrigation project is also the question of how public authorities regulate the management and use of water resources. The long-range objective in the control of rivers and streams is to maximize the next benefits, to the extent practicable, from the development of the land and water resources for all purposes necessary to meet man's future needs.

The mechanisms that have been developed for the coordination of water resources management are in many countries embedded in generally fragmented national governmental policies, regional water plans and regulations, and in diversified documents attempting to design comprehensive plans for river basin development and management. There is general agreement in many countries that there is a pervasive lack of coordination and integration of the objectives, programs, and operational procedures both within and among relevant agencies.

Irrigation projects, as all other forms of water resources planning, are also political processes, despite our past preoccupation with their engineering or economic characteristics. Therefore, national policies and political constraints are important considerations in planning any irrigation policies. The governmental institutions and structures are key conversion processes for developing the operational procedures and rules and the forms of decision-making that would make possible the application of public policies in utilizing community and natural resources and in achieving the general goals of social and economic growth.

4. Legal constraints and facilitators

The question of who owns water in a river or in the ground although seemingly of little interest to the outsider is of immense significance
to the enterprising farmer and to the water planner whose success of their farms or new projects depend very much upon the water rights and water law as well as on the general considerations of engineering and finance. In areas where water is plentiful questions of property rights in the use of water are not so critical. However, in those places where the conditions of abundance do not seem to exist increasing demands on the water supply, not only from agriculture but also for industrial and urban uses, become vital elements and contending forces for the use of limited supply.

In many areas of the world where water supplies are inadequate or unreliable, the local population and the proper authorities have long struggled either through tradition or evolved procedures to develop workable doctrines to accommodate the conflicting interests and to provide a sound legal base for economic progress. The American West is a particular important case of how a new doctrine evolved in order to govern water rights of individuals. The doctrine of prior appropriation was a means of protecting the right of the first person to use a known quantity of water, despite the fact that he may not have been close to the water source. This legal doctrine was based on the principle that the farmer could use this amount against any subsequent upstream or downstream user.

The importance of legal institutions in water development has too often been overlooked. Throughout history, competition for the use of water has led to disputes and frequently complex legal tangles. In general, three different principles governing rights to the use of water are common in various parts of the world: the riparian, appropriation, and equitable distribution doctrines.
Where water is relatively plentiful, the riparian doctrine of water rights has developed, based on common law. It gives the holders of land bordering on water, or riparian land, the right to a "reasonable use" of water. Reasonable use is commonly defined to include domestic and agricultural uses, and may or may not include industrial use.

In lands of the world, more recently settled and characterized by usually inadequate water supply, the appropriation doctrine of water rights law described above is generally applied. According to this doctrine, the rights to the use of water are vested in the person who first uses it. This is indeed a very harsh doctrine which, especially in the western United States and because of competing urban and industrial demands, is creating vociferous demands for change.

The demand for change is leading in some areas to the creation of what has been described as equitable distribution right, which makes it possible for known riparian users to obtain the right to use a certain quantity of water by obtaining a permit or a court order and by meeting certain requirements. Separate provisions customarily apply to ground water.

We should immediately state that many of these doctrines described above are often in direct opposition with the effort for sound conservation. However, practices and water rights vary enormously in different parts of the world and in areas that have long been farmed under irrigation the legal doctrine tends to be very complex and difficult to change. Over the centuries, an elaborate series of agreements, usually verbal, have developed to deal with the construction and maintenance of irrigation works, which eventually led to well-entrenched traditional practices. Indeed, as early as 2050 B.C., early courts of water law have
developed complex requirements for water use and for resolving disputes over water.

The investigation of the legal subsystem requires a thorough investigation of various areas of substantive water and corporation law, procedural law, administrative law and regulatory guidelines, and judicial interpretation of doctrines. Once the statutory and case laws have been identified and analyzed, individual irrigation project documents need to be drawn or examined for more specific clauses impeding or facilitating effective performance.

We need to emphasize in particular the twofold important distinction of legal constraints and facilitators. One is the substantive water law which refers to that part of law which creates, defines, and regulates rights. Its origin may be found in state constitutions, statuses, or case laws. Our task is to determine the basic doctrine in each country, area, or case and to identify what concept of ownership is attached to waters within the regions boundaries. The important aspects of substantive law which will bear directly on a proposed irrigation system differ from region to region and from country to country, but they all reflect similar preoccupation with the following concerns:

1. The concept of ownership in the area.
2. The water rights and the appurtenancy requirements.
3. Meaning and application of the concept of beneficial use.
4. The related concept of waste in the allocation and distribution of water.
5. Duty of water doctrines.
6. Permissability of transfer rights and/or use of water among users or to other users.
7. The degree that conjunctive use of surface and ground waters is authorized or encouraged (Radosevich, 1972: 365).

Equally important is also the second part of our legal constraints and facilitators, namely procedural and administrative law. This law is defined as that which prescribes the method of enforcing rights or obtaining redress for their invasion. Administrative law is narrow in scope in that it pertains to the various governmental agencies and describes in detail the manner of their activities. Such general administrative and procedural law may be found in the national or state water statuses, judicial procedures act, and internal rules, guidelines, and regulations. The importance of the procedural and administrative law cannot be dismissed. It may very well be a procedural requirement that consciously or unconsciously creates efficiency impediments in any proposed irrigation system. For example, lengthy and costly required litigation to effectuate certain changes or in introducing an irrigation system may deter from the implementation of a project.

The previous brief description of four non-physical subsystems has supplemented the general discussion of a systemic analysis of irrigation projects. We need now to turn our attention to some central issues in agricultural management, to broader questions of planning, design and operation, and to an overview of a few basic methodological observations, especially in evaluating and assessing performance of irrigation systems.
III. ISSUES IN IRRIGATED AGRICULTURAL MANAGEMENT

While we have discussed previously some general aspects of water, agriculture and society, as well as subsystems involved in the planning or any irrigated agriculture system, it is also important to bring forward some overriding areas of concern associated with water resources management. Some broad understanding of what planning and comprehensive social policies imply will reemphasize the general thrust of the paper in providing general analysis. Design considerations for irrigation requirements and principles of operation and maintenance of irrigation systems also will be briefly introduced, in order to elucidate the argument on the need for an integrated approach in irrigated agriculture.

A. Planning and Social Policy

To be done properly, planning for water development obviously cannot be isolated from the planning of other resources, both natural and human. The use of the term "comprehensive planning" as applied to water resources is not a recent invention but goes back to the turn of the century when in many countries including the United States the term "multi-functional" planning was first introduced, (Hoggan, 1969:5).

The comprehensiveness of water and related water resource planning has been the subject of controversy and debate in the literature. It has been recognized, however, that in order to be able to maximize the benefits from any water resource project, a much larger systemic analysis of the surrounding environment is needed, a broadening of the horizons of traditionally narrow planning efforts, and increased sensitivity to decision-making problems associated with multi-objective and multi-dimensional interventions.
The objectives of planning become the crucial elements in understanding the need for integrating agricultural projects in a broader social policy. Objectives are statements of purpose, and their determination is in many ways the most important single phase of the planning process. Objectives may be divided into classes by degree of abstraction. One category of objectives may consist of those which are general, ultimate, or theoretical. Such fundamental goals refer to all encompassing questions of human welfare, such as increases in national income, redistribution of income, economic growth, satisfactory level of employment, and enhancement of the quality of life. They are usually set by the highest policy-making units of a particular government and serve as flexible boundaries for the determination or pursuit of more specific objectives or covert aims. Thus, other classes of objectives are much more specific and geared to the particular circumstances surrounding a given community, territory, area, region, or particular grouping.

