INSTITUTIONS AND COLLECTIVE ACTION IN IRRIGATION SYSTEMS

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Cultivators using an irrigation system face two kinds of collective action problems: joint investments in the system and the allocation of water from the system. Most irrigation systems will deteriorate rapidly if cultivators fail to devise ways to coordinate their investment and water allocation activities.

Using a theoretical framework derived from institutional analysis and transaction costs economics, I examine the structures of incentives faced by cultivators as these are shaped by rules-in-use and the physical and community systems involved. Information from 47 in-depth case studies of irrigation systems in various parts of the world is used to examine arguments about how various institutional, physical, and community attributes are related to the performance of irrigation systems. In particular, I focus on the differences in incentives, behaviors, and outcomes occurring in community irrigation as contrasted to bureaucratic irrigation systems.

Physical attributes including the size of the irrigation system, the pattern of water supply, and the availability of alternative water sources affect interactions among cultivators. Community attributes such as cultivators' sources of incomes and the presence or absence of social, economic, cultural, and locational differences among cultivators affect cultivators' incentives to cooperate with one another.

Institutional arrangements in irrigation systems can be conceptualized as rules that are distinguishable at least at two levels: operational and collective choice levels. Operational rules have to be compatible with their physical and community environments to be effective. No single set of operational rules is suitable for all circumstances. Within the sample of cases, collective choice arrangements have systematic relationships with the kinds of operational rules adopted and outcomes in an irrigation system. A greater diversity of operational rules is found among the community irrigation systems than the bureaucratic irrigation systems. More of the community systems are characterized by high degrees of rule conformance and good maintenance than the bureaucratic systems. Among the bureaucratic systems, those with irrigators' organizations at the watercourse level are more likely to be characterized by high degrees of rule conformance and good maintenance than those without.

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INTRODUCTION

Irrigated agriculture is a major means of subsistence for people in many parts of the world. It has become more important as the total irrigated area of the world nearly tripled between 1950 and 1985, amounting to around 271 million hectares in 1985 (Brown, et al., 1987: 125). Many developing countries and international agencies have invested large amounts of resources in developing irrigation systems. However, due to various institutional problems, many of these systems have failed to meet their operational targets or deteriorated rapidly soon after they were constructed. Improving the operation and maintenance of these systems is an important means of increasing agricultural production in many developing countries (Hayami and Ruttan, 1985).

Operating and maintaining an irrigation system frequently requires coordination among many participants -- mostly irrigators and irrigation officials -- who have divergent interests, preferences, and aspirations. While participants attempt to advance their own interests, their actions sometimes produce outcomes that benefit themselves at the expense of others. At other times, individuals trying to advance their interests end up producing unintended and harmful consequences for themselves as well as for others. Circumstances may also exist where individuals try to advance their own interests and produce results that are beneficial to all. An understanding of these various situations faced by participants in irrigation systems and the resulting incentives, behaviors, and outcomes facilitates the design of institutional arrangements that tend to produce more efficient and equitable outcomes than others.

In this chapter, I first describe some typical collective action situations faced by irrigators. When all irrigators act to advance their immediate interests in these situations, they are likely to produce undesirable consequences for themselves and for others. Second, I discuss one of the "solutions" frequently proposed to solve these collective action problems -- reliance on government bureaucracies -- and some of the potential problems of using government bureaucracies as the only means of solving these problems. Third, I examine two policy problems currently of some importance in regard to the organization of irrigation systems in many countries: (1) gaining farmers' involvement in bureaucratic irrigation systems, and (2) assisting community irrigation systems without undermining their viability.

Collective Action Problems in Irrigation Systems

Physical attributes of a resource affect how users and potential users of the resource relate to one another. Two independent attributes -- feasibility of exclusion and subtractibility -- are used by scholars to classify resources or goods (see Ostrom and Ostrom, 1977; Gardner, Ostrom, and Walker, 1989). Exclusion occurs when potential users can be denied goods unless they meet certain criteria. A good is subtractive when one person's use of the good forecloses its use by others. If these two attributes are arrayed in a simple matrix, four logical types of goods -- common pool resource, public good, private good, and toll good -- can be identified (see Table 1.1).

Irrigation systems, as common pool resources, are characterized by two features. First, once an irrigation system is constructed it is costly (but not necessarily impossible) to exclude potential beneficiaries from using the system. In most cases, this is due to the size of the water delivery facilities and the flow nature of water. Second, the flow of water available at any one time in an irrigation system is limited. The use of water by one individual subtracts the amount of water available to others.

Public goods, such as national defense, are similar to common pool resources in that it is difficult to exclude potential beneficiaries from enjoying a public good once it is provided. Public goods, however, are different from common pool resources because once a public good is available, one individual's enjoyment of the good does not subtract the amount available to others. The most important collective action problem in relation to public goods is how to organize for the provision of the goods. Since it is difficult to exclude potential beneficiaries from enjoying the goods, individuals have little incentive to contribute to their provision. Once the provision problem of a public good is solved, however, its allocation is not a problem since the good can be simultaneously enjoyed by large numbers of individuals without significant depletion.

