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WORKING PAPERS ON IRRIGATION PERFORMANCE 1

A FRAMEWORK FOR ASSESSING IRRIGATION PERFORMANCE

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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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FOREWORD

The Irrigation Performance Working Paper Series was initiated by the International Food Policy Research Institute (IFPRI) in 1992 to promote research, discussion, and thought on issues relating to the effectiveness and efficiency of irrigation systems in the developing world. This is not a new topic, but much of the work in this area is marked by a wide diversity of definitions, assumptions, approaches, and methodologies, which has rendered results incommensurate and nonadditive.

The purpose of this series is to provide a venue for more coherent and focused efforts to characterize irrigation performance and to understand its determinants and its effects on national food production systems. The series will consist of both concept papers and case studies representing applications of principles to field situations.

The series is rooted in an activity carried out in conjunction with the International Irrigation Management Institute (IIMI) to develop a framework and methodology for assessing irrigation performance. A number of the papers in the series had their origin in that activity, though other papers will be included as well. A fundamental criteria for inclusion in the series is consistency with the definitions and concepts presented in this, the first paper, which articulates a framework for assessing irrigation performance and provides the overall conceptual basis for the series.

Earlier versions of this framework were presented and discussed at an IIMI symposium on irrigation system performance evaluation in Colombo in 1989, an international meeting organized by IFPRI and IIMI to discuss performance issues, held in England in February 1990, a regional technical consultation organized by the Food and Agriculture Organization of the United Nations (FAO) in Bangkok in October 1990, and the World Bank Seventh Annual Irrigation and Drainage Seminar in December 1990. An earlier version, published in the journal *Irrigation and Drainage Systems* in 1990, has been thoroughly revised and reorganized in preparation for this working paper series.

This framework is not the final or the only possible framework for organizing thought and analysis on irrigation performance issues: it is, however, a reasonable and coherent one, deserving further exploration through challenges to its assumptions and principles and through its use as a guide in analytic efforts. The final test of the worth of any such framework, of course, will lie in the extent to which it is helpful in understanding and predicting the events it encompasses.

Mark Svendsen
Series Editor

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1. INTRODUCTION

Irrigation is of major importance in many countries. It is important in terms of agricultural production and food supply, the incomes of rural people, public investment for rural development, and often recurrent public expenditures for the agricultural sector. Yet dissatisfaction with the performance of irrigation projects in developing countries is widespread. Despite their promise as engines of agricultural growth, irrigation projects typically perform far below their potential.

This situation has resulted in a proliferation of interventions directed at improving irrigation performance. Many research efforts have been designed to evaluate the effects of such interventions or to enhance understanding of the determinants of performance so that new approaches to improvement might be developed. Interventions have included managerial changes, physical changes, and combinations of the two. Managerial changes have generally focused on the introduction of a set of "improved" practices for operating individual irrigation schemes. Physical changes have included such things as lining of canals, installation of measuring and recording devices, and comprehensive rehabilitation programs.

Unfortunately, this process has not resulted in substantial cumulative learning about the root causes of the problems addressed, or about the effectiveness of particular interventions under various circumstances. Moreover, the results of individual improvement efforts are often not satisfactorily measured and documented. Evaluation of any innovation designed to improve performance requires a sound assessment of the actual performance of the irrigation scheme before and after the introduction of the change. Research aimed at developing these interventions must also assess the performance of systems being studied and evaluate it against chosen standards. The ability of researchers and development professionals to make direct assessments of the results of their interventions is weak—far weaker than their ability to mount the improvement programs themselves. This leads to a situation where the efficiency of the overall irrigation improvement process is low, and knowledge about causes and impacts accumulates only slowly at best.

Although the assessment of irrigation performance is clearly important to managers of irrigation projects, to those who allocate public funds for irrigation, and to researchers, it has been seriously neglected. At the same time, the multiplicity of approaches to assessing performance makes the task confusing and difficult. The purposes of this paper are, first, to establish a context in which the great variety of different approaches to irrigation performance assessment can be understood and related to one another, and, second, to use the concepts so developed to focus on one particular type of performance assessment that has been especially neglected but which is critical to further analytic development in the field of irrigation performance improvement.

It may be helpful to the reader if we explicitly note two things that we do *not* attempt to do in this paper. First, the conceptual framework is not designed to identify factors that explain particular levels of irrigation performance. This is not to deny the importance of these factors or of research efforts to unravel and understand them. Yet, unless

performance itself is measured and evaluated satisfactorily, the validity of research efforts to identify causes is compromised. Furthermore, the ability to use the findings of numbers of individual research studies to make valid generalizations about the determinants of irrigation performance is severely limited unless these studies are consistent in their approach to assessing performance. By focusing on the slighted area of measuring and evaluating levels of performance, we can make a contribution that will strengthen the validity and usefulness of analytic research on the determinants of performance.

Second, no attempt is made here to develop a specific methodology for assessing irrigation performance. This is a logical next step to take, and work on this topic is under way. But before becoming concerned with the details of methodology, agreement is critical on a broad framework of concepts to which any specific methodology can be related.

The paper has been divided into two parts. In Chapter 2 we present a logical and comprehensive conceptual framework for understanding irrigation performance. Such a framework must specify clearly both what is being assessed and the concepts of performance that underlie the assessment. We first examine the nature of irrigation, in order to address the full range of types of irrigation that might be encountered in assessing performance. Then we undertake a similarly detailed examination of the concept of "performance." In Chapter 3 we move through the conceptual framework again, focusing on a particular class of performance assessments that are extremely important and critically neglected. Our purpose is, first, to focus attention on this class of assessments and, second, to establish the basis for a coherent set of studies. We select options that define this type of assessment. Where there are no clear a priori choices for our purposes, we discuss the nature of the various options in more practical terms. The final chapter is a summary of the paper. A glossary of terms begins on p.33.

2. THE FRAMEWORK

THE NATURE OF IRRIGATION

Definitions

Irrigation[1] can be defined as human intervention to modify the spatial or temporal distribution of water occurring in natural channels, depressions, drainage ways, or aquifers and to manipulate all or part of this water to improve production of agricultural crops or to enhance growth of other desirable plants.[2] This definition emphasizes the importance of the actions of people in modifying a natural distribution of water. It also restricts consideration of the types of action to those that involve tapping and utilizing water that has been concentrated naturally before being exploited.[3]

Our definition of irrigation thus encompasses large pump and conventional gravity schemes, as well as a variety of traditional small-scale schemes, including those where receding flood waters are captured and controlled in bunded fields. It excludes techniques such as micro-catchment water harvesting and improved management of natural rainfall (such as tie-ridging or bunding of rainfed rice fields), since water is not diverted from a naturally concentrated source and is applied to the soil without control intervention. It does include more complex water harvesting techniques, such as the small tanks of South India and Sri Lanka, because they use water in natural drainage ways and require supply manipulation for productive use of the water.

An *irrigation system* is then defined as a set of physical and social elements employed (1) to acquire water from a naturally concentrated source (such as a natural channel, depression, drainage way, or aquifer); (2) to facilitate and control the movement of the water from this source to fields or other areas devoted to the production of agricultural crops or other desirable plants; and (3) to disperse the water into the root zone of these areas.[4]

The physical elements of an irrigation system (such as dams, canals, and control structures) are easily recognized and understood. But the equally important social elements

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[1] Italicized words are included in the glossary beginning on p.33.

[2] Although phrased to include applications in noncrop agriculture, such as wildlife habitat enhancement, dune stabilization, or land reclamation, the principal application of interest here is agricultural crop production. The remainder of the paper focuses on this application.

[3] A detailed exploration of the various ways in which irrigation has been defined is available in Rodgers and Svendsen 1992, which was itself stimulated by discussion generated by an earlier version of the present paper.

[4] This definition deliberately separates an irrigation system from the watershed catchment area that supplies the system's naturally concentrated source of water and from the drainage system that removes excess water from the irrigated area. We recognize that watershed management and drainage system performance have significant implications for the impact of irrigation on agricultural production. Our focus in this paper, however, is restricted to consideration of the performance of the irrigation system component of irrigated agriculture.

are often overlooked and misunderstood because of their intangible nature. Without them, the physical elements cannot even come into being. These social elements can be categorized as *institutions* and *social structure* (Coward 1980). The concept of institutions refers to the rules governing social behavior and defining relationships among the actors in the irrigation system. Institutions, as rules, indicate expectations about social behavior. However, actual patterns of behavior usually differ in some degree from expectations. These actual patterns of behavior constitute the social structure. Both institutions and social structure may be informal (as with implicit understandings about water rights, and with patterns of interaction among farmers sharing a common watercourse) or they may be highly structured and formal (as in legally defined water rights, bureaucratically organized irrigation departments, and chartered associations of water users).

Central to the notion of both institutions and social structure is the concept of a *role*, which connotes a set of expectations and tasks associated with a particular function (Coward 1980). A distinction must be made between roles and individuals. All individuals involved in irrigation play many roles simultaneously, but only those roles that are directly related to irrigation are included in our definition of an irrigation system. Specifically, we make two important role distinctions. First, according to our definition, an irrigation system includes farmers acting in their role as irrigators, but it excludes their parallel role in other aspects of crop husbandry. This distinction is necessary to establish a clear analytic separation between the irrigation system and the broader agricultural system of which irrigation is a part. Second, in the case of public authorities responsible for both irrigation activities and other services such as agricultural extension, only the roles played by authority staff members that are related directly to irrigation are considered to be part of the irrigation system.

Like all systems, irrigation systems use inputs in various internal transformation processes that produce both intermediate outputs and final outputs. The final outputs, interacting with the larger environment, result in the system's impacts on that environment (Figure 1).

An irrigation system can be considered to be a subsystem nested within a larger set of agroeconomic and socioeconomic or politico-economic systems (Figure 2). The final output from the irrigation system (say, the provision of water for agricultural crops) serves as an input into an irrigated agriculture system. Likewise, the output of this system (say, a sustained increase in agricultural productivity) is an input into a broader agricultural economic system. The output of this system (say, increased incomes in the rural sector) represents an input into a still broader rural economic system, whose output in turn is an input into the nation's overall development.