The basic goal in the formulation of any kind of a framework analysis for irrigated agriculture is to provide the best use, or combination of uses, or water and related resources to meet foreseeable or conceivable needs. From this general quest, the major objectives for planning water resources, and more specifically agriculture projects, are:

1. National economic development and development of particular regions or communities within the country, through increased employment and improvement of the economic base.
2. The preservation of the nation's resources, including protection and rehabilitation insuring availability for the future.
3. Enhancement of the quality of the environment by improvement of certain natural and cultural resources and ecological systems.
4. **Promotion of the well-being of people and concern with the social welfare of all**, by contributing to the security of life and health; by providing educational and cultural opportunities; and, guaranteeing balanced growth among various affected persons or groups.

All such general goals have already been introduced in various parts of the present paper. What we should underline here is that a consistent relationship should be established between water resources action and national goals. In the United States, various Presidential Commissions, Task Forces, and other ad hoc groups have produced a series of documents exemplifying the increasing interest in formulating and discussing national goals, in developing hierarchies of goals and objectives, and in delineating methods logical considerations and theoretical models for a more precise definition and evaluation of alternative goal strategies (see for example the recent work of the Technical Committee of the Water Resources Centers of the Thirteen Western States: 1971).

From the broad goals incorporated in national or regional policies, more specific objectives are desired associated with the operation and output considerations of irrigated agriculture. Such specific objectives include:

1. Facilities for storage and distribution of the water supply.
2. Structural and nonstructural flood damage prevention measures.
4. Increased livestock and crop production.
5. Encouragement of exploration and multiple use of resources available.
The beginning and end of comprehensive planning is goal setting. The definition of long-term goals produces medium-term objectives from which quantifiable short-term or immediate targets may be derived. At every level, however, goal setting, the determination of trade-offs, and the establishment of priorities depend primarily on political value judgments. To help this decision-making process and despite the normative basis or expediency considerations, we need to provide essential information through various objective yardsticks. Thus, by comprehensive planning and through the establishment of more quantifiable indices, we may be able to move beyond the short-term, narrow political consideration, long-term intervention sequences, establishment of optimum time for intervention, and more rigid criteria for selecting among alternatives.

The theory of water resources planning is essentially based upon principles of scientific method and of welfare economics within a framework of public policy that can accommodate multiple objectives rather than a single objective of economic efficiency. As explained previously, there is increasing emphasis on social planning and on a move away from purely economic objectives to much more complex consideration of social welfare.

The above general remarks on planning and on objectives of social policy are guided by a sensitivity and awareness as to what any public project, including irrigated agriculture, does for the general welfare of society. The epistemology of social planning requires a consideration of definite steps in meeting the demands of this broader social policy. These considerations follow approximately the following order, or phases in planning:

1. The systemic mapping phase, which in addition to describing needs, concerns, and resource constraints, incorporates also
questions and problems of priorities in a determination
of the community system inventories physical conditions, and
investigate legal and economic requirements.

2. Valuative phase or normative phase, which includes all questions
of social goals, desirable targets, objectives, and the generation
of alternatives through a screening process of values and policy
priorities. The possible approaches to obtaining objectives
can be achieved through a value, political, resource and reality
screening in the context of a definition of the system's func-
tions, the types of intervention, technical design requirements,
and parameters of programming.

3. The decision making phase or the selection of specific targets.
This phase incorporates the considerations of the feasibility
of the project, the valuation of the ecological and socio-
economic consequences, the mechanisms and criteria for the
selection of specific targets, and trade-off studies, as well
as risk estimation of a proposed intervention.

4. The implementation phase with its specific plan of action,
design specifications, the management of the project, the
specific techniques and technological breakthroughs for the
actual implementation of an irrigation project, and finally,
the measurement of consequences and impacts.

The above phases and major requirements can be seen graphically
in the following figure (Figure 9).

(Figure 9 about here)
Figure 9: Sequences in the Planning Process (Vlachos, forthcoming)
Moving beyond the general considerations of social planning and utilizing earlier remarks of systems orientation, a multipurpose water project should involve the following factors in the design of an irrigation system:

1. Land resources considerations, such as land classification, land use, and capabilities, settlement, and drainage.

2. Water resources considerations, such as water supply, water quality and treatment, water requirements, water rights (including international treaties), flood status, sediment, project operation studies, hydraulic design requirements.

3. Engineering and geological considerations such as foundations and materials, anticipated construction problems, physical plan formulation.

4. Financial considerations, such as economic criteria for plan formulation, economic justification, cost allocation to various purposes, repayment of capital investment, payment of annual operation, maintenance and replacement costs.

5. Socio-cultural considerations, such as the size of population affected, density, composition, mobility, spatial distribution, household composition, community services, associations, public health, etc.

6. Legal considerations, such as rights to use of water, international agreements, land acquisition and rights of way.

7. Political considerations such as the determination of public interest in contemplated development, establishment of government policy and enabling legislation, administrative apparatus, political network, patterns of communication, organizational requirements for supervision of construction and operation of proposed projects, program and budget requirements control.
All in all, the formulation of an irrigation project is a process of selecting and evaluating the purposes to be served, the physical means of development, the size of facilities, and the area to be benefited. This particular process is directed toward an efficient accomplishment of socially valid objectives. Thus, social planning is a means of directing social change and social relationships toward the ultimate objective of orderly and harmonious community processes. As part of a general process of change, an irrigation project becomes a concrete means for exemplifying and realizing goals and for improving the welfare of individuals and collectivities within a given community, region, state or the nation. Using the irrigation system as a focal activity, we can trace in the following simplifying figure the major concerns which seem to run through an attempt of total comprehensive planning. (Figure 10)

(Figure 10 about here)

In this generalized figure, the underlying proposition is that an irrigation system is affecting primarily the economic, social, and physical life of a "community." The activities and impact generated by irrigated agriculture are related to, coincide, or may even conflict with values, goals, and objectives of local communities as well as of the larger society. These activities may, then, be translated to standards of a more technical level. These standards or norms may be incorporated in specific plans or programs which provide the basis for the execution, alteration, or even the abandonment of a proposed irrigation project. At the same time, all these considerations for the introduction of an irrigation project are affected by external considerations such as federal policies, the general availability of resources and the policies for their allocation and use, the state of technology and the
Figure 10: Major Effects in Comprehensive Irrigating Design (Vlachos, forthcoming)
ability of meeting the proposed objectives within existing technical capabilities, and finally, by considerations and constraints of the political culture as well as of objectives of national social policy.

What we are trying to say above is that in considering and planning for an irrigation project we are guided at the same time by an awareness of what indeed such a proposed technical project can do for the larger society. Especially in countries and situations where little knowledge exists, we need to be careful not to superimpose a technology, or transplant experiences based on blind faith on the technological experience of other nations. In any detailed study of irrigated agriculture, we must continuously review the following considerations:

1. Strive to adapt to natural conditions, by using existing ecological elements to the advantages offered by the local landscape.

2. Utilize resources to their best advantage by designing facilities requiring materials locally available, or by raising crops best suited to the temperature and moisture conditions prevailing in the particular situation.

3. Respect local culture and religious traditions. This is done by introducing improvements gradually, by avoiding disruptive established patterns, and in general, by respecting the local traditions and the prevailing norms of long experience of the local farmers.