Like public goods, common pool resources involve the provision problem because it is costly to exclude potential beneficiaries. Common pool resources, however, have an additional problem in that it is necessary to regulate the use of the limited amount of flow units

Table 1.1
Classification of Goods

	Subtractive Consumption	Nonsubtractive Consumption
Costly to Exclude	Common Pool Resource (e.g. Irrigation Systems)	Public Good (e.g. National Defense)
Not Costly to Exclude	Private Good (e.g. Bread)	Toll Good (e.g. Cable TV)

Source: Ostrom and Ostrom, 1977

available in order to ensure a productive and equitable use of the units. In irrigation, water allocation and investment are two major sources of collective action problems.

Water allocation is a major source of conflict in many irrigation systems. When the amount of water is not sufficient to satisfy the cultivation needs of all farmers simultaneously, farmers face the prospect of a decrease in crop yields or even the loss of entire crops. It is not uncommon to see this conflict develop into bloodshed or even murder (Maass and Anderson, 1986). Whenever the demand for water exceeds the supply, some kind of allocation is needed. An allocation rule may be based on the number of water shares one holds, the amounts of farmland one is cultivating, or a wide variety of other criteria. No matter what the bases of allocation are, the need for adopting allocation rules reflects the fact that some farmers will obtain less water than they desire. As the supply of water decreases, the temptation for individual farmers or groups of farmers to break the rules increases.

The situation farmers face frequently resembles a "prisoners' dilemma" game (see Wade, 1987). In such a game, the alternatives facing individual farmers are either to get more water or restrain from getting more water than they are entitled to. Assuming the flow of water is equally accessible to all farmers, each farmer's preference ordering of outcomes is as follows: (1) he does not restrain while others restrain from getting water; (2) everybody, including himself, restrains; (3) nobody restrains; (4) he restrains while others do not. If outcome (1) appears, the farmer will be a "free-rider"; if outcome (4) happens, he will be a "sucker". If every farmer tries to be a "free-rider" and avoids being a "sucker", the collective outcome will be (3), i.e., nobody restrains. This outcome is inferior to outcome (2), i.e., everybody restrains. The outcome that occurs when no one restrains is an example of what Garrett Hardin (1968) calls "the tragedy of the commons" or what some others call "the commons dilemma" (Gardner, Ostrom, and Walker, 1989).

Where farmers rely on irrigation for a living, they frequently have to invest substantial amounts of resources to construct and maintain facilities such as dams, canals, and pumps that are essential to divert and transport water. In some indigenous irrigation systems in Nepal and the Philippines, for example, each farmer devotes about one month of hard physical work every year to repair and maintain the system that supplies the farmer with water (Martin and Yoder, 1986; Siy, 1982). Whether farmers use the facilities with care also affects the condition of the facilities: pushing a valve or a gate too hard may break an important part of the water control facility; letting heavy animals walk across a canal may damage the canal. Irrigators have to discipline themselves and their animals in order to keep an irrigation system in good condition. In some instances, individual irrigators may get more water to their fields by making cuts at ditches near their fields. To restrain themselves, they have to forgo immediate benefits to refrain from activities that harm the irrigation facilities. All these are investments by irrigators in their irrigation systems.

Like water allocation, farmers face the "commons dilemma" situation in relation to their investments in irrigation facilities. Since it is often difficult to exclude other irrigators from enjoying the benefits of an operating system, individuals have incentives to refrain from investing, hoping to benefit from others' contributions. If everyone acts likewise, there will be an "under-investment" in the development and maintenance of the irrigation facilities. Like water allocation, even if all farmers have promised to contribute according to some formulae, some may still be tempted to withhold their contributions hoping others will do the job for them. This is, of course, another manifestation of the "free-rider" problem associated with the difficulty of excluding beneficiaries from the provision of a collective benefit.

The metaphors of the commons dilemma and free-riding remind us of a potential irony in the human world: rational human beings may fail to cooperate to produce mutually beneficial outcomes. The tragedy of the commons arises easily when large numbers of individuals are involved and have difficulty in communicating and enforcing agreements among themselves. In such situations, each individual believes that his or her action will not have a perceptible impact on others' actions. Even if an individual were to follow a cooperative strategy, it would make little difference on the outcome.

The tragedy of the commons, however, is inevitable primarily in those situations where the participants have no control over the structure of the situation they face (E. Ostrom, 1988). In situations where an identifiable group of individuals is involved and everyone is aware of the effect of his action on those of others, individuals may be able to develop a set of institutional arrangements that changes the structure of the situation they face. A set of institutional arrangements that can effectively monitor and impose sanctions on rule-breakers creates incentives for individuals to cooperate in water allocation and investment.