Boundaries

A framework for assessing irrigation performance requires not only a clear definition of what irrigation is, but also specification of the boundaries that will be used for the assessment. These boundaries can be defined in terms of (1) the functions performed by the irrigation system, (2) the processes involved in creating and sustaining the irrigation system during its lifetime, and (3) the geographic area corresponding to either the physical or the social elements that comprise the irrigation system.

Figure 1—Model of irrigation systems showing inputs, outputs, and impacts

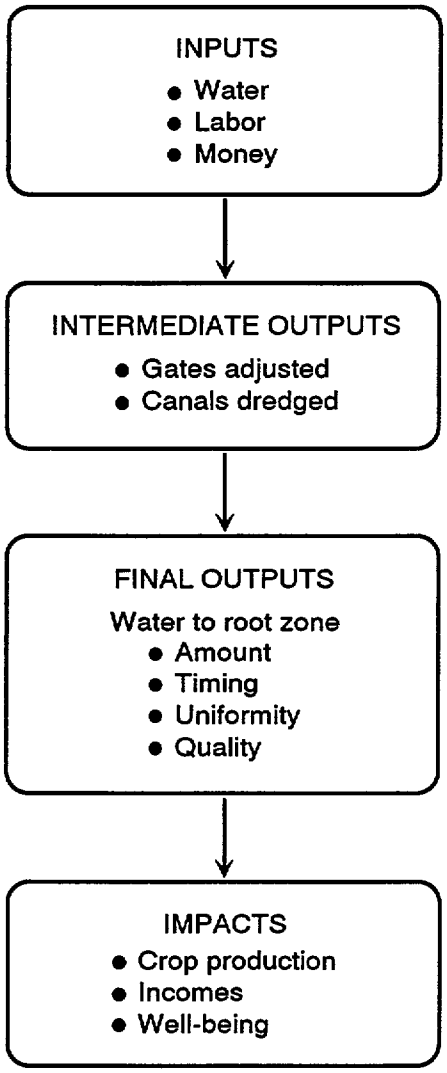
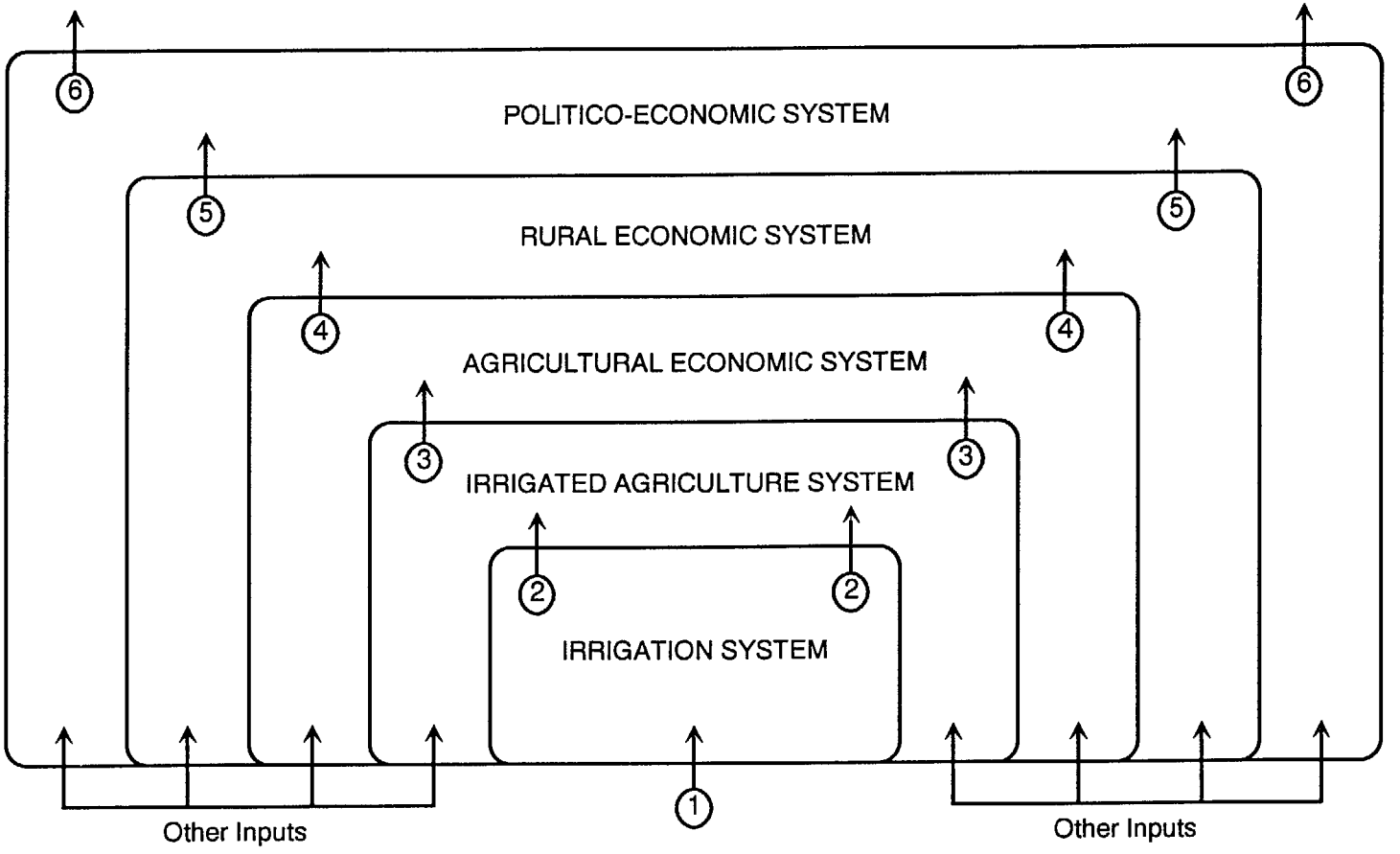


Figure 2—Inputs and outputs: Irrigation in the context of nested systems



Key to Inputs/Outputs:

1. Operation of irrigation facilities
2. Supply of water to crops
3. Agricultural production
4. Incomes in rural sector
5. Rural economic development
6. National development

System Function Boundaries. The definition of an irrigation system encompasses three relatively distinct water-related functions of the system: acquisition, distribution, and application. These functions provide the basis for establishing boundaries that divide an irrigation system into three corresponding subsystems.

The *acquisition subsystem* includes the physical and social elements associated with the capture of water from its source. The *distribution subsystem* includes elements associated with the movement of water in concentrated streams from the source to the edge of a field on which it is to be applied. In large systems, this subsystem typically incorporates many different social elements, including both the personnel of an irrigation agency and the irrigators. The *application subsystem* comprises those elements involved in applying the water to the soil. In this subsystem, the stream of water delivered by the distribution subsystem is dispersed throughout the root zone of agricultural fields. Typically, irrigators are the sole actors in the application subsystem.

Life-Cycle Process Boundaries. Activities associated with creating and sustaining an irrigation system can be classified into a number of processes that occur over the life of the system. These processes provide useful boundaries for delineating the scope of performance evaluations. Six relatively distinct processes can be identified: planning, design, construction, operation, maintenance, and support. The activities of planning, design, and construction are all associated with creating and modifying the physical and social irrigation infrastructure. These activities occur periodically throughout the life of an irrigation system, but at longer intervals than the other three processes. *Operation* comprises the recurrent activities necessary to capture, allocate, and deliver water to the fields of irrigators. *Maintenance* involves both periodic and recurrent activities designed to sustain the long-term capability of the facilities to function.[5] *Support* encompasses a variety of recurrent activities that permit and facilitate the execution of the other five processes. Support activities include personnel management, equipment acquisition and management, financial management and accounting, and resource mobilization. The need for boundaries based on these life-cycle processes reflects the great differences that can exist among the methods and measures appropriate to the assessment of the various processes.

Geographic Boundaries. The definition of an irrigation system implies the existence of geographic boundaries. However, the geographic extent of the set of physical elements that comprise the irrigation system is not necessarily contiguous with that of the social elements. It is thus necessary to consider both physical and social factors as possible determinants in delineating geographic boundaries.

Physical Basis. Both the design process and the demands of effective operation require that geographic boundaries for irrigation systems be specified in physical terms. This leads to the identification of the natural water source and the surface drainage network as the fundamental determinants of a system's geographic boundaries.

Often, water diverted into an irrigation system has already been used for some human purpose since it fell to the earth as rain—perhaps for industrial cooling, for municipal water supply, or for irrigation in an upstream system. That water may have been used

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[5] Although "operation" and "maintenance" are often lumped together as "O&M," they involve quite different tasks, so that for many purposes it is appropriate that they be treated as separate sets of activities.

previously is a less important criterion in defining a geographic boundary than is the presence of the water in a natural waterway or aquifer. A natural waterway that receives drainage from one irrigation system may serve simultaneously as the water source of a second system. Noting the existence of such reuse is extremely important in evaluating irrigation performance, particularly when concepts of technical efficiency are employed. Recognizing that boundary definition may often be somewhat arbitrary, one must remain aware of the significant interactions that can exist among irrigation systems. This is particularly important where water that enters a system is reused in one or more other systems, or where two or more systems acquire water at different points from a common source.

Geographic boundaries specified by water source and surface drainage are reasonably unambiguous in arid regions with deep water tables. When multiple sources of water are involved, however, as with conjunctive use of canal and well water or with extensive drainage reuse, more judgment is required to establish geographic system boundaries, and alternative delineations are possible. For example, an area receiving water from both a general source such as a reservoir and a local source such as a private tubewell might be defined as a small system served by the local source supplemented with canal water. Alternatively, it could be included within the boundaries of the larger system, with the well water considered supplementary.

