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IRRIGATION MANAGEMENT NETWORK

THE GOVERNANCE AND MANAGEMENT OF IRRIGATION SYSTEMS
An institutional perspective

Shui Yan Tang and Elinor Ostrom

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by

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Shui Yan Tang and Elinor Ostrom

Introduction

During the past three decades, massive resources have been invested by donor agencies and developing countries in technologically sophisticated, large-scale irrigation projects. Even though the planning processes for these projects rely on modern benefit-cost analysis, many projects that looked outstanding on paper have not fared well "on the ground." Costs have usually been higher than expected, and benefits have been lower. Cost recovery has often not proved feasible.

Widespread recognition of these failures has led to repeated calls for farmers' participation in the management of irrigation projects (Cernea, 1985; Asian Development Bank, 1973; Uphoff, 1986). Our own theoretical and empirical work leads us to agree with the recommendations to involve farmers in the day-to-day management of irrigation systems (E. Ostrom, Shroeder and Wynne, 1993). Our prior work also leads us to argue that "participation in management is not enough." In addition to participation in the management of irrigation systems, farmers have an important role to play in the governance of these systems.

By governance of an irrigation system we refer to the establishment of specific working rules used to allocate water, to assign responsibilities for labor and monetary resource mobilization, to resolve conflicts, to record certain information and to make that information public, to select and pay officials and workers, and to sanction non-conformance with these rules. Governance processes involve the crafting of rules as well as the choosing of officials to make day-to-day policy and operational decisions. Management involves individuals making decisions at the operational level, within constraints set by governance structures. Since operational decisions are made within constraints defined by governance structures, management will be ineffective unless well-designed governance structures are in place. A governance structure will be ineffective unless it helps participants formulate rules that meet the needs of farmers, detect and sanction rule violations, and hold officials accountable for their performance.

Efforts to involve farmer participation have frequently produced disappointing results because government officials have not understood the importance of fanners' roles in governance itself. Developing farmer organizations have too often consisted of central officials designing the "blueprint" for how fanners will organize themselves. In some projects, officials have ignored preexisting irrigation associations and have recognized only the farmer organizations they mandated. In other projects where efforts have been made to organize farmers, farmers meet and elect the officials they are requested to elect, but any further organization is thwarted. The failure of these projects to achieve predicted benefits is blamed on the fanners themselves rather than on engineering design or on the lack of effective institutional development.

Nirmal Sengupta (1991) provides a cogent example of the "misplaced emphasis" of imposing a pre-established organizational form on an already functioning, informal farmers' organization in Tanrwan village served by the Sone canal system in Bihar, India. Prior to the establishment of a Command Area Development Program with an objective of demonstrating the advantages of "on-farm development" (OFD), the farmers living in Tanrwan had already established ways to repair channels twice a year and to patrol the higher reaches of their distributary to prevent illegal diversions of water. Part of the official program was to establish formal irrigation associations. The The Tanrwan Chak Society was created by the Sone Command Area Development Agency in 1978. An outsider examining the formal records would find bylaws that closely follow the 42-clause long Model Bylaws. But the way that farmers in this village regularly relate to the governance and management of the irrigation works on which they depend does not conform in any meaningful way to these bylaws. What is particularly tragic about the Tanrwan Chak Society case described by Sengupta is that the farmers were willing to organize themselves to accomplish several major group projects and in many respects achieved remarkable results. But the farmers were required by the Agency to line 3.1 kilometers of irrigation channel with bricks provided by the agency and to adopt an official rotation system that was not well-suited to their local terrain or soil conditions. The rotation system never worked well given that the officials themselves were not motivated to release water on schedule. Further, illegal diversions made higher in the system generated highly unreliable water deliveries.

The farmers wanted to line the canals in a conservative manner by waiting until the earth had settled. The Agency interpreted the resultant delay as both a lack of cooperation and a potential misuse of the supplies provided. The leader of the Chak Society was later accused of embezzling materials even though no procedures were established for keeping records by the Agency or by the Society. Thus there was no way of establishing who, if anyone, obtained supplies improperly. After several decades of mismatched expectations, the "once enthusiastic organizer, has lost all enthusiasm and has become extremely guarded in his dealings" (Sengupta, 1991: 245). Unresolved conflicts among the farmers have reduced their overall level of cooperation below what it was prior to the creation of the Chak Society[1]. So long as farmer participation is interpreted as supplying needed labor and following the rules laid down by others, similar experiences will occur elsewhere as well. Farmers who are willing to work and cooperate with one another for their mutual benefit will be left worse off after efforts to "organize" them have occurred than before the "help" was offered.