At the same time, attention should be paid to larger constraints encompassing local circumstances, but essential in any comprehensive water plan. These include:

2. Allocation of water among competing areas and users.

3. Water quality criteria and the general concern with the increasing problem of maintaining environmental quality.

To summarize, any successful technical and institutional arrangement for managing water resources projects needs to meet certain important criteria which center around our concern of how to respond to local demands. In addition, competency in planning, coordination in research, control over both water quality and quantity, and the ability to provide flexible financial support and alternative ways of responding to changing situations are among the guarantees for designing a good irrigation system.

B. Design, Operation, and Maintenance of Irrigation Systems

The success of an irrigation project depends to a large degree on a good program of operation and maintenance of the entire system. The objectives of such a program of operation and maintenance include:

1. Maintenance and protection of all water rights.

2. Delivery of an adequate water supply to the water users when water is needed.

3. Improvements to keep the physical structures and properties in working order, guaranteeing optimum use of water and of water facilities.

4. Keeping records of water deliveries and project costs needed in order to insure equitable water distribution and evidence of beneficial use.

5. Educating water users in the means of obtaining high water use efficiency.

6. Developing sound budgets for covering costs of operation and maintenance and obtaining necessary funds by assessments, loans, bonds, etc., for continuous financing.
It has been observed that irrigation projects devaluate rapidly through lack of proper operation and maintenance and, therefore, farmers are unable to derive expected benefits from them. To prevent the deterioration of development projects and to continuously solidify morale and participation of individual farmers and groups in irrigation systems, it is imperative that adequate operation and maintenance of the irrigation and drainage systems must be assured by an appropriate organization established for such purposes. Such an organization can be any of the many forms, ranging from government operated schemes to an informally organized farmers association.

It should be recalled at this point that the systems approach model introduced before underlined the role of the thruput considerations and the major dimensions of organizational arrangements. They are: (a) personnel, i.e., the labor constraints, recruitment and quality of people involved, discipline and morale, etc; (b) facilities and infrastructure, i.e., the means of resource allocation, the existing facilities and physical structure of the irrigation system, and the technological innovations required for the operation of the system; (c) procedures and rules of operation, including project organization, project management and relations with the community as well as maximum involvement of the farmers.

The basic task of such an organization is to operate and maintain the irrigation system efficiently so that planned water management can be made effective. Organizationally then, an irrigation authority should be comprised of two bodies, one for policy, the other for routine technical and administrative tasks. Efficient operation, on the other hand, implies not only a well-maintained irrigation and drainage system
(with a wide range of both routine maintenance and annual and emergency repairs), but also trained personnel familiar with the operational procedures covering an entire range of a well-integrated system of irrigation. What should be emphasized is that such procedures need to be up-dated periodically, and, therefore, the organization should also incorporate a system of feedback of information concerning its adequacies of operation for continuous review and improvement. Since, a newly completed project is seldom perfect, inadequacies will come to light and additional works may have to be carried out in order to improve its operational efficiency. Thus, feedback mechanisms must exist and continuous monitoring of the performance of the system must be maintained in order to meet present inadequacies, as well as forecast future bottlenecks in the system.

A few remarks should be made about various specific administrative forms under which irrigation systems tend to organize themselves. The discussion that follows revolves around operation and maintenance formed by water users primarily in the Western U.S.A.

Irrigation organizations in the United States are primarily under the direction of two sets of legislation. The first set is quite general and fairly abstract, that being the Federal laws. The Federal laws primarily designate which States have water and how much of this water they are entitled to. These laws are also incorporated in inter-state water compacts and in agreements which are laid out among the States. In recent years Federal laws have also been passed which specify the amount of water degradation, part of an increasing effort to protect the quality of water. The second set of laws are the State laws. State laws are very explicit in nature and they vary widely from State to State:
For example, in Wyoming water is tied to the land, and attached water is considered part of it. In Colorado, on the other hand, water is unattached and can be sold as a separate unit. The water can be sold first, and then the land, or they both can be sold simultaneously. Such laws, then, provide us with a range of conditions as to ownership, rights for transfer, and with an overall framework for the evolution of specific organizational firms for the operation of an irrigation system. Briefly, the following major kinds of organizations are used:

1. **Irrigation district.**

   This is a quasi-public corporation organized under state law for the purpose primarily to provide water to irrigate lands within its legal boundaries. Most irrigation districts are nonprofit organizations, incorporated under the state irrigation district law, with taxing power, and because of size and large enough legal powers enabling them to finance significant project developments.

2. **The water conservancy district.**

   This is another quasi-public corporation, similar in many respects to the irrigation district but with broader functions and powers. Such a district may engage in multi-purpose projects, contract with government and private agencies for the investigation, maintenance and operation of water projects, tax the people who live within the defined boundaries, levy and sell bonds, and exercise the right of eminent domain, so that they can purchase right of ways for irrigation systems.

3. **Water users associations** are typically groups of farmers banded together for the maximization of collective benefits in water use. Such associations rest on typical advantages of sheer organizational group power. Typically, water users associations are incorporated so that they
can sue people or be sued by other people if the need arises, in either of the two situations. Water users associations, however, have neither the power to tax nor the ability to exercise rights of imminent domain.

4. Irrigation companies.

There are two principal types of irrigation companies. The most common type in the United States is a mutual irrigation company, i.e., a private cooperative association of irrigators organized under state corporation law to provide water at cost to the members of the company. Typically, a mutual irrigation company is one in which individual farmers have joined together and have built a diversion, as well as a canal system, so that water may be applied to their land. These farmers do not enjoy the rights that previous organizations have, since they cannot tax or sell bonds as a result of their limited size and scope of operation. Mutual irrigation companies, however, do have the right of levying assessments on the people who own shares within the company and, in some cases, can institute punitive action if assessments are not paid. The second type of irrigation company is the commercial, usually incorporated under state laws and organized for the purpose of constructing and operating irrigation systems for the profit of those who have provided the capital. In the past such companies developed both the land and the irrigation system. When land was sold to individual farmers, the irrigation system was generally relinquished, although occasionally it was kept by the company as a profit making operation. In general, commercial companies have not been profitably enterprises because returns on the investment have been rather low. In the United States they are more or less a dying system.

The above typology of irrigation organizations was offered as an indication of the range of organizational and management alternatives.
associated with irrigated agriculture. Similar remarks can be made in various countries concerning the institutional mechanism devised for designing, operating, and maintaining irrigation systems. Whatever the form or cultural uniqueness, however, the success of all such organizational schemes will ultimately depend on the willingness of each individual farmer to cooperate or even take advantage of both an organizational and or a more general growth environment. To start with, we should point out the fact that often in developing countries the farmers are inadequately prepared for the advent of much larger supplies of water than they have hitherto dreamed possible. This being so, farmers may be suddenly faced with such day to day problems as the correct timing of irrigation, the desired depth of wetting per irrigation, or the amount of water required to wet a given depth of soil, as well as problems of how to apply the required amount of water and of how to coordinate irrigation practices with other agriculture treatment as to overcome adverse soil, water and climatic conditions during the irrigation season.