Even when the conceptual geographic boundaries for irrigation are reasonably clear, complications emerge in their actual delineation. At least three different types of coexisting geographic boundaries based on physical considerations can be identified — those defining design area, service area, and net irrigated area.[6] The *design area* is the area that the system was intended to serve at the time plans for it were developed. The *service area* is the area provided with water distribution facilities at the time of construction. The *net irrigated area* is that which is actually supplied with water once the scheme is operational. The particular set of boundaries employed, and the resulting area values used, depend on the intended purpose of the evaluation.

Design area is usually somewhat larger than service area in a given system. Physical, social, or political problems unforeseen during the planning process can prevent the entire design area from being provided with irrigation facilities during construction. Service area, in turn, often exceeds actual irrigated area because of construction defects, unauthorized use of water by cultivators not officially included in the system, and the failure of the managing entities to control deliveries as precisely as presumed.

Net irrigated area (or "irrigated area") must be specified on a seasonal basis. In the common situation where annual wet and dry seasons are distinct, the wet-season irrigated area is often considerably larger than the dry-season irrigated area. Furthermore, irrigated

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[6] Various terms are used in different countries to represent these three concepts. The terms used here are intended to be generic. In addition, the concept of "net irrigated area" is sometimes troublesome. In India, net irrigated area denotes the largest area that is supplied with water during any one cropping season in a given year, which is usually the rainy season. Gross irrigated area is the sum of the areas irrigated during all cropping seasons in a given year. Most other countries report wet- and dry-season irrigated areas separately and use the terms gross and net irrigated area to correct total area (gross) by excluding certain subcategories of land (net). Land thus excluded includes wasteland, areas occupied by houses and buildings, areas occupied by roads and railroads, areas under pasture or nonirrigated crops within the system command, or even the area occupied by field bunds. One attempt to develop a more complete list of area definitions can be found in Bergmann and Boussard (1976); however, these definitions do not appear to have become widely accepted, and are, in some instances, convoluted and lacking in clarity.

area varies from year to year. Net irrigated area can thus be presented as a series of annual figures, as an average across a particular period, or as a frontier based on a set of peak values from a range of years.

An additional complication associated with the delineation of irrigated area arises when irrigation water from the system is used in areas not originally included in either the design or service areas. Such uses may be technically illegal and may involve unauthorized physical works constructed by farmers. As such, they are often not recognized on official irrigation system maps, nor included in official statistics on irrigated area. Considerable scope thus exists for important differences to arise between the official administratively delineated geographic boundaries of an irrigation system and the boundaries defined by actual patterns of water flow.

Social Basis. Irrigation systems comprise social as well as physical elements. As discussed in the section defining irrigation systems, these elements involve patterns of human interaction (social structure) governed by rules of interaction (institutions). To some extent, these interactions are geographically circumscribed, thereby providing an alternative basis for delineating the geographic extent of an irrigation system.

In some cases, social boundaries coincide, at least partially, with physical ones, as in subdivisions of an irrigation department whose areas of responsibility coincide with physically delineated irrigation systems. This is a common though not a universal practice. In Indonesia, for example, many operation and maintenance functions are carried out by units of public works departments organized by general administrative districts, irrespective of physical system boundaries. In Indonesia also, farmers often manage irrigation water distribution in smaller systems through social organizations based on village residential boundaries, which may cut across several physically defined systems.

Other complications arise from the use of social structure to define an irrigation system. First, in larger systems a single organization is seldom responsible for management from the source of water to the field. In some cases there are different government agencies responsible for abstracting water from its source and for conveying water to and distributing it within the command area. In almost all cases, farmers and groups of farmers are involved in the final stages of water allocation and application. Often also, there is a significant incongruency between the nominal area of responsibility of the public irrigation agency and its actual span of control. Usually, farmer control extends higher up in the system in practice than it does in policy.

This creates particular problems in conjunction with the dynamic nature of irrigation systems. As the interface between different organizations shifts over time (that between an irrigation department and an irrigators' association, for example) a socially based definition of system boundaries shifts also, making comparisons over time difficult. Because social arrangements differ from locale to locale, comparisons among systems are also problematic.

Data-based considerations also come into play. The division between farmers associations and irrigation departments is difficult to document since functions are articulated vertically rather than horizontally. Area irrigated by the irrigation department is typically nil, since farmers do the final allocation and application themselves. Yet without the irrigation department there would be no water to apply. Data on area irrigated are routinely collected in most larger systems, while information on implementation of particular managerial functions by agencies and farmers is seldom recorded. It is theoretically possible to define irrigation systems in terms of related sets of organizations, but this begs the

question, since then a new principle specifying the extent of the system becomes necessary. Although it is desirable to delineate geographic boundaries in ways that ensure that important social elements of the system are included, exclusive reliance on social patterns to delineate irrigation's geographic boundaries can lead to ambiguous and inconsistent results in assessing performance.

CONCEPTS OF PERFORMANCE

Having supplied definitions for the concepts of irrigation and irrigation systems and having discussed boundary-related issues involved in the practical application of these concepts, we now turn to the second major task involved in establishing a conceptual framework for evaluating irrigation performance. In this section we offer a definition of performance and explore the concepts associated with the term as it might be used in evaluating irrigation.

Definition

According to Webster's dictionary, the "performance" of a system relates to both the manner in which it carries out specified actions and the extent to which it has, by means of these actions, fulfilled specified requirements. Broadening this slightly, we define the *performance* of a system as encompassing the totality of both its activities—acquisition of inputs and the transformation of inputs into intermediate and final outputs—and the effects of these activities on the system itself and on its external environment.

Models of Performance

Several different approaches or models for understanding performance have been proposed (Cameron 1984; Quinn and Rohrbaugh 1981; Miles 1980), however, most of these can be categorized as reflecting one of two broad perspectives—the goal-oriented (or rational system) model and the natural system model.[7]

The *goal-oriented model* is the older and more common of the two approaches (Scott 1979; Seashore 1983). A system such as irrigation is viewed as existing for the purpose of producing some type of good or service that can either be consumed directly or used as an input in another production process. The purposes of the system are defined by powerful individuals and groups who are, in effect, "owners" of the system (Becker and Gordon 1966). This model leads to emphasis on measures of performance or "effectiveness" related

[7] Although these models were developed with specific reference to the performance of bureaucratically structured organizations, many of the insights generated are useful in understanding the performance of systems (such as irrigation) whose existence and performance are greatly dependent on human behavior. The strength of the analogy between bureaucratic organizations and irrigation systems is based on the fact that most irrigation systems are characterized by the existence of a central coordinating organization, whose behavior strongly influences the performance of the entire system.

to the degree to which a system attains the goals that have been established.[8]

The goal model implies the impossibility of evaluating the performance of a system in a purely objective fashion. Subjectivity enters the evaluation in the establishment of the goals themselves and in the assignment of weights to differing (and sometimes conflicting) goals. For assessments of performance based on the goal model, it thus becomes important to specify whose values and goals are being considered. Using the goals of different constituencies of a system will lead to different, although equally valid assessments of performance (Seashore 1983). In general, three broad categories of constituencies for human systems can be delineated. The first is society as a whole, for which an evaluation of performance from the perspectives of the general public interest is appropriate.[9] A second category of constituents consists of specific individuals or special interest groups who are outside the system, notably those for whom the system's output is intended. Other external perspectives could include those of a researcher whose interest in a system's performance reflects values stemming from a particular professional background; a citizen concerned with ecology and the environment; a populist or social reformer concerned with increasing the political power of the poor; a donor or lender to the system or the government; or a politician seeking to gain popular support. The third category of constituents comprises individuals who are a part of the system itself, and who have a variety of internal perspectives on performance. The most obvious of these perspectives are those of the top management of an organization having significant operational responsibilities for a system. If such an organization is large, however, managers of the various internal units are likely to have differing perspectives on performance. An additional type of internal perspective stems from the organization's members who have their own personal interests and values that may not be fully reflected in the formal goal structure of the organization.[10]

In contrast to the goal-oriented model, the *natural system model* is derived from a view of an organization as a social unit concerned with its own maintenance, elaboration, and expansion (Scott 1979; Strasser et al. 1981; Seashore 1983). The natural system model would define a system's performance in terms of the extent to which it is able to produce the amount and types of outputs necessary to ensure the acquisition of inputs for its continued existence and expansion. This places the primary emphasis of performance

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[8] The term "effectiveness" is not used consistently in the literature. Our use of the term to mean goal attainment regardless of the specific nature of the goal is consistent with definitions either stated or implied by several authors (Etzioni 1960; Price 1968; Zammuto 1982; Goodman and Pennings 1979; Hannan and Freeman 1979; Van De Ven and Ferry 1980, Chapter 2; Strasser et al. 1981). Other writers, however, restrict the term to the attainment of a particular type of goal. For some, the goal involves the production of specified outputs (Nash 1983); for others, it involves the achievement of certain impacts (McKinney and Howard 1979); still others focus on goals that relate inputs either to outputs or to impacts (Katz and Kahn 1966; Dubin 1976; Burton and Franks 1983). Some writers explicitly differentiate "effectiveness" from "efficiency", with the latter used to indicate the relationship (typically expressed as a ratio) between the quantities of outputs and inputs (Katz and Kahn 1966; Dubin 1976; McKinney and Howard 1979; Nash 1983; Kiggundu 1989). To the extent that efficiency considerations are incorporated into the goals established for the performance of irrigation systems, they become part of the concept of effectiveness, as we are using the term.

[9] We do not wish to imply the existence of a unique and objectively verifiable public interest. At any given point in time, however, a representation of the public interest is established in some fashion through the political process.

[10] The ideas in this paragraph are adapted from Seashore (1983).

assessments on a system's ability to obtain inputs, rather than on either its outputs or impacts.

Although these two models may appear to offer conflicting views of the nature and determinants of system performance, in many respects they are complementary, with both providing useful insights. For example, one implication of the natural system model is that assuring a system's survival may be a strong, though generally implicit, goal affecting the decisions of those individuals and groups with power to establish its goals. Similarly, the goal model implies that a system's survival may depend on its ability to recognize the importance of meeting the goals established by powerful groups and individuals.