Encouraging farmer participation in the management of irrigation projects will produce poor results unless effective institutional arrangements exist to structure the governance and management processes of irrigation projects. In this article, we discuss the concept of institutions and the distinction between the governance and management processes related to irrigation systems. This distinction enables us to understand ways to integrate effective farmer participation with institutional development. We also examine patterns of institutional arrangements found in an analysis of 47 case studies of irrigation systems from many countries to illustrate the relationships between institutional arrangements and performance of irrigation systems.

Institutions as Rules-In-Use

In the social science literature the term "institution" is used to refer to many concepts. It can refer to a specific organization, such as a particular Department of Irrigation; it can describe certain established human relationships, such as the family; or it can denote the rules that individuals use to order specific relationships with one another. We *use* the term

[1] For further debate about Command Area Development Agencies in India and whether these new support initiatives should be state agencies and NGOs and whether they can lead to better performance, see Raja, 1992; Sivaraohan and Scott, 1992; comments by Rakesh Hooja and C Dan Bithu in the current Newsletter (June 1993).

"institution" in this last sense: an institution is the rules actually used (rules-in-use or working rules) by a set of individuals to organize repetitive activities that produce outcomes affecting those individuals and potentially affecting others (E. Ostrom, 1990). Hence, an irrigation institution is the set of working rules for supplying and using irrigation water in a particular location.

Working rules are used to determine who is eligible to make decisions in some arena, what actions are allowed or constrained, what procedures must be followed, what information must or must not; be provided, and what costs and payoffs will be assigned to individuals as a result of their actions (E. Ostrom, 1986). All rules contain prescriptions that forbid, permit, or require some action or outcome. Working rules are those actually used, monitored, and enforced when individuals make choices in operational or collective-choice settings (Commons, 1957).

Institutions shape the pattern of human interactions and their results. Institutions shape human behavior through their impact on incentives. For instance, rules determining access rights affect the perceived costs various individuals pay for the use of water from an irrigation system. Depending on how well access rights are enforced and penalties imposed for illegal diversions, those without access rights may consider the costs of breaking access rules sufficiently high that they refrain from efforts to take water.

Changes in formal regulations, however, do not automatically change rules-in-use and thus incentives. A new regulation increasing the penalty for stealing water may even produce different changes in incentives than presumed: officials may use the threat of heavy fines to extract bribes from errant fanners. Consequently, the rule-in-use may change so that diversions considered illegal under formal regulations may continue in practice so long as payments are made to corrupt officials. Thus, the incentives facing individuals cannot be determined by reading promulgated laws and regulations without examining how they fit into the physical, economic, and social context of a particular system. To actually use a set of rules, farmers must know these rules, consider them legitimate, and be willing to follow them so long as many others are following them.

Developing Irrigation Institutions

Developing irrigation institutions is a long-term process that requires the investment of resources and extensive trial and error. It often takes years

and extensive efforts to develop and eventually to benefit from a set of functioning institutional arrangements. Developing an appropriate set of water allocation rules, for example, requires careful experimentation and fine adjustments. Large government agencies may be able to develop uniform rules that deal with those common problems that are shared by many fanners. Yet a great diversity of working rules is needed to tackle various context-specific problems that occur on specific branches of a large system.

Generating variety in institutional arrangements is important for resolving diverse problems farmers encounter in different locations. This requires considerable investment of time and resources in learning about the effects of various institutional rules on the behavior of participants and the results they can achieve. Thus, the choice of institutions is not a "one-shot" decision in a known environment, but rather an ongoing investment process in an uncertain environment.

When investments of any type are involved, two levels of analysis are required. First, an analyst needs to understand what is happening at an operational level, where individuals attempt to do as well as they can within existing constraints. Second, an analyst needs to consider what options are available to change the existing physical and institutional constraints. Considering these changes is like shifting to a "time-out" during the play of a game to reconsider the rules of the game itself. This type of shift happens when the suppliers of an irrigation project consider installing a new type of control gate or when farmers consider new rules for water allocation.

It is useful to distinguish three layers of rules that cumulatively affect the actions and outcomes achieved in irrigation systems (Kiser and E. Ostrom, 1982).

Operational rules directly affect the day-to-day decisions made by users and suppliers concerning when, where, and how to withdraw water; who should monitor the actions of others and how; what information must be exchanged or withheld; and what rewards or sanctions will be assigned to different combinations of actions and outcomes. The processes of allocating water, clearing canals, and monitoring and sanctioning the actions of irrigators and officials occur at the operational level.

Collective-choice rules indirectly affect operational choices. These are the rules used by irrigators, their officials, or external authorities in making policies - the operational rules - about how an irrigation system should be managed. Policy-making, management, and adjudication of policy decisions occur at the collective-choice level. A change in "policy" implies a change in operational rules. Constitutional-choice rules affect operational activities and results through their effect on: (1) who is eligible to participate in the system and (2) what specific rules will be used to craft the set of collective-choice rules, which in turn affect the set of operational rules (V. Ostrom, 1982). Formulation, governance, adjudication, and modification of constitutional decisions occur at the constitutional level. Constitutional choices may be made by many individuals in an ongoing process of learning and constitutional development. Any self-organizing activity is constituted and reconstituted over time as individuals learn more and more about how past rules have operated in practice.