These problems simply point out that as an important means of meeting the demands of integrating the farmer in the complex system of irrigated agriculture can be achieved by means of education and continuous cooperation. It has been repeatedly stated in almost every major project that the so-called human element is a major challenge to comprehensive planning and to the rational use of resources because it is usually hard to predict patterns of behavior or guarantee the cooperation of the people in any large-scale technological innovation. It should be reiterated that water planning must never ignore the impact of traditionalism and sentimentalism. Indeed, one of the hardest elements to deal with is the well entrenched population tied to land or bound to a routine occupation which has been handed down for many years.
We do realize, therefore, that people and social institutions are equally vital elements to efficient water management as technology is. Regardless of our difficulties in making people change well-established patterns (which may look to us as inefficient or wasteful), we need to develop an appreciation of existing customs and of the great amount of inertia that needs to be overcome if we are to bring about changes in long-established practices. Improved water management cannot be successfully accomplished without proper education and training.

The agricultural water user has to be shown how to achieve sustained production from his land. Demonstrate to him how water should be applied throughout the agricultural year rather than a great deal in the early part of the summer and none in the latter part of the year. It would be also necessary to begin implementing programs of teaching weed control because water is an excellent vector of weed seeds. Persuade the irrigator against the use of too much water because certain types of soil become waterlogged and sour as a result of overapplication. Explain to users when crops become too dry and burn. Fertilization has to be explicated as part of the production cycle and as means for reducing in many cases ill effects of over-irrigation.

Education and training for improved water management can be seen as a two-fold attempt. First, as a means of encouraging public response in implementing a water plan by keeping the public informed and interested and, thus, water users in the area feeling that they are becoming part of an emerging scheme of irrigated agriculture. Second, as a higher level educational process and professional training programs on the professional, the technical, and the field level.

At the professional level, engineers, agronomists, and social
scientists who may be directly responsible for irrigation development should involve themselves into continuous training and research concerning comprehensive planning, design and construction of irrigation and drainage networks; operation and maintenance of irrigation systems; improvement of irrigation efficiency and all the major aspects of planning discussed previously. At the technician level, on the other hand, the emphasis can be much more practical and operational with less theoretical background and overall comprehensive planning commitments. Finally, the field experience level is a very difficult one because it involves a grassroots approach of a great number of operators and extension workers in cooperation with the farmers. The training here needs to be very much geared to the local conditions by being simple, direct, and practical. The traditional way of approaching such a training procedure is to use representative pilot areas, where basic data for project operation and maintenance can be obtained and where the favorable response of farmers can be tested and assured. It has been repeatedly stated in the literature that such demonstration farms are perhaps the most effective ways of disseminating information.

In discussing the operation and maintenance of irrigation systems, we should not at the same time ignore that the success of the system does not depend only on the organization the procedures and the general public response. A great part of success will also depend on general socio-economic incentives for motivating the farmers to use available land and water resources for optimum returns. Such socio-economic incentives involve such items as pure economic incentives (flow of returns from investments), price incentives (a stable and an attractive price for a particular agricultural product), incentives by tax exemption and
direct subsidies, incentives through reduction of input costs (such as use of fertilizers), and finally, institutional incentives (of extreme importance in many developing countries) such as better land tenure systems, tenurial reforms and institutional credit. Ultimately, the combination of economic and institutional incentives becomes only a facet of a larger national social policy requiring strong legislative action. The strong legislative action will supplement appropriate organizational arrangements for a successful planning and management of water programs. Needless to say, a vigorous and well-coordinated water resources research program, adequate data, and scientific manpower are, in all cases, important ingredients for carrying out various efforts for integrated irrigation systems.

With the above general remarks concerning both the need for comprehensive planning and important dimensions in the design, operation and maintenance of irrigation systems, we have come full circle back to the introductory theme: given the complexity of irrigated agriculture, a change in approach is imperative. The new approach and directions, based on the integration of engineering undertakings and socio-economic activities, become imperative requirements in order to provide more cogent solutions to problems of national development. One particular point that is associated with changes in engineering approach is that planning and design of water development projects should be based on a water-use concept, as contrasted to spectacular structures, and should reflect the expected development of agriculture resulting from the need for further intensification and diversification of production and the consequential changes in agricultural practices.
While the engineering approach may be a primary force for changing existing conditions, it should never be forgotten that it must be complemented by suitable changes in the institutional environment. Engineering is only the means to an end; the ultimate success of irrigated agriculture will depend on how best the facilities are put to use and how much benefit the farmers can derive on the flow of return on their investment involved and the general improvement of the quality of life in the particular agricultural system. Institutional changes, however, need knowledge of the conditions to be changed, and valid information and devices for being able to evaluate, assess, predict, and control social effects and cultural consequences of any major project. It is important, therefore, to discuss also briefly the methodological peculiarities of social investigation and present in broad outline the research strategies and tactics used by social scientists in order to produce valid, reliable, and comparable data that will increase decision-making abilities.
IV. METHODOLOGICAL CONSIDERATIONS

A. Data Requirements and Research Tactics

Effective water development cannot proceed unless basic information is at hand with respect to a wide range of conditions, variables, and parameters of affected environments. In addition to data on water resources, realistic planning for water development programs of any type and of any use cannot be accomplished unless adequate information is developed with respect to a wide variety of socioeconomic matters. The design of research and the compilation and analysis of data of every kind is a necessary part of every water program.

Turning our attention to data requirements for social sciences we need to establish the general model of research which any type of socioeconomic investigation will be following. Essentially we are talking of three major phases in the systematic conceptualization, collection and interpretation of socioeconomic data:

1. Conceptual phase, or the definition of the problem and the development of a general "model" incorporating the essential questions of the specific inquiry, concepts, and the general hypotheses.

2. The empirical or field phase which incorporates all the efforts for finding the proper population, the strategies and tactics for the collection of data, and the specific techniques for acquiring valid and reliable data.

3. The interpretative phase which, in addition to the classification of findings provides clues as to inferences which can be made about the data collected and an evaluation of the findings in the context of the problem formulated.
Figure 11: General Model of Sociological Research
The logic of inquiry in social sciences is not dramatically different from parallel procedures in natural sciences. A basic debate, however, has to do with the application or not of science in the study of human behavior. Although this debate has long ceased for most social scientists, there is continuous reexamination of the concepts and procedures used in the study of social phenomena. There still remain great methodological issues, despite predominant consensus that we can have also in social science objective, logical, and systematic methods of analysis of social phenomena permitting accumulation of reliable data.

Underlying the above general model of inquiry, as well as the overall quest for collecting valid and reliable data, there seem to be major problems on data requirements. We should not attempt here to provide a treatise on the methodology of social sciences. We need only to indicate that there are major concerns as to the types of inferences that can be made about social phenomena centering around three major categories of concern.

1. **Sources of data.**

What are the types of sources needed to be tapped in order to provide data concerning the effectiveness of a proposed irrigation project? Two major sources are of use for the social scientist. First, available data or existing information from various governmental, federal, state, and private reports or studies. This type of data is particularly important for establishing general outlines or the parameters of our problem. They provide the major categories for collective analysis, such as the results of censuses, vital statistics, economic indicators, and other measures of aggregate data.
The other major source of information is that resulting from primary data. The origination of new data, especially in the form of surveys, is important in the effort of locating information on the less tangible dimensions of our project, such as attitudes of the population and the general climate of values and cultural heritage of the surrounding communities. Such primary data is usually exemplified in the various surveys or questionnaires which social scientists use in order to elicit information about surrounding environments.

2. Questions of validity and reliability

As in any other type of scientific investigation, the social scientists are also working hard towards the development of specific techniques for collecting data plus sets of rules for using this data. Three conditions seem to make such a quest particularly important. First, if we are to measure or account for the effects of an irrigation project, we need to have valid criteria, i.e., criteria free of systematic error. At the same time, our criteria and units of measurement need to be reliable, in other words, comparable in successive measurements. Finally, our criteria need to be refined, i.e., able to make fine distinctions among various categories and levels of analysis.