Rationale for Performance Assessments

The nature of an assessment of a system's performance depends on the rationale for its being conducted. In some cases periodic assessments are undertaken to evaluate the operational status of the system and to suggest changes (opening or closing of gates, for example). In other cases the assessments are structured to modify the behavior of certain actors in the system, with the purpose of the assessment simultaneously being to modify and to monitor behavior. Whatever the rationale, it must be clearly specified because assessments appropriate for one purpose may be quite unsuitable for others.

In general, three broad types of performance assessments can be identified—operational performance monitoring, accountability assessment, and intervention assessment. These differ in terms of the audience for the results of the assessment, the time frame of the assessment, the haste with which field data must be processed, and the standards employed in making judgments. *Operational performance monitoring* is designed to provide, to those who have management responsibility for a system, information that can be used in making daily operational decisions. *Accountability assessment* is designed to provide information with which to judge the activities of those responsible for a system's performance. *Intervention assessment* is generally undertaken because of a desire to improve some aspect of a system's performance. A fourth type of assessment, a *sustainability assessment* might also be identified, though it is a variant of the intervention assessment. This type of assessment addresses performance over longer time periods and is also concerned with unintended consequences of irrigation activities.

Types of Performance Measures

Process, Output, and Impact Measures. The selection of specific measures of performance needs to be guided by a clear idea of whether the evaluation is to focus on a system's own internal processes, its outputs, or its impact on its external environment.

Process measures of performance relate to a system's internal operations and procedures in the creation of intermediate and final outputs (Figure 1). Because of this focus, they tend to be of greatest concern to system managers at various levels. Internal processes help determine a system's final outputs and its effects on the environment and are therefore important in explaining a system's outputs and impacts. They are, however, actual measures of neither.

Output measures of performance examine the quantity and quality of the system's final outputs. Specification of output measures must, of course, be consistent with the boundaries used in defining the system.

Impact measures of performance pertain to the effects of the system's outputs on the larger environment. Impact evaluations tend to be difficult to conduct, in part because of the large number of intervening variables whose influences must be sorted out, and in part because of the difficulty of placing an appropriate boundary on the assessment. Following Brewer (1983), we find it useful to distinguish between impact measures designed to evaluate the relatively direct spatial and temporal *outcomes* of irrigation (such as changes in agricultural production) and those designed to assess the farther removed, longer-term, and more geographically dispersed *effects* (such as changes in the welfare of rural people). The difficulties of impact evaluation are more likely to be manageable when the assessment focuses on outcomes. They often become nearly insurmountable when the focus is on effects.

Achievement versus Efficiency Measures. *Achievement performance measures*, whether dealing with internal processes, system outputs, or broader system impacts, focus only on specified achievements while ignoring the resources used in producing those achievements. Examples of achievement measures of performance might be the amount of irrigation fees collected (a process achievement measure); the volume of irrigation water delivered to farm fields (an output achievement measure); and the amount of agricultural production achieved (an impact achievement measure). By contrast, *efficiency measures* consider simultaneously both the achievement and the amount of resources used. An efficiency measure is thus usually expressed in the form of a ratio in which the magnitude of the achievement is divided by the magnitude of the resource used. Examples of efficiency measures include the amount of fees collected divided by the amount spent on the collection activities (a process efficiency measure); the volume of irrigation water delivered to farm fields divided by the amount of water entering the irrigation system at its head (an output efficiency measure); and the amount of agricultural production in the irrigated area divided by the total cost of operating the irrigation facilities (an impact efficiency measure).

Direct versus Indirect Measures. All irrigation performance measures, whether process, output, or impact, may be categorized as either direct or indirect. *Direct measures* focus specifically on the variables of interest in assessing performance. An *indirect measure* serves as a proxy for the direct measure in situations where data on the direct measure are unavailable.

Direct measures of performance are inherently more desirable than indirect measures for two reasons. First, the relationship between the indirect measure and the variable for which it serves as a proxy is never completely certain. A key question in the use of such proxy measures is the predictive validity of the proxy (Schmid 1989, 28). If the correlation between the measure and the variable for which it is a proxy is high, then the variable on which data are actually collected is a good proxy for the direct but unmeasured performance indicator, in the sense that it is a good predictor of it. If, on the other hand, the correlation is low, or if there is considerable uncertainty about the degree of correlation, then the reliability and usefulness of the proxy is cast in doubt. Reliance on indirect measures may thus lead to incorrect conclusions about performance.

The second problem with indirect measures is that their use can lead to perverse results if the performance assessment itself causes modifications in the behavior of some of the system's actors. This can easily happen when it is known (or believed) that the results of performance assessments will affect job performance ratings. It has been reported, for

example, that the U.S. Navy once experimented with a performance measure for dentists consisting of the number of teeth pulled per month. The results of this approach to assessing performance were "predictably unfortunate" (Daly and Cobb 1989, 149)!

Obtaining reliable data on direct measures is often an extremely difficult—and thus costly—process. It is therefore necessary to balance the increased value of the more accurate and reliable information provided by the direct measures of performance with the additional cost of obtaining that information.

Performance Standards

Raw measures of the performance of a given system relating to a single point in time have little meaning because nothing is available with which to compare them—neither earlier measures of performance for the same system nor normative standards. Although intertemporal comparisons of performance of a single system can show trends over time, in the absence of standards it will be impossible to assert whether or not the observed changes are favorable. Comparisons among systems will likewise not be meaningful because no judgments can be made without knowing what the desirable state is. As a result, objective measures of performance are useful only in conjunction with normative standards against which they can be compared (Campbell 1979; Hannan and Freeman 1979; Scott 1979). These standards may be internal, external, or relative.

Internal standards are those established within an organization. In bureaucratic organizations, the internal standards often reflect the managers' operational goals. In an irrigation system with facilities operated by a government agency, the managers of the agency may establish standards for the area to be irrigated, the number of water deliveries to be made during a season, the quantity of each delivery, the timing of water deliveries, the date of commencement of irrigation service, and so forth.

External standards may be derived from a variety of sources. Some sources are technical. For example, performance standards linked to crop water requirements come from plant physiology. Other external standards may be derived from political, economic, or ethical sources, such as those based on concepts of equity and those involving accountability of an irrigation agency to higher-level government authorities or to water-users groups.

Conflicts may arise between internal and external standards. Political authorities, for example, may establish standards of performance that differ significantly from those of the top management of a government irrigation agency. It is possible for an irrigation system that is meeting the goals of its operating agency (and thereby performing well in terms of internal standards) to be performing very poorly according to the standards established by the nation's planning body or finance ministry. The issue of explication and articulation of goals at the various levels of government is thus important where external and internal standards are being applied.

Relative standards are derived from the performance of other similar systems. Comparing the value of a performance measure for a given system with average values derived from a large group of comparable systems provides a unique means of avoiding subjective standards set for particular measures. Objective statements about the performance of a given system in terms of a particular measure can be made—for example, that the value is larger than the average for the group or that it falls in the lowest quartile of values for the group. However, a normative value must still be assigned to the

relationship between a measure for a particular system and the standard values characteristic of the group of systems as a whole. Thus a value that exceeds the group mean must be deemed "good" or "bad" depending on whether the measure is indicative of a desirable or an undesirable trait of system performance. In addition, normative value may be contingent on the level of other indicators. The importance attached to high values of an equity measure, for example, may decline as the abundance of the water supply increases.

Relative standards provide a useful yardstick for testing the appropriateness of targets for performance improvement. The realism of such targets can be checked by comparing them with the mean of values in the upper (or lower) quartile of the distribution for the group of systems to which the sample system belongs. Likewise, relative standards can serve as benchmarks in establishing design parameters for planning new systems.

Dynamic Considerations

Systems are not static. The external environment in which they operate changes over time, and their internal operations also change. A performance evaluation conducted at a specific point in time represents a "snapshot" of the system's performance and may give a rather misleading picture of its performance over a more extended period of time. This is particularly true for systems such as irrigation that operate in situations where environmental conditions fluctuate unpredictably over time. As Hannan and Freeman (1979) have noted, managers of such systems face a choice in strategies: either they can specialize in ways that allow them to deal effectively with certain of the varying environmental states (such as severe drought), or they can adopt a strategy that serves reasonably well in most states, but that is inadequate in some. A single evaluation of performance must take into consideration both the strategy chosen by the system's managers, and the environmental conditions that existed at the time of the performance evaluation. A more complete performance evaluation needs to take into consideration changes in performance over time in response to changing environmental conditions.

3. ASSESSING RECURRENT PROCESSES OF IRRIGATION: AN APPLICATION

In Chapter 2 of this paper we laid out a comprehensive conceptual framework for the assessment of irrigation system performance. The key elements of this framework are outlined in Table 1. In considering performance assessments, this conceptual framework makes clear the nature and limitations of any individual assessment and highlights the similarities and differences among particular approaches. By emphasizing the points of choice in the design of a performance assessment, the framework should encourage a more systematic approach to the planning of assessments, the need for which is particularly acute where comparisons across individual schemes, geographic regions, or nations is intended.

The conceptual framework is broad enough to accommodate the key characteristics of all types of irrigation performance evaluations. In this section we use the framework to narrow our focus to a particular class of assessments, which has been profoundly neglected. Our ignorance in this area represents a key constraint to further advances in our analytic understanding of irrigation system performance. In addition, a widely shared interest in the ability to compare irrigation system performance across time and space motivates our interest in this type of assessment.

The assessments in which we are interested are characterized by a concern with the recurrent processes of irrigation systems, rather than the episodic design and construction processes; a primary focus on the irrigation system proper, rather than the irrigated agricultural system; and an interest in the collectively or bureaucratically managed portion of the system. This is a critical type of performance assessment for at least four reasons.

- First, because of the current reduced level of new irrigation investment, donors and policymakers are placing strong emphasis on wringing improved performance out of existing systems.

- Second, the point at which water is delivered to farm fields usually marks the transfer of responsibility for irrigation from some form of group or organization to the individual farmer. The group in question may be an irrigation bureaucracy, a formal or informal farmers' organization, or a combination of the two. Assessment at this point makes it possible for the group providing this collective service to evaluate and improve its own performance.