Rules are changed less frequently than the strategies individuals adopt within rules. Changing rules at any layer increases the uncertainty that individuals face in making strategic choices at that level. Rules provide stability of expectations. Efforts to change rules rapidly reduce that stability. Operational rules are usually easier and less costly to change than collective-choice rules.

Different sets of collective-choice rules and different communities of participants may be involved in collective-choice decisions. Depending on attributes such as the size and the number of users of the irrigation system, different collective-choice entities may be constituted to exercise collective-choice prerogatives on behalf of the users and other concerned parties. Some irrigation systems, for example, are governed solely by a national government agency; operational rules may be created, changed, and enforced according to statutes adopted by the national legislature or executive. The collective-choice entity in this case involves not just one specific community of irrigators but also potential irrigators, interest groups, politicians, government officials, and the general public who share an interest in irrigation and other related activities. In other irrigation systems, the relevant entity is constituted primarily by irrigators who adopt and enforce their own collective-choice and operational rules.

Sometimes, a community of irrigators may be following multiple sets of operational rules adopted by different collective-choice entities. For example, irrigators in large irrigation systems are frequently subject to at least two sets of operational rules adopted by two different collective-choice entities - a collective-choice entity at the system level and another at a sub-

system level. Collective-choice entities at the sub-system level, constituted by farmers themselves, are important for the effective operation and maintenance of large irrigation systems.

While collective-choice entities at a system level can help solve problems that occur on all units and facilitate adaptation to the specific needs of individual units, collective-choice entities at a sub-system level, however, can maintain their autonomy in relation to water allocation and maintenance within their respective areas. By constituting different levels of collective-choice entities to deal with problems of different scales, many coordination and control problems associated with larger irrigation projects can be avoided.

Crafting Operational Rules for Varying Physical and Social Conditions

If local farmers participate in crafting operational rules, system performance is more likely to be enhanced. One reason for this is the vast variety of physical and social conditions that affect the operation of any particular system. For example, what kinds of water allocation and input rules are the most effective and how these rules should be implemented depend on such specific attributes as the soil type, field topography, cropping pattern, and the amount of water available in the specific irrigated area. Frequent, quick, but non-routine decisions have to be made about water allocation and maintenance in response to such changes as the volume of water flow, climate, and the growth stage of plants. In many large irrigation projects, different watercourses vary in these attributes. If there is only one collective-choice entity to create and enforce a uniform set of operational rules for an entire project, it is unlikely that the resulting rules could serve the needs of all watercourses equally well. Local collective-choice entities at the watercourse level, if properly constituted, are likely to facilitate the utilization of specific time and place information (Hayek, 1948) in formulating and enforcing appropriate operational rules and choices.

Further, irrigators are more likely to have incentives to follow and enforce rules adopted by themselves than those handed down from an outside authority. Irrigators can also mobilize such informal mechanisms as social shunning to enforce their own rules, mechanisms unavailable to any external authority. The need to involve local users in crafting operational rules for varying physical and social conditions can be illustrated by examining the patterns of allocation and input rules found in a sample of 47 irrigation systems from around the world (see Appendix for the research method used).

Illustration I: Allocation Rules and Varying Circumstances
Allocation rules stipulate the procedures and bases for water withdrawal. They are important especially when the supply of water is inadequate to meet the crop requirements of all cultivators simultaneously. If proper allocation rules are adopted and effectively enforced, they can reduce uncertainty and conflict among irrigators. Three types of rules - percentage, fixed time slots, and fixed orders - are frequently used for water allocation:

1. *Fixed percentage*: the flow of water is divided into fixed proportions by some physical device.

2. *Fixed time slots*: each individual is assigned fixed time slots during which he or she may withdraw water.

3. *Fixed orders*: individuals take turns to get water.

Among the three types of procedures, fixed *time slots* are the most commonly used: 22 out of 37 cases use *fixed time slots* as the sole distribution procedure. The other 15 cases use *fixed percentage*, *fixed order*, or a combination of procedures. Assigning irrigators fixed time slots may be an economical way of distributing water. If all irrigators know their own time slots, each shows up and diverts water to his or her own plots from certain outlets when his or her time begins. This arrangement is self-enforcing and requires minimal supervision. Problems arise, however, if the water flow is erratic: an irrigator owning a share for a particular time slot is still uncertain about his or her supply.