As in many other cases, and this is particularly true for the social scientist, the most important methodological problem seems to be the presence of constant errors referred to as validity. Here one finds all those factors which systematically effect the characteristics being measured or the process of measurement itself. Despite tremendous improvements in the methodology of social sciences, there are still no definite answers as to what constitutes a valid criterion or
measure of the characteristic that is supposed to be measured. A host of methodological principles have been devised which try to increase both validity and reliability but still it is important to remember that this is a perennial problem when offering conclusions about a given project and its measurable characteristics.

3. **Field procedures and tactics**

There are various procedures and techniques involved in any type of a social research model. The techniques and methods for acquiring data range from the well-controlled laboratory experiment to more loose observational techniques. In any project involving social considerations, there are four specific ways of obtaining concrete data (assuming a given research strategy): use of available data, obtaining new data (either through observation or through questioning), new data through measurement and scaling, and computer applications or simulation models.

We should also mention in this respect that another major concern of the social scientist in the area of field procedures and tactics are various questions associated with sampling and the validity of inference. Since most of our data is usually partial rather than complete and since we want to use this partial data to characterize the entire set, it is imperative to find out the types of representative populations which would provide the requirements of good sampling. Social scientists follow the major distinctions between random and non-random sampling and the basic requirements for representativeness and adequacy in the same familiar fashion that natural scientists are accustomed to.

These few remarks on some broad methodological requirements for the generation of valid and reliable data were introduced only as an indication of the similarity of inquiry between "soft" and "hard" sciences. Again,
such similarities should not blind us to major underlying differences in
approach, in subject matter, and in question raised in any social research
effort. There is a great danger in using analogue models of research,
borrowed from the elegant and orderly world of the physical sciences, with­
out respect to the subjective peculiarities of understanding and analyzing
recurrent patterns of social behavior.

B. **Evaluation and Assessment**

From the general discussion of some major requirements of research
designs, we must move to much broader considerations of evaluation and
assessment, the presence, effects, or consequences of an irrigation project.
An assessment methodology would enable us to identify in a systematic fashion
potential causes and corresponding effects, a description of the characteristics
of our system, and the possible consequences of various physical and
non-physical variables operating in a water system. In the context of an
overall model of planning and program operation, we can outline the rationale
for an evaluative research design. The conditions and sequence of events
in which our irrigation program becomes only one of many possible actions
or events bringing about the desired effect is depicted in Figure 12 (based
on the work of Suchman, 1967).

(Figure 12 about here)

In trying to determine effective water management, we should remember
that alternatives offered or evaluation of impacts must be examined under
three different conditions of "effectiveness." These alternatives and
considerations of differential evaluation are very much in accordance with
earlier remarks made concerning a systems approach in irrigated agriculture.

Traditionally, the most widely used term has been that of **efficiency**
which attempts to relay in simple, economic benefit-cost analysis the
Figure 12: Causal sequence in an evaluative design.
relationship between existing resources (input) and proposed goals or attempted objectives (output). Various economic formulas and much more advanced techniques exist and diversified detailed documents have continuously offered working methods for relating questions of minimal cost and money values in estimating the efficiency of a given project.

Another term used is that of effectiveness mostly understood in terms of organizational performance or the meeting of purely organizational goals. In other words, we are emphasizing here the relationship between a given organizational structure (thruput) and perceived or expressed goals (output). This particular term has also been used in the context of an overall measurement of achievement for a system, derived from its subsystems performance or related to its interactions with other systems. Effectiveness reflects mostly our concern with alternative structures, devised to meet under conditions of given resources specific objectives.

Last, but not least, the term efficacy is increasingly used. Such a term attempts to incorporate the meeting of social goals and much more comprehensive relationships between the three system component parts, namely, input, thruput, and output. Efficacy, then, attempts to move beyond purely economic considerations or criteria of organizational effectiveness by trying to answer the question of how a particular system can efficiently, effectively, and guided by principles of social awareness meet goals of a given society or group. The term efficacy is associated with a measurement of a number of intangible benefits as well as larger social costs associated with any water system. Thus, the term efficacy extends our horizon beyond the traditional quantitative criteria used in the measurement of benefits to be accrued from any type of an irrigation project into new areas of qualitative criteria transcending purely utilitarian considerations.
What this implies is that any water management system, including irrigated agriculture, would be also dependent on subjective models which are much more difficult to construct, yet they contain long-range policies for a social use of natural resources.

The general categories of the design of Figure 12 can be extended to incorporate the systemic distinctions made above in a more formal model of evaluation, such as the one depicted in Figure 13.

(Figure 13 about here)

This figure, as well as all previous remarks, shows that no event or output has a single cause and that each event has multiple effects and consequences. All input constraints and output, or results, are interrelated in a complex causal system, with no single factor being a necessary and/or sufficient condition of any other factor.

The distinction between efficiency, effectiveness, and efficacy help us raise an important point when we try to evaluate the consequences and the benefits and/or costs associated with irrigated agriculture. Irrigation systems are not only abstract simulation models responding to general physical or broad economic imperatives. All irrigation programs include individuals and communities that have developed a pattern of life and whose welfare and future may even depend on inefficient water systems. Even a marginal or not particularly efficient agriculture fulfills the purpose of being a supportive social system for a number of individuals and part of the ongoing life of quite a number of people in a given society. It is not easy to dictate a planning policy that would be based only on criteria of efficiency and effectiveness without considering at the same time the so-called "human factor." This is why many times in the developmental literature we find out the great concern with the introduction of
Figure 13: A generalized model of evaluation.
highly efficient, large-scale technological projects which may not be the proper response for the particular local circumstances. In other words, because of the social costs of dislocation and disruption, because of the need for intermediate technology that may absorb excess labor, many times a policy of continuing present practices may be dictated as a response to long established cultural practices and social arrangements.

From such general notions and with the important distinction between efficiency, effectiveness, and efficacy, we may be able to examine in a more systematic way the problematic situations arising from the introduction of, or new forms of, irrigated agriculture in a given region. If we connect our present remarks with the previous examination of a systems approach, we can contrast conditions of input constraints, the limitations of existing institutions or organizational structures, and the basic objectives or long-term goals to be achieved through irrigated agriculture. From the interconnection of the system's parts, we can, then, generate matrices which not only point out areas of concern, but provide us with the range of variables and indicators concerning the performance, effect, and consequences of an irrigated agriculture project.

A descriptive figure attempts to provide a proposed evaluation matrix for a systemic analysis of an irrigation program. Figure 14 summarizes the systematic mapping of persistent problems, the ideal or desirable criteria, conceivable alternatives, and feasible alternatives in the major dimensions of various subsystems. (Figure 14)

(Figure 14 about here)

Each cell of this matrix could be filled with specific variables of the type described earlier in the general discussion of subsystems and their dimension. For each specific irrigation project, special conditions will
Figure 14: Evaluation Matrix for a Systemic Analysis of an Irrigation Program
provide countless combinations and permutations of criteria and alternatives and, therefore, much more sensitive guidelines and comprehensive juxtaposition of trade-offs for improved decision making.

In concluding our section on evaluation and assessment of irrigation projects, we should alert ourselves to important distinctions between evaluating impact, i.e., present or short-range effects; and, technology assessment, i.e., the long-range, unanticipated, and higher order consequences of a given project. Time perspective is an additional dimension and crucial element in estimating primary and secondary effects of irrigated agriculture.