- Third, evaluation of irrigation performance in terms of water deliveries minimizes the confounding influence of other nonirrigation variables. Assessments that focus more broadly on the agricultural consequences of irrigation, although clearly important and relevant, face the very real and difficult analytical problem of separating the effects of irrigation from the myriad other factors affecting agricultural production.

Table 1—Outline of the conceptual framework for evaluating irrigation performance

I. **DELINEATING BOUNDARIES ON WHAT IS TO BE EVALUATED**
- A. System
  - **1. Irrigation system only**
  - 2. Irrigated agriculture system (including irrigation system)
  - 3. Other systems (including irrigated agriculture system)
- B. Irrigation subsystems (system functions)
  - **1. Acquisition**
  - **2. Distribution**
  - 3. Application
- C. Life-cycle processes
  - 1. Planning
  - 2. Design
  - 3. Construction
  - **4. Operation**
  - **5. Maintenance**
  - **6. Support**
- D. Geographic extent
  - **1. Physical basis**
    - a) Design area
    - **b) Service area**
    - **c) Net irrigated area**
  - 2. Social basis

II. **DELINEATING TYPES OF EVALUATION: CONCEPTS OF PERFORMANCE ASSESSMENT**
- A. Models of performance
  - **1. Goal-oriented**
    - a) Goals of society
    - b) Goals of external constituents
    - c) Goals of internal constituents
  - 2. Natural system
- B. Rationale for assessment
  - 1. Operational performance monitoring
  - **2. Accountability**
  - **3. Intervention**
- C. Types of performance measures
  - 1. Level
    - a) Process
    - **b) Output**
    - c) Impact
  - 2. Scope
    - a) Achievement
    - b) Efficiency
  - 3. Relationship to conceptual indicator
    - a) Direct
    - b) Indirect
- D. Source of performance standards
  - 1. Internal
  - **2. External**
  - **3. Relative**
- E. Time dimension of assessment
  - 1. Single point in time
  - 2. Multiple points in time

Note: Items shown in bold type under each dimension define the application area identified in Chapter 3.

Generally, an evaluation of performance based on water deliveries is a prerequisite for a sound assessment of irrigation's agricultural consequences.

- Fourth, the point of water delivery to farm fields is the most appropriate one for linking two analytic models — the hydrologic model, on the one hand, and the agroeconomic (production function) model, on the other. Specification of water flows at this point can lead to significant improvements in the analytic ability to predict the agronomic and economic consequences of alternative irrigation scenarios.

In this chapter, we explore the choices among alternatives within the framework dimensions developed in the first part of this paper. To clarify the relationships between the discussion in this section of the paper and the conceptual framework, cross references to the outline of the conceptual framework presented in Table 1 are given in the corresponding subsection of the text. In the table, the allternatives within each dimension that define the area of particular interest are shown in boldface type. In some cases, a choice among alternatives is not required, and the alternatives are simply reviewed in the text.

PERFORMANCE MODELS

This section relates to Table 1, II.A.

Goal-Oriented Model

Public irrigation systems are generally created by societies as part of a formal, goal-oriented process. Our definition of irrigation systems implies the existence of such goals. Efforts to improve irrigation performance reflect concern that the goals underlying irrigation investment decisions have not been fully realized; they represent attempts to bring about changes that will enhance their achievement. These considerations lead us to conclude that the goal model of performance is likely to be more useful than the natural system model in assessing performance of the recurrent activities of irrigation systems. Even where a natural systems model might be better able to predict behavior — in a rigid, well-entrenched bureaucratic system — performance improvement would probably involve efforts to shift the bureaucracy to a goal-oriented management approach.

Goals

Levels. An evaluation of irrigation system performance will therefore require a specification of the goals against which performance is to be evaluated. A listing of goals for an irrigation project often presents a picture of bewildering diversity, however. Sometimes the focus is on irrigation as an input to agricultural production, for example, where it is stated that the goal is to deliver water in accordance with crop needs (Hillel 1988; Fukuda 1976). In other cases, the emphasis is on the agricultural output made possible by irrigation, the implication being that the purpose of irrigation is to increase the nation's agricultural production or its food supply (Colombo et al. 1978). A nation's public planners may view irrigation primarily as a way to foster the overall economic development of a region or the entire nation. Social scientists with a focus on human conditions may advance the goal of making possible

"adequate, secure, and decent livelihoods" (Chambers 1988, 33) or even more broadly, of enhancing the well-being of people (Chambers 1988, 39).

These disparate types of goals can be characterized by the directness of their relationship to the activities of irrigation, namely, the capture and manipulation of water supplies for agricultural production. Irrigation relates very directly to the production of agricultural crops, with a relatively small number of intervening variables. By contrast, irrigation affects the well-being of people very indirectly, with many intervening variables playing a role. The more direct the relationship between irrigation and the achievement of a goal, the more specific and narrow that goal tends to be, whereas goals that are only indirectly related to irrigation tend to be broad in scope.

To capture this complexity, we conceptualize irrigation goals within a nested means-ends framework.[11] In this framework, a narrow goal is seen as the means for achieving some specified end, which is the broader goal within which the narrow goal is nested. This end, in turn, becomes the means for achieving another end, reflecting a still broader goal. Thus beginning with the narrowest, or proximate, goal of irrigation, one moves outward through a series of broader goals, the achievement of each of which is partly dependent on attaining the goal of the previous level. This process continues until one arrives at the "ultimate" goal (see Figure 3).

Our definition of irrigation emphasizes that human manipulation must be involved in supplying water to crops. The means to this proximate end is the operation of physical irrigation facilities. But this "end" of irrigation is in no sense the "ultimate" end—there must be some purpose for supplying crops with water. Supplying water is thus the means to another end, which might be defined as supporting a sustained level of agriculture that is more productive than the agriculture possible under rainfed conditions. But neither is increasing agricultural productivity an ultimate end. It may be the means to increasing incomes in the rural sector, and thereby be an engine of rural economic development, which in turn could be a means to achieving two "ultimate" ends—improving the livelihoods or general welfare of rural people and achieving sustained socioeconomic development for the whole economy.

This approach to conceptualizing the diversity of goals for irrigation is directly related to the concept of an irrigation system as a component of broader agricultural, economic, and social systems (Figure 2). Thus the idea of narrow ends being means for achieving broader ends is equivalent to the concept of outputs from one system serving as one of the inputs to a broader system within which the former is nested.

Constituencies. Application of the goal model also requires that the constituency for particular sets of goals be examined (Table 1, II.A.1.a, b, and c). Typically there is some correspondence between particular categories or levels of goals, as discussed above, and the interests of particular constituencies or stakeholder groups. The selection of goals against which to evaluate performance will thus be influenced by the interest and involvement of various stakeholder groups, which, in turn, will help define the nature and purpose of the assessment. If the assessment is initiated by the top managers of an

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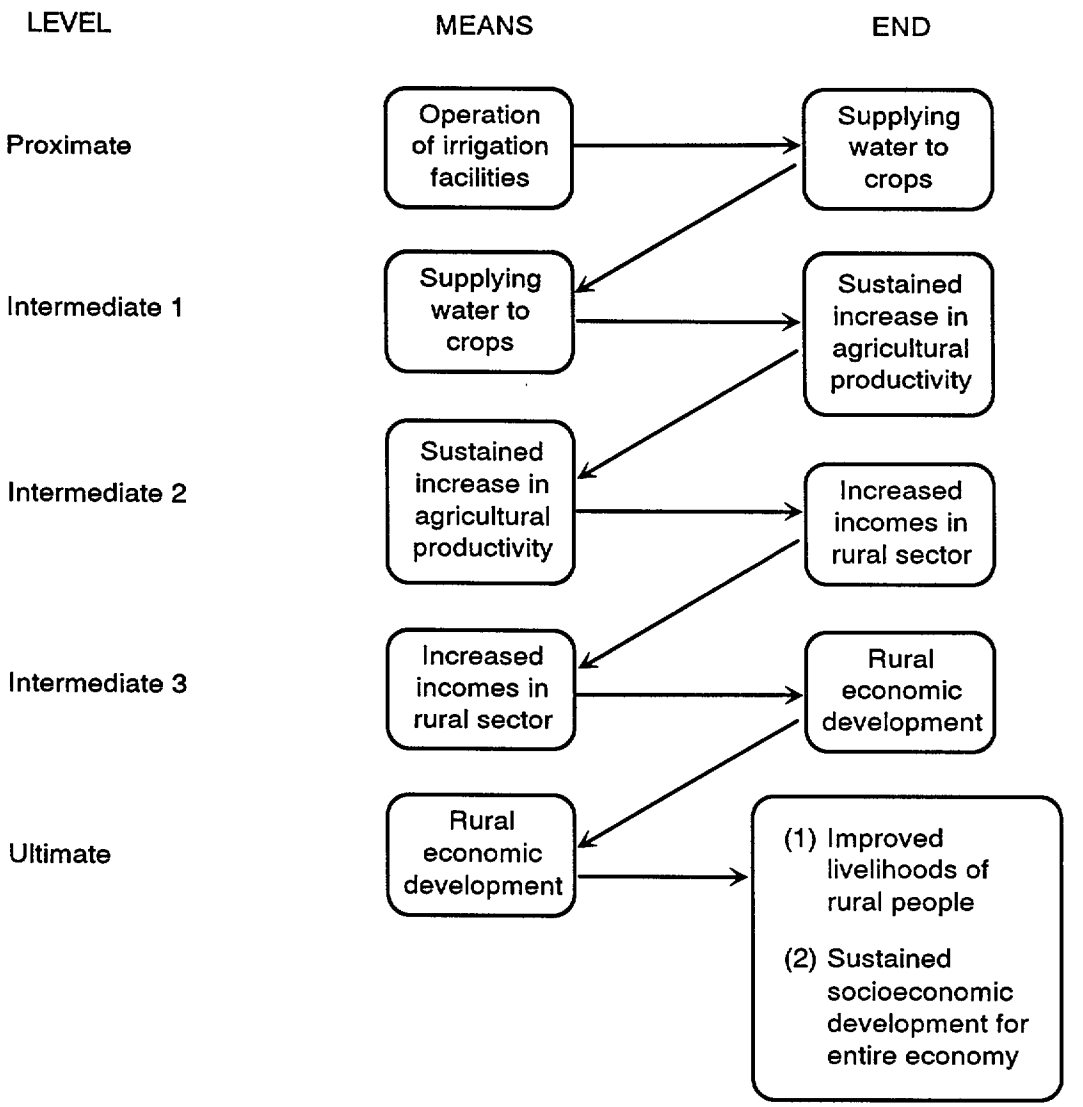
[11] Our approach is essentially the same as the means-ends chain suggested by Kast and Rosenzweig (1985). Campbell (1979) also suggests that an organization's objectives can be identified either as means or as ends. Our approach differs from his, however, in that we conceive that a given objective can, at one and the same time, be both a means and an end, depending on the level of analysis.