Dhabi Minor Watercourse, for example, is located in a government-operated irrigation system where irrigators are assigned time slots in different water distribution cycles within a watercourse (Reidinger, 1980). At the system level, water supplies to various watercourses are determined by yet another water distribution cycle within a watercourse. Because of a lack of coordination between distribution cycles at the two levels, an irrigator assigned a particular time slot may fail to get any water if no water is scheduled to flow into the watercourse during the time. Irrigators in Dhabi Minor Watercourse, therefore, face a high degree of uncertainty about their water supplies, which in turn affects their willingness to cooperate in water allocation and maintenance.

A higher percentage of the cases using fixed time slots as the sole distribution procedure is characterized by problems in rule conformance or maintenance than those using other types or combinations of distribution procedures (see Table 1). Distributing water by fixed time slots may require less administrative costs than other distribution procedures. Serious collective-action problems, however, may arise if the procedure is used

Table 1: Rules-conformance/maintenance by allocation rules

	Fixed time slots as the sole distribution procedure	*Other types or combinations of distribution procedures*	*(Total)*
Positive in both Rule-conformance & maintenance	45% (10)	87% (13)	(23)
Negative in either Rule-conformance or maintenance or both	55% (12)	13% (2)	(14)
(Total)	100% (22)	100% (15)	(37)

Percentage difference = 42%
Chi-Square with continuity correction factor = 6.4
D.F. = 1 $P < 0.05$

Source: Tang (1992). This table is adapted from Table 5.4 in Tang (1992). Some numbers in the original table are inaccurate. The present table has corrected the inaccuracies in the original one.

without considering whether it is compatible with other institutional and physical factors. Within the sample, this kind of incompatibility appears to happen mostly in government owned and operated irrigation systems: seven of the thirteen cases that use fixed time slots as the sole distribution procedure and that have problems in rule conformance or maintenance, are governed and managed by an irrigation agency.

Even within one particular irrigation system, more than one set of allocation rules may be used for different occasions. A more restrictive set of allocation rules, for example, is used during certain periods in a year and a less restrictive set is used during other periods. In some irrigation systems, demands for water may temporarily exceed supplies during dry seasons or some growth stages of the crops. Water allocation rules in these irrigation systems may have to be adjusted in the light of changes in the balance between the supply and demand of water. Within the sample, 19 cases are reported to have two sets of allocation rules. All of them, except one, have more restrictive rules when water is scarce than when water is abundant. In some of them, appropriators are permitted to withdraw water freely during periods when water is abundant; some types of turns or time schedules are used when water gets scarce. In some other cases, officials or monitors begin to exercise discretion in setting up time schedules or turns for water allocation when the supply of water decreases.

Different rules may be adopted to coordinate water allocation under various circumstances. Even holding all other conditions constant and allowing only changes in water supplies, as within any one watercourse, allocation rules have to be adjusted from time to time to accommodate various degrees of water scarcity. Imposing a rigid set of allocation rules on a large irrigation system may create more problems than it is intended to solve.

Illustration II: Input Rules and Maintenance Intensity

Input rules prescribe the types and amounts of resources required of each cultivator. A major type of input required of farmers in most irrigation systems is labor for maintenance. Two major types of rules for labor inputs can be identified. One type of rule simply requires equal contribution from all the appropriators. The other requires labor inputs from appropriators roughly in proportion to the benefits each obtains from the resource, for example, proportional to one's share of the resource, to the amount of land cultivated, or to the amount of water needed.

Maintenance intensity appears to be a major factor affecting the choice of labor input rules. Maintenance intensity can be roughly measured by dividing the total number of person-days of labor per year mobilized in an appropriation area to maintain the irrigation system by the total number of irrigators in the appropriation area. Only eleven of the cases report information about both maintenance intensity and labor input rules for maintenance. For the seven cases that require equal labor contribution, the average maintenance intensity is 2.3 days per person per year. For the four that require proportional labor contribution, the average is 17.7 days per person per year. One possible inference from this limited amount of information is that systems with a higher maintenance intensity tend to adopt the proportional rule for labor inputs, while systems with lower maintenance intensity tend to adopt the equal-contribution rule.

Administrative costs appear to be a factor that makes equal-contribution rules a better choice than proportional rules in some circumstances. In order to enforce the proportional rule, resources have to be expended in counting, recording, and organizing various contributions from different appropriators. For systems that require only two or three days of work from each irrigator every year, the potential benefits of proportional rules could easily be offset by the costs for implementing the proportional rules. Whereas for systems with higher maintenance intensity, the gain from the proportional rules may be higher than the administrative costs.

This argument is supported by the emergency labor rules found in the sample of cases. In eight of the fifteen cases where information is available, equal contribution rules are used for emergency labor inputs. These resources are all located in steep terrain. The water distribution system can be destroyed easily by sudden increases in water flow in rainy or stormy weather. Speedy repair is needed to ensure the continual functioning of the entire system. By using equal contribution rules, labor can be mobilized rapidly. The prospect of losing the entire irrigation system can be a sufficient incentive for the cultivators to participate in the joint endeavor.