No more general remarks are needed for the emphasis on the methodological requirements for evaluating non-physical dimensions of irrigation projects. An important aspect of the previous discussion has been the classification of the component parts of an irrigation program in an evaluative model emphasizing the core steps of:

1. Definition of program goals and objectives to be used as criteria for evaluation.
4. Relationships and indicators, especially of program inputs and intervening process.
5. Collection of necessary data.

These steps and the questions raised earlier lead us to an overall strategy for evaluating irrigation projects, outlined in Figure 15. The self-explanatory research strategy outlined in Figure 15 shows in a rudimentary flow-chart important steps involved in a systematic methodology which utilizes a multi-disciplinary model of assessment and of alternative means for evaluation.
Figure 15: Research Strategy and Assessment Methodology (Vlachos, 1972a)
The methodological discussion on research strategies and on impact, assessment, and long-range consequences of public projects is important in the development history of agriculture during the last fifty years. The history of development in the Third World reveals that the classical models as they have been applied do not seem to be responsive to the unusual or specific situations of many developing nations. Extreme rigidity and narrow alternatives in planned change schemes, transplantation of inflexible models and of engineering routines from the developed nations, as well as limited feedback information have impeded the creation of a growth environment in many developing countries. As many authors have pointed out, agricultural development in the Third World is too complex to be fully programmed with the classical models of developed nations. Such authors have been increasingly calling for new methodologies and new models that would be a synthesis between the technologically sophisticated information of developed nations and the culturally rich situations of many countries in the Third World. Such a synthesis includes a planning methodology, characterized by a variety of responses, insuring compatible mixes and uses of relatively meager resources. At the same time, proposed agricultural programs should combine sensitivity to the socioeconomic structure of the developing country and recognition of the importance that planning will depend on major transformations through public intervention. Finally, political compatibility between technological imperatives and crucial decision making processes can be achieved through the refusion of social considerations based on a planning methodology of adequate data basis, comprehensive analysis of the surrounding environments, and cybernetically oriented open systems models of control, intervention, and response mechanisms.
V. SUMMARY AND CONCLUSIONS

In both developed and developing areas large irrigation projects are used as means by which the standard of living can be raised through higher crop yields. The engineering preoccupation with such projects has resulted to paying little attention to the actual practice of field irrigation, as compared with the major efforts made in the development of water resources and water diversion and conveyance to the field.

Irrigation itself is only one of many agricultural operations which determine the yield level, but it is a very decisive limiting factor whenever water is applied in measure or whenever water is short. This is particularly true in arid and semi-arid areas, where water has to be applied intelligently in order to make the best use of it. The overall irrigation limitations not only in the areas of inadequate water supply but also for unreliable and supplemental water situations are as follows:

1. **Storage of water.** In order to maximize the production of agricultural products, it is necessary to utilize all available sources of water. This in turn creates increasingly a problem of overall shortage of water both for the rural and the urban populations, accentuated by conflicting demands of new uses associated with development and modernization.

2. **High total cost of water.** Water can be a very expensive commodity in most countries. If we combine the price the farmer has to pay for water with the amortization on irrigation and installation of equipment, the cost can often reach prohibitive limits.

3. **Soil, water and climatic limitations.** When developing a new area under irrigation, the soil and water characteristics and the selection
of crops to be grown are important considerations for conditions of optimal growth.

4. Irrigation organization. As repeatedly emphasized throughout this paper, the irrigation organization and the efficient use of existing inputs or resources are crucial factors and problems for the success of irrigated agriculture. In addition to larger institutional factors, one needs to emphasize such important items of actual daily irrigation problems as the correct timing of irrigation, the application of the correct amount of water, the coordination of irrigation practices with other agricultural treatments, and the continuous effort to overcome adverse physical conditions during the irrigation season. From the socioeconomic point of view these last limitations and problems are truly the key factor for a correct and efficient use of water throughout the various dynamic functions or cycle of water application.

What we have then in any effort of introducing irrigated agriculture is a rather unpredictable pattern of wet and dry seasons, wet and dry years and many times various dry cycles. Properly planned and constructed and appropriately organized for operation, conventional systems will normally be adequate to cope with natural variations in the water supply cycle for which it has been designed. Changing conditions, the attempts for modernization, population pressure, and the constant need for increased food production will require new techniques and innovative efforts for meeting water needs, especially when future demands may outstrip available supplies. In various parts of the world, in both developed and increasingly in the future in developing nations which will face similar pressures of competing demands from urbanization and industrialization, attempts are being made for both augmenting natural water supplies and for alternative or innovative ways of meeting demands.
Concerning the efforts for augmenting natural water supplies, we have a whole array of conventional methods which may divert the water from areas of surplus to areas of shortage provided, of course, that questions of economics, and legal and political jurisdiction considerations have been faced. In this respect, nations are increasingly tapping their groundwater potential, although in many cases the occurrence, movement, and replenishment of subsurface water is not as fully understood as surface waters. Other efforts for augmenting supplies include attempts for desalination, weather modification (the results of which are rather sporadic and relatively uncontrolled, as well as full of many social, legal, and ecological ramifications). Weather modification, in particular, may be an important future supply since as it has been estimated, e.g., in the United States opportunities are great, because only about 10 per cent of the available moisture that passes over the country each year actually falls to the earth as precipitation. If the yield from this potential can be increased by only 1%, the water supply of the United States would be increased by 10%. Finally, in augmenting natural supplies vegetative manipulation, including snowpack management in the upper timber zone, brushland conversion in the areas below the commercial zone, treatment of riparian vegetation, etc., can be alternatives designed for increasing present water yields.

Parallel to the efforts for augmenting in the natural water supplies, there can be alternative means for meeting increased demands. The counterpart of increasing water supplies has to do with the possibilities of conservation of use and efficient management. This is becoming particularly important for nations which have been traditionally accustomed to economies and environments of abundant supply. Thus, a major consideration in
achieving a solution to water shortages is to examine critically the water use practices and try to reduce wastage. In this respect many nations are considering the systematic allocation of available water resources to its most economic use as a desirable method for achieving water economy. Other alternative means include recirculation of water, reduction of losses by suppression of evaporation or other conveyance losses, and pricing of water services which can have significant implications to water use practices.

Once again, however, the most crucial factor in alternative means for meeting water demands are all the attempts of improved organizational and institutional arrangements and increased efficiency in water management. We may see the improvement in water management not only in terms of typical technical solutions, such as improved water measurement, modification of delivery schedule, and modernization of project facilities; equally important are also the non-technical considerations which exemplify our concern with the socio-economic environment or the irrigation system. We may begin with management improvements in operational practices, such as streamlining of companies, innovative administrative procedures, trained personnel, etc. The consolidation of irrigation companies and districts will contribute to achievement of lower operating costs per unit area and more efficient regulation and control of the water supply, as well as avoidance of duplication and increased capital waste. Other institutional changes such as the interpretation of the legal doctrine are also crucial efforts for improving water management. Comprehensive planning and concerted social policies are part of the larger complex scene of resource utilization in most countries. Finally, education programs are all important as informational inputs attempting to reach all those responsible for the operation of a given irrigation system and the ultimate use of water on the farm.
The end result of all such technical and socio-economic improvements in current irrigation practices or the comprehensive planning of new irrigation systems will be the catalytic effect of proper management in bringing about agricultural development. The basic requirements for agricultural production, i.e., new farm technology, incentives for farmers, and markets for farm products will be accelerated by education for development, by group action and collective organization, by the improvement and expansion of agricultural land, all in the context of comprehensive planning and articulated policies of national development.