Figure 3—Irrigation purposes as nested means and ends



irrigation agency (internal constituents of the irrigation system), then their own goals will figure prominently in the set selected for the evaluation. To the extent, however, that the goals of the top managers include some notion of satisfying water users, then the goals of the farmers in their roles as agriculturalists (external constituents) would also be included in the set of appropriate goals. If, on the other hand, the assessment is initiated by a group of external constituents of the irrigation system—such as officials of a national planning agency, a ministry of finance, or an international financing agency—then the appropriate goals would center on those of these external groups.

Generally, however, it is appropriate to evaluate the performance of a system in terms of the goals of a variety of constituent groups, regardless of who may have initiated the study, since effective performance of the system usually depends on the active cooperation of a number of different constituencies. Some examples of these different constituents and their possible goals are given below:

- The managers of an irrigation operating agency may be concerned with distributing water in ways consistent with operational guidelines they have established, or in ways that minimize the inconvenience they face as a result of complaints about the irrigation service.[12]

- Irrigators are likely to have a number of goals relating to the quality of the irrigation service they receive, including adequacy, timeliness, equity, tractability, convenience and predictability, and desirable physical and biological characteristics of the irrigation water (Svendsen and Small 1990).

- A government planning agency or finance ministry that must allocate funds to operate, maintain, and support the irrigation system is likely to be concerned about the economic and financial returns to these funds.

BOUNDARIES ON WHAT IS TO BE EVALUATED

Having established the basis for restricting the remainder of the discussion of performance assessments to the goal model, we can now return to examine in more detail the critically important boundary questions (Table 1, I). One of the most controversial issues in assessment of irrigation performance concerns the system and subsystem boundaries to be used. In this section we make a case for evaluations that are focused specifically on the performance of the water acquisition and distribution subsystems of the irrigation system. First, we discuss reasons for excluding all but the irrigation system from the evaluation.

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[12] Managers may also be concerned with ways of increasing their income through extracting extralegal payments from irrigators or from construction contractors; however, this is unlikely to be stated as an explicit goal in any formal evaluation process. Such personal goals will be present in any human system, and can distort the planning and evaluation process if they are not recognized. The objective should generally be to bring these goals to the surface in order to understand their underlying motives and then to try to co-opt them into the formal goal structure. For example, whereas the extralegal payments from irrigators mentioned above could probably not be sanctioned in their present form, some type of employee profit-sharing plan based on an open assessment of system performance is a potentially powerful tool in improving system performance, where performance is driven by open, rather than private or covert, goals.

Then we argue for the usefulness of evaluating irrigation at the interface between the distribution and application subsystems, thereby limiting the evaluation to the performance of the acquisition and distribution subsystems.

The Irrigation System as the Unit of Analysis

The definition of an irrigation system developed in the first part of this paper explicitly restricts the scope of a system to the physical and social elements that supply water to plant root zones (Table 1, I.A.1). Agriculture that is supported by irrigation remains outside the irrigation system per se. Yet agriculture and irrigation are clearly interlinked, and there are valid reasons to examine the transactions and interactions between them. We argue, though, that there is considerable advantage in first conceptually separating the irrigation system and the irrigated agricultural system and discussing the two component systems before turning to their interactions. There are three strong reasons for designing and undertaking performance assessments that are limited to the irrigation system.

- First, such assessments focus on goals that correspond to the only system outputs that are directly the result of irrigation, and over which the managers of an irrigation scheme have any control. They thus give information about how well the system is doing in achieving its immediate goals, which should be the direct concern both of scheme managers and of those who desire to improve performance of the scheme.

- Second, such assessments avoid the problems of "confounding" variables — other unmeasured influences that arise when efforts are made to attribute changes in the performance of a broader system (such as the irrigated agriculture system) to the behavior of the irrigation system. For example, the performance of the irrigated agriculture system is affected not only by irrigation, but also by natural phenomena (such as pest infestations or typhoons) and political and economic policies (affecting such things as the availability of other inputs and the incentives of farmers).

- Third, assuming that the immediate goal of irrigation (output) is appropriately specified relative to the means (input) that irrigation is intended to provide to the irrigated agriculture system, then the achievement of the immediate irrigation system goal is a necessary condition for the achievement of the broader goals set for irrigated agriculture.[13] Failure to achieve these immediate goals implies that irrigation is not contributing to the broader goals established for it. It is thus important to begin an assessment of irrigation with an examination of the extent to which it has achieved immediate goals.

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[13] If the immediate goal has been specified inappropriately, then achieving it might not be a necessary condition for achieving the broader goals, and in fact could be incompatible with the achievement of them. An example would be a situation where the specified immediate goal for the irrigation system was such small quantities of water delivered to farm fields that farmers were unwilling to make use of it. For performance assessments designed to detect the problem of inappropriate immediate goals of a system, the system component boundaries must include the system for which the immediate goals serve as a means (input). Our discussion in the text should not be misconstrued to imply that these broader assessments of performance are inappropriate; rather, we are simply making the point that given the current gross lack of systematic assessments of the performance of irrigation operations, an appropriate place to begin is with these narrowly defined assessments.

Irrigation Subsystem Functions

Having made the case for the value of performance assessments of irrigation that exclude the broader systems in which irrigation is embedded, we now turn to the rationale for further limiting the evaluation to the acquisition and distribution subsystems (Table 1, I.B). Evaluations of this type focus on the interface between the distribution and application subsystems and the delivery of irrigation service across this boundary.

In the typical situation found in Asian and African countries, where irrigation schemes serve large numbers of small farmers, this interface is of particular importance because it often marks a significant change in the social elements of the irrigation system. Specifically, it is at this interface that responsibility for irrigation performance often shifts from some type of collective arrangement (involving interactions among farmers and between farmers and irrigation agency staff) to activities undertaken independently by individual irrigators. Beyond this interface the individual irrigator almost invariably has full control over the irrigation input.

Evaluations at this interface are thus critical to both system operators and individual farmers. For system operators responsible to varying degrees for the long chain of transformations of the raw water input, this interface represents the point beyond which their control ceases completely. The subsequent performance of the application subsystem thus depends on the quality of the service the farmer receives at the interface, and on his or her own individual skills in spreading the water over the farm field. Restricting evaluations in this way thus avoids the potential problem of confounding an assessment of the quality of irrigation service received by farmers with the separate issue of the quality of farmers' own water application skills.[14]

Life-Cycle Processes

By focusing our evaluation of irrigation performance on the delivery of irrigation water to farm fields, we are limiting the assessment primarily to the three recurrent life-cycle processes of operation, maintenance, and support (Table 1, I.C). We thus exclude from further consideration assessments of the periodic processes of planning, design, and construction that occur less frequently. We do not deny the importance of improving performance of these longer-period processes; however, reasonably well-established assessment procedures for these activities already exist. Systematic assessment of performance related to the recurrent activities of operation and maintenance, while equally important, is a less-worn path. Moreover, system output performance represents the culmination of the investment process that includes system planning, design, and construction, as well as operation, maintenance, and support.

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[14] Much of the evaluation of irrigation performance in countries such as the United States, where individual farm and field sizes are large, focuses solely on the application subsystem and its output (for example, El-Hakim, Clyma, and Richardson 1984; Reddy and Clyma 1982; and Hart, Peri, and Skogerboe 1979). This reflects the fact that on large farms, much of the distribution subsystem as well as the application subsystem is under the control of the individual farmer, making off-farm distribution issues less important. In this situation, a more useful interface to evaluate may be the one between the farm unit and the portion of the distribution system leading up to it.

Geographic Extent

The focus on water deliveries to farm fields implies boundaries on geographic extent that are based on physical rather than social elements of the irrigation system (Table 1, I.D). Of the three types of physically based geographic boundaries—design area, service area, and irrigated area—irrigated area is clearly of primary relevance to an assessment of irrigation performance that is focused on water deliveries to farm fields. In some cases the service area might also be considered, in order to evaluate the extent to which the geographic area actually receiving irrigation water encompasses the entire area for which irrigation facilities were constructed. Design area, however, would generally be of no relevance to this type of performance assessment, because divergence between the design area and the service area relates to design and construction processes rather than to the processes of operation and maintenance.

RATIONALE FOR ASSESSMENT

Assessments of the recurrent activities of irrigation could involve any one of the three types of rationales identified in the conceptual framework (Table 1, II.B). Because the requirements for the assessment vary with the larger reason for undertaking it, it is important that this rationale be clearly identified. We argue that attention should be focused initially on the second and third types of assessments discussed below, due to their greater strategic importance and relative neglect. Some of the most significant changes affecting irrigated agriculture now taking place in the Third World relate to irrigation financing policies, to the basic structure of irrigation agencies, and to the relationships between irrigation agencies and higher-level government authorities, on the one hand, and organized groups of farmers, on the other. The power and breadth of these trends suggest that relatively greater attention should be paid to accountability and intervention assessments, which are the most useful types for implementing and evaluating the processes that these forces are likely to set in motion. A secondary effect of the resulting restructuring of the irrigation sector very likely will be increased demand for operational performance monitoring techniques and systems, which will spur subsequent development of such techniques.