Crafting Operational Rules in Ongoing Processes

The patterns of allocation and input rules described above illustrate the need to craft operational rules to suit specific physical and social environments (see E. Ostrom, 1992). No single set of operational rules will fit all circumstances (Coward, 1980a; Uphoff, 1986). More important than searching for the "one-best" operational arrangement is involving irrigators in the ongoing process of crafting rules to deal with varying problems that they know about with some precision.

Crafting operational rules is a continuing process due to the complex task of devising rules to match the unique combinations of variables that are present on any one system, as well as to adapt to changes in many of these variables over time. The system is never really stable. Not only are climatic conditions variable, but physical systems tend to "wear out." In the case of an irrigation system, dams and canals silt-up, control structures break down, and underlying strata give way. If effective institutions are in place, considerable efforts can be devoted to counteract physical deterioration.

It is necessary to stress the ongoing nature of the process of crafting institutions since it is so frequently described, if at all, as a one-shot effort to organize the farmers. Rather, those who are directly involved with the flow characteristics of a particular system, the economic conditions of a locality, and the values and norms of the users must have continuing authority to craft at least some of the rules that impinge most directly on that system.

Crafting Governance Structures

Governance structures refer to the collective-choice rules that stipulate the terms and conditions for formulating, modifying, and enforcing operational rules. A set of collective-choice rules will be effective only if it can help those involved to formulate rules that meet the needs of fanners and officials, to detect and sanction against rule violations, and to hold officials accountable for their performance. Several collective-choice arrangements facilitate these processes. First, irrigators' direct involvement in making major collective decisions in water allocation and maintenance helps to ensure that the decisions meet the needs of farmers. Second, individuals will have little incentive to comply with a set of rules unless they believe that their non-compliance will be noticed and, if continued, will result in substantial loss. To enforce operational rules, it is necessary to develop mechanisms that are capable of detecting and sanctioning against rule non-compliance.

Officials vested with special authority are in a position to abuse their powers by interpreting rules to their own advantage or to demand favors from individual irrigators. Third, to hold irrigation officials accountable, rules are needed that stipulate how officials are selected and removed, to whom they have to report, and how they are compensated for their services.

Within the sample of cases discussed above, the collective-choice entities in most of the cases that describe "community irrigation systems" are characterized by governance structures with these three features: (1) the direct involvement of irrigators, (2) effective monitoring and sanctioning, and (3) holding officials accountable. Cases that describe systems governed and managed by government agencies are rarely characterized by these three features. We now focus somewhat more specifically on the difference in the governance structures of community irrigation systems and government irrigation systems.

Community Irrigation Systems

Collective-choice arrangements are present in 21 of the community cases in the sample. Ten of these cases are governed by irrigators' associations that are responsible only for activities related to the irrigation systems. In nine other cases, some village-wide or communal organizations that have other responsibilities besides irrigation are responsible for governing the irrigation systems.

In most of the community systems, major collective decisions are made in general meetings that involve most irrigators. In Thulo Kulo and Raj Kulo in Nepal, for example, general meetings for the entire membership of the irrigators' organizations are held in mid-May (Martin and Yoder, 1986). At the meetings, plans for major annual maintenance are drawn, new officials are elected if necessary, and operational rules for the coming season are reviewed and amended if needed. In Raj Kulo, the accounts of the organization are also presented and reviewed in the meetings. In both systems, other general meetings may be held throughout the year whenever major decisions concerning the operation of the system have to be made. General meetings are considered a major event in most of the community irrigation systems. In Oaig-Daya in the Philippines (de los Reyes, 1980), farmers are even required to pay a fine for being absent from a general meeting.

Specialized officials or monitors are appointed to enforce operational rules in most of the community systems. In Calaoaan in the Philippines (de los Reyes, 1980), for example, the chairman and the board members of the irrigators' association are responsible for organizing maintenance works. In Nabagram in Bangladesh (Coward and Badaruddin, 1979), water is distributed successively from one block to another during the post-planting period. A water distributor is employed to determine when an individual plot has received an adequate supply of water and to divert the water flow from one plot to another. By taking the water allocation process out of the hands of individual irrigators, the chance of rule violations is reduced. Provided that the water distributor is held accountable to irrigators, his service helps to reduce the chance of rule violations.

The chief executives in most of these collective-choice entities are selected through direct or indirect elections by irrigators. The periods that the chief executives serve, however, vary from case to case. In some of the cases, officials are subject to reelection periodically. In Silean Banua (de los Reyes, 1980), for example, the six officers on the board of directors are subject to re-election every two years. In other cases, officials can serve an indefinite period of time, subject to a vote of non-confidence by members.