We have been concentrating throughout the paper on broad issues and of irrigated agriculture with little reference to specific problems or the potential for irrigated agriculture in such areas as West Africa. We feel rather poorly prepared for discussing the specific situation in Africa, but we would like to extend some remarks part from our impressionistic knowledge of the continent and as an extension of experience with irrigated systems in the western United States and other semi-arid areas.

Among the things that impresses one as he reads about efforts for development in West Africa is the debunking of various myths having to do with agricultural production in the region. Three key problems have already been discussed among various authors concerning needs about West African agricultural development: (1) the general problem of "lazy" farmers and their unresponsiveness to economic opportunities; (2) the inefficiency resulting from "plantation crops"; and (3) the adverse role of land fragmentation and of the general land tenure system.

As in many other cases, the degree to which African farmers respond to economic opportunities is very important to any social planner. Although numerous studies have reported that African farmers are not responsive
to motivating factors of economic opportunities recently many authors seem to negate this particular finding. There is an impressive body of evidence in West Africa which leads to the generalization that the behavior of farmers in this region can be understood in the generally accepted framework of traditional economic analysis. On the other hand, the term plantation crop implies that economies of scale in producing certain crops make it extremely difficult for small farmers to compete with plantation units of production. Here again, the literature is producing more empirical evidence pointing out that small farmers can produce almost all crops competitively, provided that they have access to new technology, credit extension assistance and central processing. Finally, as it is true in many other traditional societies, there have been numerous works concerning the constraints of the system of communal land tenure and the adverse role of land fragmentation in modernizing agriculture in West Africa. Although this is a rather complicated problem, there seems to be hesitation among various authors as to an outright condemnation of this communal system and no particular enthusiasm for attempts to superimpose governmental solutions of land consolidation at least in the more densely populated areas. If nothing else, especially for communal land problems, there seems to be inconclusive evidence and need for further studies by social scientists on pointing out how the transition from communal land to private land can be achieved with minimal human costs.

Assuming that these three often repeated concerns for agricultural development in West Africa can be further explored and delineated, what remains in understanding the potential for irrigated agriculture in the region are the typical problems and research topics associated with rural development in any country. These include such items as the role of
population and the concomitant problems of unemployment and underemployment; the socio-economic and political implications of uneven development within and between the regions of West Africa; differential income distribution; alternative means for taxing agriculture; general institutional problems involved in the trade of agricultural products; transfer, adoption and assimilation of agricultural technology; and, finally, a better accounting of the role of natural resources for development.

The list offered above is part of any general discussion concerning agricultural development, and we do not need to discuss further principles and aspects of national development. In addition to the immediate need for income distribution, the generation of effective demand (given the fact that West African countries are virtually self-sufficient in staple foods with the exception of rice) and the stimulation of intra-West African trade, we would like to emphasize two major topics that should be associated with attempts towards irrigated agriculture. One has to do with the use of natural resources, especially the "wise use" of water, and the second with an understanding of the socio-demographic context within which future development of irrigated agriculture in West Africa might take place.

In 1963 Africa had approximately 14 million irrigated acres, representing only 3.8 per cent of the world's total irrigated acreage. Although there are large tracts of land which are arid and semi-arid and which could benefit from irrigation, Africa is unfortunate in having fewer alluvial valleys whose river regimes or surface contours are as favorable as those in the Nile Valley. Thus, with the exception of the Nile Valley, where there is a long-standing tradition of irrigated agriculture, irrigation is relatively limited and sporadic throughout most of the parts of the continent. The following table shows the rather limited acreage of irrigated land in the major irrigated areas of Africa.
TABLE 1.

<table>
<thead>
<tr>
<th>Country</th>
<th>Irrigated Land ('000s of Acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>500</td>
</tr>
<tr>
<td>Egypt</td>
<td>6,400</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>74</td>
</tr>
<tr>
<td>Kenya</td>
<td>17</td>
</tr>
<tr>
<td>Libya</td>
<td>250</td>
</tr>
<tr>
<td>Madagascar</td>
<td>1,625</td>
</tr>
<tr>
<td>Mali</td>
<td>150</td>
</tr>
<tr>
<td>Morocco</td>
<td>540</td>
</tr>
<tr>
<td>Rhodesia</td>
<td>40</td>
</tr>
<tr>
<td>Somalia</td>
<td>50</td>
</tr>
<tr>
<td>South Africa</td>
<td>1,500</td>
</tr>
<tr>
<td>South-west Africa</td>
<td>25</td>
</tr>
<tr>
<td>Sudan</td>
<td>2,500</td>
</tr>
<tr>
<td>Swaziland</td>
<td>28</td>
</tr>
<tr>
<td>Tanzania</td>
<td>100</td>
</tr>
<tr>
<td>Tunisia</td>
<td>120</td>
</tr>
</tbody>
</table>

Africa: Major Irrigated Areas
(Source: Cantor, 1967:178)

It has been estimated that irrigation in Africa could be tripled, partly by extending the present irrigated areas and partly by bringing new areas under irrigation. Again, as important as finding new supplies of irrigation water, the key element for agricultural production is the conservation and efficient use of present available water supplies. In too many areas, not only in Africa, but all over the world, water is used wastefully and salinity and waterlogging have resulted. At the same time, we should note that large irrigation schemes by themselves are no definite guarantee for increased agricultural productivity. In many cases, and this is true for newly developing nations and for their need of intermediate technology, a way of extending and improving irrigated agriculture in many areas is by the installation of simple, small scale, water conserving dams rather than constructing large and expensive projects. As a matter of fact, many authors have repeatedly cited what they call the "engineering
reflex," in that traditional engineering solution and limited alternatives are offered from developed to developing nations with little consideration or respect of the local cultural conditions and the need for flexible alternatives appropriate for the specific socio-economic circumstances of various developing nations. A limited number of studies in Africa have indicated how various communities and groups manage to fairly easily adapt to new environments created by the new technology of irrigation farming. However, repeatedly, serious social problems have also arisen as a result of removal from long established cultural settings and from the disturbing influence of new technological innovations.

In terms of the demographic context within which irrigated agriculture might be taking place, there are three aspects of population affecting economic development:

1. The age distribution, especially the so-called burden of dependency having to do with the increasing presence of people in two extremely important but highly dependent age groups, i.e., young children and older people.

2. The growth rate, as an important determining condition whose differential presence over time can become a major constraining factor in the continuous race for meeting increasing demands.

3. The total size of population as a basis and a limiting factor in developmental efforts.

We might give a specific example in order to indicate the role and the effect of population growth on economic development. We may use a rule of thumb which is popular among planners because of its simplicity: a population with a rate of increase of 1 per cent per year will use up in investments 4 per cent of the gross national income just to stand still and make no progress. Concretely, then, if we use as an example that the
population of West Africa grows by 2.3 per cent annually between 1965 and 1980, an annual investment of 9.2 per cent of the national income will be necessary in order to accommodate the increase, and only investment in excess of this rate will contribute to any improvement of the standard of living. Although these particular rates are not fixed, they point out the problematic situation arising from a rapid growth and the need for both meeting expanding populations and at the same time achieving increasing rates of economic expansion in the quest for improved quality of life.