Operational Performance Monitoring

Managers of an irrigation agency need a continual flow of current information about a system's performance as input to their daily operational decisions. Performance information is needed both on internal processes and the resulting intermediate outputs and on the final outputs of the system. The useful lifetime of this information for controlling the system is counted in hours and days rather than weeks or months. In some cases managers may aggregate the information into a longer period format (such as an agricultural season) for retrospective analysis, and this might be considered a form of intervention assessment if changes in operating rules or system improvements are considered as a result. Their typical concern, however, is with the day-to-day monitoring of operational performance. Considerable attention has been devoted to the development and introduction of improved operational performance monitoring systems in recent years, with mixed though generally disappointing results.

Accountability Assessments

Accountability is an important feature of any management model. There are at least three different areas in which information from assessments can be applied in judging accountability: the internal processes of the organization managing the irrigation system, the relationship between the irrigation agency and its supervising board or body, and the relationship between the farmer clients of the system and the agency.

In many countries, a national irrigation agency is responsible for operating the physical facilities of most or all large irrigation systems in the country. Comparative information on the performance of the various systems can assist top management in evaluating the performance of individual project managers. Careful thought needs to go into the choice of the dimensions and measures of performance used, however, since project managers are likely to attempt to enhance their performance ratings by modifying their behavior in accordance with the assessment criteria.

Those who supply resources as inputs to the irrigation system generally have a vested interest in its performance. Routine performance assessments on a seasonal, annual, or multiyear basis allow providers to evaluate not only the effectiveness with which the resources have been used, but also the appropriateness of requests for additional resources. A requirement for regular performance assessments can strengthen the accountability linkages between the operating and funding agencies. The knowledge that such assessments are to be undertaken is likely to cause the operating agency to modify its behavior in ways that will cause the assessments to be more favorable. The need for this type of assessment may vary, depending on the structure of the agency and its relationship to higher authorities. In a financially autonomous operating agency, the need for such accountability assessments is partially replaced by the internal incentives resulting from the agency's need to remain financially viable. As a result, the government's task of monitoring and controlling the operation of the irrigation agency may be significantly reduced.

There is increasing awareness that developing superior levels of performance in large irrigation systems depends in important ways on a healthy and mutually respectful relationship between the operators of the major physical facilities and farmers. A key mechanism for helping create this type of relationship and using it to maintain strong performance is a program of regular assessments of system performance that focus on the mutual accountability links between operators and users.

All accountability assessments need to be regarded as objective and fair in the eyes of the involved parties if they are to perform their intended function. In some cases an external agency may need to undertake the assessment to ensure objectivity in the collection, analysis, and presentation of the data. In the case of joint assessments of irrigation service to farmers, involvement of both farmers and system operators in the assessment provides countervailing interests that help ensure objectivity. In other cases, the primary responsibility for undertaking the assessment could be given to the irrigation agency, but with some external body having oversight responsibilities to monitor and validate the process.

An analogy can be made with the practices of private businesses that raise capital through public stock markets. These firms are often required to prepare financial statements providing information that can be used by their investors and the public to assess their performance in a variety of financial dimensions. The content of these financial statements and the procedures used in their underlying calculations are the subject of detailed rules

promulgated by governmental or professional bodies established for this purpose. An external auditing firm certifies that the firm has followed these rules.

Intervention Assessments

A desire to improve some aspect of irrigation performance underlies a wide variety of interventions made by managers and government agencies. These interventions may range from modest changes in water distribution procedures to major rehabilitation of physical facilities. They may be done on a routine basis or episodically. A system might engage in a year-end review of its annual performance, for example, to assess the need for changes in operating rules or maintenance procedures, changes in staffing patterns, or perhaps to detect a gradual year-to-year decline in performance that would suggest the need for a more thoroughgoing intervention assessment.

Often ad hoc assessments are carried out when there is indication of a significant problem with system performance or when a major change in system configuration or operation has been made. Many individuals and organizations — including government planning agencies, external donor agencies, managers within an irrigation agency, and professional irrigation researchers — will want both *ex ante* assessments to evaluate the desirability of or need for a proposed intervention and *ex post* assessments to judge the results of the intervention. Such assessments generally require data for one or more complete seasons. Lags between the initiation of an intervention and the resulting changes in performance may make it necessary for *ex post* assessments to cover a period of several years. Annual variability in conditions may also make it prudent for an evaluation of an intervention to incorporate data from several years into the analysis even after the impact of the intervention has stabilized.

This type of assessment is also useful in applied research studies that attempt to understand the causes of particular levels of irrigation performance, even when no intervention is immediately contemplated. The aim of such research is typically to improve our ability to understand and predict the level of performance likely to result from particular combinations of system configuration and environment, ultimately leading to the design of improved interventions and better targeting of interventions in particular circumstances.

TYPES OF MEASURES

Level

As discussed in the section on types of performance measures, assessments of irrigation performance may be conducted at the level of internal processes, system outputs, or system impacts (Table 1, II.C.1). Process measures involve analysis of the transformation of inputs into intermediate outputs, whereas output measures consider final outputs of the system. Impact measures of irrigation performance report the effects that irrigation has had on the broader systems in which it is embedded.

The recurrent internal transformation processes of an irrigation system are complex and rely on a number of inputs in addition to water. First, there are the physical facilities (which are themselves outputs of the periodic activities of planning, design, and construction). A second input is money, which usually is either provided by a government

agency or obtained from the water users in the form of fees. A third input is the labor of the irrigators. Equipment and material provided for construction purposes are sometimes also used for recurrent irrigation activities. Leadership and management are less tangible but nonetheless important inputs. Finally, there is water itself, which may come both from concentrated sources and from rainfall occurring within the system's physical boundaries.

Using these inputs, irrigation systems engage in transformation processes that produce many intermediate outputs: personnel are hired and trained; irrigation schedules are developed; meetings are held with farmers; gates are opened, closed, painted, and greased; pumps are operated; canals are dredged; conflicts are arbitrated; information is collected; water-users organizations function; communication takes place; and so on. A complete list of the transformation processes and their associated intermediate outputs would be very long indeed!

Many process measures of performance focus on these internal transformations. Others focus on how well a system responds to secular changes in its environment. Examples include responses to changes in characteristics of the water source, such as those caused by new diversions upstream of the system's headworks, and responses to changes in cropping patterns induced by such things as the introduction of new varieties and changes in product prices.

Ultimately, all of these internal processes lead to the final outputs from the distribution subsystem, namely, the time-dated quantities and qualities of irrigation water supplied at the edge of farm fields. Process performance measures can be helpful managerial tools for system operational control, but they are unable to provide definitive information on the actual outputs of a system.

Thus, for assessments that specifically focus on the irrigation service received by the farmers, output measures of performance are essential. The outputs that need to be measured consist of the amount, timing, spatial uniformity, and physical, chemical, and biological properties of water delivered. It is these outputs that serve as inputs to the application subsystem, where the individual irrigator takes responsibility for infiltrating the water into the root zone of the crop, thereby affecting crop production and, indirectly, the incomes and well-being of farmers, consumers and others in society.

The assessment of impacts on crop production, incomes, and well-being becomes increasingly difficult as one moves to higher levels of purpose (see Figure 3), and at some point it becomes impossible to trace these impacts back to the operation of a single irrigation system. The measurement and interpretation problems that apply have already been treated in the section discussing the irrigation system as the unit of analysis.

For the application of the conceptual framework proposed in this part of the paper, the primary focus must be on output measures of performance. This follows from our focus on the irrigation system rather than on the irrigated agricultural system, and from having accorded priority to accountability and intervention assessments rather than operational performance assessments. Complete exclusion of these other two categories is not called for as certain process and impact measures are relevant for some accountability and intervention assessment purposes. However, the centrality of output measures of performance and their past neglect require that they be assigned first priority. To the extent that impact measures are considered, they must be "outcome" measures rather than measures of the more diffuse "effects."

Achievement Versus Efficiency

Both achievement and efficiency measures of performance are useful in assessing the recurrent activities of irrigation (Table 1, II.C.2). Output measures that assess whether the irrigation system achieves its goals are discussed in the following section on direct and indirect performance measures.

Efficiency measures of performance combine an output achievement measure with a measure of input amount, often in the form of a ratio. Because achievement measures are one component of all efficiency measures, the discussion in the following section is also relevant to efficiency measures. In addition, one must consider the types of inputs to be used in the denominator of the efficiency measure. The amount of water diverted or released into the head of the irrigation system is one possibility and leads to efficiency measures that can be interpreted in terms of traditional concepts of water use efficiency. Alternatively, a cost measure (such as total cost of the system's recurrent activities) might be used. Exploration of these issues is beyond the scope of this paper, but well within the ambit of the irrigation performance series.

Direct Versus Indirect

Direct measures of the output of the distribution subsystem involve measurement of flow and water quality, using an appropriate sampling framework to deal with variability over time and space (Table 1, II.C.3). Obtaining satisfactorily comprehensive and accurate data on these direct measures of performance is likely to be fairly expensive. In situations where it is not feasible to obtain such data, it is necessary to consider possible indirect measures to serve as proxies for the direct measures.

The most obvious candidates as proxies for direct flow and water quality measurements are crop yield or, in the case of flooded rice, seasonal water-shortage indices such as those proposed by Wickham (1971), Small, Capule, and Oallares (1981), and Wijayaratna (1986). Although geographic sampling would still be necessary, one striking advantage of both yields and water-shortage indices as indirect measures of the volume, timing, and quality of irrigation water delivered is that they integrate, for the entire season, the effects of temporal variability. On the other hand, yield data in particular suffer from the problem, previously noted, of being affected by many additional factors besides water flow and quality. Weather and pest conditions are perhaps the most obvious of these factors, although use of inputs and other agricultural practices are also of considerable importance. Another of these factors is the quality of the performance of the application subsystem.