The chief executives are compensated in most of the cases. Some of the commonly used compensations for irrigation officials in these cases include: reduced labor obligations; reduced membership dues; and fines or direct payments, in the form of cash or agricultural products, by irrigators. In return for their services, the irrigation headmen in Chiangmai in Thailand (Potter, 1976), for example, are excused from paying taxes on certain amounts of land, they do not have to contribute labor for maintenance, and they can keep some of the fines levied.

There are, however, a few exceptions where officials are not paid. In Diaz Ordaz Tramo in Mexico (Downing, 1974), officials have to perform various duties including the organization of water allocation, maintenance, and conflict resolution. For these duties, the officials receive no compensation and little praise. Every landholder within the appropriation area, however, is obliged to occupy the positions through rotation; each has to take an office for one year. In Cadchog and Calaoaan in the Philippines (de los Reyes, 1980), irrigation leaders are not compensated for their duties. Their own interests in the irrigation systems may have been a sufficient incentive for them to help govern the systems.

As a whole, the governance structures in most of the community irrigation systems appear to involve farmers in making major collective decisions, to spend substantial resources in enforcing operational rules, and to hold leaders accountable to fanners.

Bureaucratic Irrigation Systems

In a bureaucratic irrigation system, the headworks are governed by national or regional government agencies. In some irrigation projects, the same agencies may govern the entire system down to the watercourse level. In others, different collective-choice entities, such as irrigators' associations, are involved in governing activities at the distributary and watercourse levels. In six of the bureaucratic cases in the sample, the entire systems are governed solely by government agencies. In the other eight cases, the watercourses are governed by both government agencies and local collective-choice entities constituted by irrigators.

The governance structure of most government agencies in the sample appear to be unfavorable to rule formulation, rule enforcement, or holding officials accountable to irrigators. The major financial source of all these agencies, with the exception of one in Taiwan, comes from government allocation. Since these agencies and their officials are not financially dependent on irrigators, officials in these agencies are usually not as motivated to serve irrigators as their counterparts in irrigators' organizations. In all the cases, officials who are responsible for making major operating decisions concerning various watercourses are not irrigators themselves but full-time employees of government agencies. Instead of reporting to irrigators, these officials report to a higher authority within or outside their agencies. Local "water guards" or water operators responsible for local water provision often play a vital role or interface in translating information both ways, diffusing local tensions and helping irrigators arrange informal flexible scheduling where formal operational rules are inappropriate and difficult to change. Good examples of the role of such local officials come from the El Operado scheme in Western, Mexico (van der Zaag, 1992) and the Gezira scheme in Sudan (El Tom and Osman, 1989).

The Provincial Irrigation Department that governs Gondalpur Watercourse in Pakistan (Merrey and Wolf, 1986), for example, receives funding for recurrent and operational expenditures through allocations by the Provincial Finance Department. The allocations are based on the physical characteristics and inventory of the irrigation facilities. The Irrigation Department receives a fixed amount of funding per year for each kilometer of canal that exceeds a certain discharge capacity. The basis for budget allocations is rigidly fixed and often based on formulae that were established decades ago. The day-to-day field work of the Department is carried out under the direction of the Executive Engineer at the Divisional level who is responsible for thousands of hectares of farmland. The supply of water to various watercourses is decided by the Executive Engineer whose decisions are based primarily on instructions from headquarters and the available water supply in the main river, and not the conditions and demands in the command area. The Irrigation Department as a whole "can be fiscally accountable and fully responsible in [its] work and yet have minimal interaction with farmers, who often feel that the irrigation service they receive is not satisfactory" (Merrey and Wolf, 1986: 10).

In most of the bureaucratic cases, officials who make major decisions for watercourses reside in places far away from the watercourses they serve. These officials develop little identification with the interests of the local communities and have little incentive to be actively involved in solving farmers' problems. Their distance from the watercourse also prevents them from acquiring timely and accurate information about different needs of various watercourses. In all but two cases, government officials do not convene any general meetings with irrigators. Irrigators themselves usually have few formal channels to articulate their interests and grievances to officials.

Complex, bureaucratic irrigation systems that are governed solely by government agencies are unlikely to solve all water allocation and maintenance problems at the watercourse level. Within the sample, all six cases that are governed solely by government agencies are characterized both by a low degree of rule conformance and poor maintenance. In these cases, operational rules handed down from government agencies often turn out to be incompatible with the special circumstances of individual watercourses.

In some of these bureaucratic irrigation systems, even though local farmers are unable to develop their own collective-choice arrangements, they have developed "extra-legal" rules to suit their own circumstances. Examples of the difference between informal, farmer-established rotations and formal rotations established by the Irrigation Department are seen in the Gondalpur Watercourse.