If we look at the larger picture on the total population growth in Africa and the projections concerning future growth in the continent (including the increased percentage of urban population and, therefore, competing demands for future water supplies), we may see how rapid population growth would be a major constraining factor in any attempt for agricultural development. Table 2 incorporates present estimates and projection of main African regions. The rates of growth are much higher than those experienced in Europe during its demographic transition.

(Table 2 about here)

Without elaborating the obvious, we can reinforce the picture of rapid growth by a map showing the total 1967 population estimates as well as estimated rates of annual increase.

(Map 1 about here)

A number of demographers have been indicating that Africa is expected to have one of the highest growth rates in the world by the year 2000, though this rate may no longer be accelerating at that time. UN projections made in 1963 for the year 2000 were as follows: low 684 million, medium 768 million, and high 865 million. In rather simple terms, this means that by the year 2000, and using the UN medium projection for that year, the population
Table 2:
United Nations estimates and projections concerning the populations of main African regions and countries

<table>
<thead>
<tr>
<th>Region and country</th>
<th>Mid-year estimates</th>
<th>Density per km²</th>
<th>Average annual growth</th>
<th>Total</th>
<th>At % of total population</th>
<th>Average annual growth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1960 millions</td>
<td>1980 millions</td>
<td>Persons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Africa total</td>
<td>2709</td>
<td>4573</td>
<td>11</td>
<td>2.4</td>
<td>2.7</td>
<td>4.0</td>
</tr>
<tr>
<td>North Africa</td>
<td>660</td>
<td>1140</td>
<td>9</td>
<td>2.7</td>
<td>3.1</td>
<td>20.4</td>
</tr>
<tr>
<td>West Africa</td>
<td>1967</td>
<td>1980</td>
<td>17</td>
<td>2.6</td>
<td>2.9</td>
<td>12.4</td>
</tr>
<tr>
<td>Nigeria</td>
<td>486</td>
<td>880</td>
<td>30</td>
<td>3.0</td>
<td>3.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Ghana</td>
<td>66</td>
<td>120</td>
<td>34</td>
<td>3.0</td>
<td>3.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Upper Volta</td>
<td>634</td>
<td>66</td>
<td>17</td>
<td>1.7</td>
<td>2.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Mali</td>
<td>411</td>
<td>65</td>
<td>4</td>
<td>2.0</td>
<td>2.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Ivory Coast</td>
<td>334</td>
<td>51</td>
<td>12</td>
<td>2.0</td>
<td>2.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Guinea</td>
<td>39</td>
<td>51</td>
<td>15</td>
<td>2.2</td>
<td>2.8</td>
<td>0.3</td>
</tr>
<tr>
<td>Senegal</td>
<td>53</td>
<td>47</td>
<td>13</td>
<td>1.6</td>
<td>2.2</td>
<td>0.9</td>
</tr>
<tr>
<td>Niger</td>
<td>31</td>
<td>49</td>
<td>3</td>
<td>2.1</td>
<td>2.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Central Africa</td>
<td>385</td>
<td>416</td>
<td>5</td>
<td>1.6</td>
<td>2.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Congo (K)</td>
<td>146</td>
<td>222</td>
<td>7</td>
<td>1.8</td>
<td>2.8</td>
<td>1.7</td>
</tr>
<tr>
<td>Cameroon</td>
<td>51</td>
<td>67</td>
<td>12</td>
<td>1.2</td>
<td>1.7</td>
<td>0.4</td>
</tr>
<tr>
<td>Chad</td>
<td>33</td>
<td>44</td>
<td>5</td>
<td>1.6</td>
<td>2.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Burundi</td>
<td>4</td>
<td>45</td>
<td>120</td>
<td>2.1</td>
<td>2.4</td>
<td>0.1</td>
</tr>
<tr>
<td>Central Afr. Rep.</td>
<td>14</td>
<td>8</td>
<td>3</td>
<td>1.1</td>
<td>1.8</td>
<td>0.2</td>
</tr>
</tbody>
</table>

| East Africa       | 65.4               | 102.4           | 14                    | 2.2   | 2.5                      | 4.5                  |
| Ethiopia          | 90.8               | 30.1            | 19                    | 1.8   | 2.0                      | 2.0                  |
| Tanzania          | 103                | 174             | 13                    | 2.7   | 2.8                      | 0.5                  |
| Kenya             | 84                 | 141             | 17                    | 2.5   | 2.9                      | 0.6                  |
| Uganda            | 69                 | 105             | 34                    | 2.0   | 2.3                      | 0.2                  |
| Madagascar        | 55                 | 89              | 11                    | 2.1   | 2.9                      | 0.6                  |
| Malawi            | 37                 | 51              | 15                    | 2.2   | 2.9                      | 0.9                  |
| Zambia            | 33                 | 58              | 5                     | 2.8   | 3.1                      | 0.9                  |
| Rwanda            | 30                 | 40              | 126                   | 1.3   | 1.5                      | 0.8                  |

| Southern Africa   | 330                | 53               | 8                     | 2.3   | 2.5                      | 7.8                  |
| Rep. of South Africa | 158              | 266             | 15                    | 2.7   | 2.7                      | 6.2                  |
| Mozambique        | 64                 | 89               | 9                     | 1.6   | 1.6                      | 0.3                  |
| Angola            | 42                 | 63               | 4                     | 1.2   | 1.4                      | 0.4                  |
| Rhodesia          | 36                 | 70               | 12                    | 3.3   | 3.5                      | 0.7                  |
| Lesotho           | 9                  | 13               | 29                    | 1.6   | 2.0                      | 0.0                  |

* In towns of 20,000 and more inhabitants

of Africa may be increasing by almost 100 million people every five years. It also has been estimated that by about 2010 Africa's population may well exceed 1 billion, the world total population of no more than about 120 to 140 years ago. Needless to say, the implications of these extremely rapid increases on planning, development, pressure on the land, and on agricultural productivity, as well as urbanization, are immense and far reaching.

We do not need, however, to go as far ahead as the year 2010 in order to indicate that already in various parts of Africa, including West Africa, population pressures are already apparent through such indicators as soil deterioration, degradation or outright destruction, declining crop yields, breakdown of the indigenous farming system, food shortages, land fragmentation and landlessness, unemployment and underemployment in rural and/or urban areas, and, increasing migratory streams.

Given, then, the perceived population pressure (although a number of authors would emphatically deny that such population pressures do exist), there are three major ways of reducing this pressure: either by extension of agriculture to lands not presently used, by intensification and rationalization of agriculture in already cultivated areas, and, by absorbing an adequate number of people in non-agricultural activities. We should not attempt to describe what each of the three solutions implies because detailed studies are needed in each country and in each specific agricultural region in order to be able to assess both the limitations and the advantages involved in each particular solution. Water, however, will also become an important means of achieving the larger goals of national development. Thus, as it is true in many other cases, water should not be perceived only as an end in itself, either in terms of infrastructure or as a product
but as an important and vital part of larger goals of socio-economic development. This implies that traditional engineering approaches and engineering solutions to problems of increasing agricultural solutions are not per se adequate. Other alternatives, including major socio-economic changes and comprehensive planning of natural resources in developing countries are imperative in order to understand better population/land relationships, as well as the role of natural resources in the development process. The literature in development is offering quite a range of models, usually explicated along a continuum of transformation of social organization from traditional to modern, with increased communication, fluidity of social structure, extensive communication, increasing frequency and intensity of land use, and increasing individual and collective involvement at local, regional, national and international levels. Irrigated agriculture as a public project can become a vital link and an important catalyst for facilitating development in the context of the specific physical, social and economic circumstances of West African nations.
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