Thus, in certain cases a measure of yield or water shortage might represent a cost-effective proxy for the output of the distribution subsystem. But water shortage indices have been developed principally for rice and are far more cumbersome when applied to dry-footed crops. And in order to use yield data to draw valid conclusions about irrigation performance at the interface between the distribution and application subsystems, it is necessary to correct for the effects of the various confounding variables such as weather and levels of other input use. Unfortunately, complete correction for all of the confounding variables is never possible, and so judgments regarding indicator selection must be made on a case-by-case basis, considering tradeoffs among data availability, precision, accuracy, cost, and purpose. Where these considerations permit, direct measurements of water flows and quality are generally preferable to indirect ones.

It is beyond the scope of this paper to deal in depth with alternative formulations of direct and indirect output measures of irrigation performance at the interface between the distribution and application subsystems; however, these will be the primary subject of a subsequent paper in this series.

SOURCES OF STANDARDS

Performance standards are the criteria against which the data on any particular performance measure can be compared to allow formulation of normative statements about aspects of performance. As indicated in Table 1, II.D, these standards may be derived from sources either internal or external to the irrigation system, or they may be based on measured levels of performance of other systems, in which case they represent a relative basis for the evaluation of performance.

In situations where the top management of an irrigation operating agency initiates a performance evaluation, the same top management very well may establish the performance standards to be used, although external or relative standards could also be adopted. If an external agency initiates the performance assessment, external or relative standards are much more likely to be imposed.

Although internal standards may sometimes be appropriate for assessments undertaken to monitor operational performance, they have limited use in other situations, such as intervention assessments and accountability assessments. This is particularly the case with accountability assessments, where there is often a desire to make comparisons of performance among systems. When internal standards of performance are used, comparisons among systems are generally not meaningful (Hannan and Freeman 1979). There is no way of knowing whether achievement of, say, 85 percent of the goal set in one system makes that system's performance better or worse than the performance of another system, which achieved 95 percent of its own, perhaps less demanding, goal.

To make comparisons among systems it is necessary to use either external or relative standards of performance. In both cases the validity of the comparison depends on the similarity of the systems in various key respects, since otherwise the use of the standards can easily lead to inappropriate interpretations. It is therefore important to identify those features of irrigation systems that permit them to be classified into categories within which the systems are reasonably comparable.

When comparisons are based on external standards, the establishment of the standard is critical. For irrigation systems built with government funds or subject to government support there will often be, at some relatively high level in the government, an agency or group of people with a mandated concern about the performance of the systems. Standards derived from this group's criteria and values should apply to all the irrigation systems that it oversees. In the absence of such an agency, the establishment of external standards for comparative purposes is more arbitrary. In the case of intranational comparisons, it is desirable that these standards be developed with reference to some set of values in society that is relevant to all the systems being compared.

TIME DIMENSION OF ASSESSMENT

The time scale for the analysis of irrigation performance is an important consideration because of both the year-to-year variability in conditions and the possibility for conflict between short-term performance and the sustainability of the irrigation system over the longer term (Table 1, II.E).

Irrigation systems are subject to stochastic fluctuations in the supply and demand for irrigation water.[15] Performance in periods of relatively abundant water supplies may not be indicative of performance in periods of severe shortage. To complicate the analysis, different systems may elect to follow different strategies to deal with these fluctuations. For example, an irrigation system might be structured so that it can respond rapidly and effectively to a drought by increasing the intensity of management control over the flow of water. An evaluation of performance in a drought year might result in a very high rating for this irrigation system. But the utility of the system's structure would be less apparent during years of normal water conditions.[16]

For irrigation systems, two important possibilities exist for conflicts between short- and long-term performance. First, the physical facilities for water distribution may not be maintained in a manner consistent with their sustained operation. Second, operational procedures may lead to harmful physical changes in the system, the most notable ones being waterlogging and salinization of the irrigated land. Only by explicitly incorporating time into the analysis can an evaluation of irrigation performance take into account the possibility of short-term performance being achieved at the expense of the long-term sustainability of the irrigation system.

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[15] Both types of fluctuations depend greatly on rainfall variability, although in the case of supply, the relationship may be indirect and include complex time lag structures.

[16] In such years the operating agency might appear to be overstaffed. An evaluation concerned with operating costs (that is, with the efficiency of the system's internal operation processes) could easily conclude that the system's performance was below a desirable standard.

4. SUMMARY

In this paper we have first presented a conceptual framework designed to give an overall perspective on alternative approaches to irrigation system performance assessment. The framework, which is summarized in Table 1, offers a basis for understanding the purposes, strengths, and limitations of the many different approaches to assessing performance. No single assessment of irrigation performance could involve all the facets identified in this paper. But the framework makes it possible to relate any particular assessment of irrigation performance to the broader "universe" of performance assessments, thereby placing it in a more meaningful context. By making explicit the choices involved in selecting a particular type of performance assessment from among the wide range of alternatives, the framework can facilitate sound planning of performance evaluations, and sound interpretations of their results. We hope that it will also be useful in reducing the potential for confusion resulting from the comparison of incommensurate assessments and measures.

Having presented the conceptual framework, we then apply the broad concepts developed to the problem of assessing the quality of irrigation service to farm fields. In doing this we highlighted a critically important and neglected class of performance assessments. Its characteristics can be summarized in terms of the framework (Table 1) by noting that the focus of such an assessment is limited to the acquisition and distribution subsystems of the irrigation system; that it includes only the functional irrigation processes of operation, maintenance, and support; that it involves physically based geographic boundaries reflecting either irrigated area or service area; that it is based on a goal-oriented model of performance; and that, regarding the level of assessment, it is limited to performance measures that assess irrigation system outputs.

This is a particularly important class of performance assessment for several reasons. To farmers, the pattern of irrigation flows at this point represents the resource available to them as they undertake the task of converting these flows into a productive agricultural input stored in the root zone of their fields. For irrigation agencies, day-to-day operating decisions affecting the acquisition and distribution of water are aimed at making water deliveries to farm fields. Since this is the last point at which these agencies can have influence over the water, assessments at this point provide a basis for comparing desired and actual results. For those concerned with a broader analysis of the impact of irrigation on agricultural production, assessments at this point provide information that is critical to a rigorous and analytic approach to an analysis of these effects.

GLOSSARY

Accountability assessment	Undertaken to provide information with which to judge the activities of those responsible for a system's performance.
Achievement measures	Focus on specified accomplishments while ignoring the resources used in producing those accomplishments.
Acquisition subsystem	The physical and social elements associated with the capture of water from its source.
Application subsystem	The physical and social elements involved in applying water to the soil.
Design area	The area that a system was intended to serve at the time plans for it were developed.
Direct measures	Quantify the variable of interest directly.
Distribution subsystem	The physical and social elements associated with the movement of water in concentrated streams from the source to the edge of a field on which it is to be applied. In large systems, this subsystem typically incorporates many different social elements, including both personnel of an irrigation agency and irrigators.
Effects	Impacts further removed from the immediate outputs of an irrigation system and more geographically dispersed than outcomes—changes in the welfare of rural people, for example.
Efficiency measures	Consider simultaneously both achievement and the amount of resources used, usually expressed as a ratio of the magnitude of the achievement divided by the magnitude of the resource used.
External standards	Standards derived from sources outside an organization, such as technical standards or those derived from political, economic, or ethical sources.
Goal-oriented model	A performance model emphasizing assessment of effectiveness according to the degree to which a system attains the goals that have been established for it.

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Impact measures	Evaluate the effects of the system's outputs on the larger environment.
Indirect measures	Serve as proxies for direct measures in situations where data on the direct measure are unavailable.
Institutions	Rules governing social behavior and defining relationships among the actors in the irrigation system. Institutions, as rules, indicate expectations about social behavior.
Internal standards	Standards established within an organization. In bureaucratic organizations, the internal standards often reflect the managers' operational goals.
Intervention assessment	Undertaken to provide information useful in designing and implementing activities to improve some aspect of a system's performance.
Irrigation system	A set of physical and social elements employed (1) to acquire water from a naturally concentrated source (such as a natural channel, depression, drainageway, or aquifer); (2) to facilitate and control the movement of the water from this source to fields or other areas devoted to the production of agricultural crops or other desirable plants; and (3) to disperse the water into the root zone of these areas.
Irrigation	Human intervention to modify the spatial or temporal distribution of water occurring in natural channels, depressions, drainage ways, or aquifers and to manipulate all or part of this water to improve production of agricultural crops or to enhance growth of other desirable plants.
Maintenance	Periodic and recurrent activities designed to sustain the long-term capability of the facilities to deliver water.
Natural system model	A performance model that defines effectiveness in terms of the extent to which it is able to produce the amount and type of outputs necessary to ensure the acquisition of inputs for its continued existence and expansion. This model places primary emphasis on a system's ability to obtain inputs, rather than on either its outputs or impacts.
Net irrigated area	The area actually supplied with water once an irrigation scheme is operational.

Operation	The recurrent activities necessary to capture, allocate, and deliver water to the fields of irrigators.
Operational performance monitoring	Designed to provide, to those who have management responsibility for a system, information that can be used in making daily operational decisions.
Outcomes	Impacts that are closely related, spatially and temporally, to the immediate outputs of an irrigation system — changes in agricultural production, for example.
Output measures	Assess the quantity and quality of the system's final outputs.
Performance	A system's effectiveness in carrying out its internal activities — acquisition of inputs and the transformation of inputs into intermediate and final outputs — and the effects of these activities on the system itself and on its external environment.
Process measures	Assess a system's internal operations and procedures in the creation of intermediate and final outputs.
Relative standards	Standards derived from the performance of other similar systems.
Role	A set of expectations and tasks associated with a particular function. Individuals involved in irrigation play many roles simultaneously, but only those roles that are directly related to irrigation are relevant to discussions of irrigation and irrigation performance.
Service area	The area provided with water distribution facilities at the time of scheme construction.
Social structure	Actual patterns of behavior, usually differing in some degree from expectations.
Support	A variety of recurrent activities that permit and facilitate the execution of the other irrigation processes. Support activities include personnel management, equipment acquisition and management, financial management and accounting, and resource mobilization.
Sustainability assessment	A variant of the intervention assessment, this type of assessment addresses performance over longer time periods and is also concerned with unintended consequences of irrigation activities.

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