> *. . . unlike the formal rotation, the informal rotation takes into consideration local conditions such as the sandiness of soils and the height of the field relative to the ditch. Thus, a sandy or high field is awarded extra time to ensure it can be irrigated. More time is also allowed for filling long sections of the watercourse (Merrey and Wolf, 1986: 46).*

The effectiveness of operational rules depends on local circumstances. Involving cultivators in the formulation and enforcement of operational rules at the watercourse level facilitates adaptation to the specific needs of different areas within a larger irrigation system. In some of the bureaucratic cases, local appropriators have adopted and enforced their own operational rules at the watercourse level. Complex, bureaucratic cases with local irrigators' organizations usually perform better than those without because operational rules developed and enforced by local collective-choice entities are usually more effective in meeting the needs of farmers. Among the bureaucratic cases in the sample, a higher percentage of those with local collective-choice entities is characterized by a high degree of rule conformance and adequate maintenance than those without (see Table 2).

Table 2: Rule-confonnance/maintenance by Local Collective-Choice Entity ii» bureaucratic cases

	With Local Collective-choice Entity	*Without Local Collective-choice Entity*	*(Total)*
Positive in both Rule-conformancc & maintenance	**75%** **(6)**	**0%** **(0)**	**(6)**
Negative in either Rule-conformance or maintenance or both	**25%** **(2)**	**100%** **(6)**	**(8)**
(Total)	**100%** **(8)**	**100%** **(6)**	**(14)**

Percentage difference = 75%
Chi-Square with continuity correction factor = 5.1
D.F. = 1 P < 0.05

Source: **Tang (1992).**

Local collective-choice rules in the bureaucratic cases are very similar to the ones found in community irrigation systems. Most of the local organizations in the bureaucratic cases involve their members in making major collective decisions. Specialized officials or monitors are appointed by irrigators to enforce operational rules within the watercourse. Executives are selected by irrigators.

Despite these similarities, however, one should avoid making any unqualified analogy between irrigators' organizations in community irrigation systems and those within bureaucratic irrigation systems (Hunt, 1989). Irrigators' organizations in community irrigation systems are self-contained entities, while those in bureaucratic systems are embedded in a larger organizational structure. Irrigators' organizations in bureaucratic irrigation systems will be unsuccessful if irrigators fail to perceive a need for them to organize or if they lack the freedom to govern and manage the day-to-day activities within their irrigated area.

Amphoe Choke Chai, for instance, is an irrigators' organization established under the auspices of the Royal Irrigation Department of Thailand to help govern two water zones within the Lam Pra Plerng Irrigation Project (Gillespie, 1975). Even with the encouragement of the government agency, the irrigators' organization has been unsuccessful in attracting members and organizing water allocation and maintenance activities. This is because farmers are able to receive sufficient water from the natural flooding of rivers and are not motivated to operate and maintain the canal networks that belong to the irrigation project.

This case is contrasted with Kaset Samakee, located near the head end of the same irrigation project. The water zone of Kaset Samakee has a reliable supply of water but no alternative source of water. The soil in the zone is porous in nature. To minimize water loss through seepage, water needs to be distributed quickly. Silt and weeds also need to be removed regularly to facilitate the flow of water in the ditches. Because of these physical features and the farmers' dependency on the water from the project, most farmers in the zone follow water allocation schedules and participate in maintaining ditches in the zone.

Kottapalle in India, as described by Wade (1988), is an example where fanners have been able to constitute their own collective-choice arrangements and to enforce their own rules governing their investments. The government agencies responsible for the irrigation system neither support nor interfere with the activities of the fanners' organization. Most of the officials are even unaware of the organization's existence. Members of the organization, therefore, have a free hand in developing and enforcing their own governance and management arrangements. This, together with the need for cooperation in water allocation, enables fanners to sustain their own governance structure.

Further, the irrigators' organization in Kottapalle also performs an important function by helping to secure water supplies to the community. When the water supply is scarce, leaders of the organization may organize to collect resources from members to lobby officials for more water supplies. Employees of the farmers' organization also help to ensure that the water flow to their community is not blocked by upstream communities.

Similar functions are also performed by the irrigators' association of Sananeri Tank in Sri Lanka (Meinzen-Dick, 1984). In that association, the president expends considerable efforts in obtaining more water issues to their water tank from the Public Works Department. These efforts benefit all irrigators in the watercourse and motivate irrigators to support their association.

In other cases, such as Nam Tan Watercourse (Coward, 1980b) and El Mujarilin (Fernea, 1970), government officials and local leaders cooperate in governing a watercourse. In El Mujarilin, for example, an official representing the Ministry of the Interior is responsible for hearing complaints between irrigators. However, unless the dispute involves a clear infraction of the civil code, the official routinely refers the case back to the leader of the local tribe or other tribesman whom the petitioners might choose. This practice allows the traditional tribal organization to remain a viable instrument for resolving conflicts among irrigators.

Fanners will have incentives to participate in governing an irrigation project only if they perceive that the benefits they obtain from their participation exceed the costs of the resources they devote to it. In the cases where irrigators' organizations perform relatively effectively, the organizations are able to secure extra benefits for the community of irrigators. Members of these organizations are also relatively free to develop their own governance and management processes that directly affect their own welfare.

Conclusion and Implications

During the past few decades, increased agricultural production in developing countries has resulted from massive investments in large-scale irrigation projects, in addition to investments in new agricultural inputs and technologies. The least expensive sites for irrigation development, however, have already been developed in most developing countries. The costs of new investments in large-scale projects tend to rise faster than farm produce prices. Thus, the rate of new irrigation water made available to farmers from new, large-scale projects will slow considerably. The key to increase agricultural production in the future is the improvement of existing irrigation systems.

While the operation of existing irrigation systems can be improved from better physical structures and technologies, the key problem concerns the incentives facing officials and farmers. If these individuals are not motivated to operate and maintain irrigation systems effectively, large-scale irrigation projects will continue to perform ineffectively. Over the next several decades, the most important consideration in irrigation development will be integrating farmers' participation with effective institutional development. While irrigators' organizations can potentially play an important role in the operation and maintenance of large-scale irrigation projects, these organizations may not always be successful. It is important to involve farmers themselves in crafting their own operational and collective-choice rules. Unless farmers have the freedom to participate in both the governance and management processes of their irrigation system, they will be uncertain about the returns of their efforts. Without considerable confidence about their ability to affect outcomes, farmers will have little incentive to participate in collective efforts in operation and maintenance.

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Appendix

Comparing irrigation systems requires a consistent way of identifying their boundaries. One way of conceptualizing such boundaries is to consider the four stages of the water delivery processes: production, distribution, appropriation, and use (see Plott and Meyer, 1975). Water is produced, for example, by damming a river. The dam is the *production resource* of the irrigation system. From the production resource, water may be distributed through a canal to the irrigated area; the canal is the *distribution resource.* In the irrigated area, water may be appropriated from the local ditches, tanks, or pumps; these physical structures are the *appropriation resource.* The water appropriated is then used to irrigate crops in the fields; the fields and crops together constitute the *use resource.*

With this distinction among production, distribution, and appropriation resources, two kinds of irrigation systems can be identified. In a simple system, the production and distribution resources supply water to only one appropriation area. In a complex system, the production and distribution resources deliver water to multiple appropriation areas. This study analyzes activities and attributes related to the entire appropriation resource of a simple system and selected appropriation areas (i.e., watercourses) within a complex system.

The data for this study were collected as part of a research project on common-pool resources including fisheries, forests, grazing land, groundwater basins, and irrigation systems conducted by the Workshop in Political Theory and Policy Analysis at Indiana University. Members of the research project have developed a series of coding forms, containing mostly closed-ended questions, to capture key physical, community, and institutional attributes of common-pool resources. These forms were used to code data provided by in-depth case studies.

Extensive efforts have been undertaken by members of the project to identify empirical studies of irrigation systems. Over 1,000 items, including books, dissertations, journal articles, monographs, and occasional papers have been identified in the area of water resources and irrigation (Martin, 1989). Over 500 documents have been collected by the research project on irrigation. Cases were selected from these documents for coding only if they contain detailed information about: (1) participants in the resource, (2) strategies used by participants, (3) the condition of the resource, and (4) rules-in-use for the resource. Cases were also selected in such a way as to include in the sample as much diversity in terms of physical, community, and institutional attributes, and collective outcomes as possible.

The sample of cases used in this study consists of 47 cases: 29 community systems that are governed entirely by irrigators; 14 bureaucratic systems whose production resources are governed by a national or regional government agency or enterprise; and 4 other systems whose production resources are governed by local governments. Twenty-nine of the cases are simple systems; 18 are complex ones. The major irrigated crop in most of the systems is rice. The systems are located in the following countries:

IRRIGATION SYSTEMS **STUDIED:**

Community	Bureaucratic	**Other**
Bangladesh (1)	India (4)	Peru (3)
Indonesia (4)	Indonesia (1)	Mexico (1)
Iran (2)	Iraq (1)	
Nepal (5)	Laos (1)	
Philippines (13)	Pakistan (4)	
Tanzania (1)	Thailand (2)	
Thailand (1)	Taiwan (1)	
Switzerland (1)		

For the detailed profile of these cases see Tang (1992). A special study has been made of over 127 irrigation systems in Nepal. Please contact Elinor Ostrom if you wish to obtain the reports written from this study.

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