Many actual irrigation situations are also more complex than the "simplified versions" I have just presented. In many irrigation systems, for example, irrigators cultivating crops in the head portion of a canal have a more secure supply of water than those in the tail portion no matter whether any allocation rule is in place or not. Headenders may initially be less motivated to find institutional mechanism to solve water allocation problems than tailenders. In some situations, however, the need for coordination in investment may induce headenders to bring tailenders effectively into an active role in devising rules that protect the interests of both parties. Tailenders' contributions in constructing and maintaining water diversion works such as dams and pumping devices could lessen headenders' burden considerably. In order to solicit tailenders' contributions, headenders may have to make concessions to them regarding water allocation.

In summary, two major kinds of collective action problems -- water allocation and investment -- are frequent sources of sub-optimal performance in irrigation systems. Some of these problems have incentive structures similar to the "prisoners' dilemma". However, when additional factors such as locational differences are considered, the kinds of problems facing many farmers are even more complex than the symmetric prisoners' dilemma game presented in many introductory textbooks. Whether presented as simple or complex problems, water allocation and investment problems exist in all irrigation systems and have to be solved by some form of institutional arrangement or substantial conflict and inefficient outcomes will result.

Government Bureaucracies as a Solution

What kinds of institutional arrangements can solve these collective action problems in irrigation? Garrett Hardin (1968) argues that the "tragedy of the commons" is unavoidable in a common pool resource unless a bureau, backed by coercive power, is established to discipline the use of the resource. The experiences of large bureaucratic irrigation systems in many developing countries, however, show that bureaucratic governance is not a panacea for solving the commons dilemma. In the words of Wade:

> Many theorists of Prisoners' Dilemma have concluded that the socially desirable outcome of restrained access by all can be sustained only by the imposition of an external authority of powerful penalties against rule violation. If so, the conclusion is a counsel of despair, because in most Third World countries legal mechanisms and the authority of government are simply not powerful enough to make a sufficiently plausible threat [across] myriad microsituations (Wade, 1987: 178).

Government bureaucracies will fail to solve collective action problems in irrigation if their officials lack both incentives and capabilities to do so (see Bottrall, 1981; Wade, 1987). In countries such as India, Sri Lanka, and Pakistan, irrigation officials responsible for making regular water allocation and maintenance decisions for various watercourses in large bureaucratic irrigation systems are usually recruited from outside the area they serve. Most of these officials do not expect to serve a particular area for a long period of time. Their career advancement usually depends on their formal qualifications and recommendations by their superiors rather than on how well they have served the irrigators. These officials have little identification with the interests of the local communities and have little incentive to help the farmers solve their problems.

Even if some irrigation officials are committed to serving the farmers, they would face many practical difficulties (see Reidinger, 1980; Wade, 1987). For example, when a junior engineer has to be responsible for thousands of hectares of irrigated farmland, he will not have the time and energy to take care of every area, especially if he is stationed in an urban center far away from the irrigated areas. Their distances from the irrigated areas also prevent them from acquiring up-to-date and accurate information about the divergent needs of different areas. In water allocation, for example, immediate cooperative action is frequently needed to respond to erratic changes in the volume of water flow in order to utilize water productively. Even if these officials wish to help the local irrigators, their actions may be either inappropriate or untimely.

Unless an effective system of accountability exists, irrigation officials who face large numbers of irrigators competing for a scarce resource are in a position to misuse their power by demanding bribes from the irrigators. Bureaucratic corruption not only increases the financial burden of the irrigators, but also tends to discriminate against the poorer farmers who can less afford the "price" for water. Furthermore, if contractors for constructing and repairing irrigation facilities can get by with substandard works by paying kick-backs to officials, an irrigation system could remain in bad shape even after huge amounts of money have been spent in construction and maintenance (see Wade, 1982).

Irrigation officials' poor performance creates distrust by farmers. From the perspective of a farmer, even if he follows the allocation rule, there is no guarantee that he would get the share of water he is entitled. After farmers have become accustomed to an anarchic form of water acquisition, officials can no longer count on the farmers to follow rules and orders. This creates a vicious cycle. Officials and farmers do not trust one another and no institutional arrangement can be effective in disciplining water allocation and maintenance activities (see Hart, 1978; Wade, 1987).

These examples, of course, do not mean that all government involvements in irrigation must fail. Examples exist in countries such as Taiwan and South Korea where government-built irrigation systems function efficiently and equitably (see Abel, 1977; Wade, 1987; Levine, 1981). In these countries, specialized government agencies are responsible for constructing sizable irrigation systems. After these systems are constructed, parastatal organizations (called irrigation associations in Taiwan and farmland improvement associations in South Korea) are established to govern their operation and maintenance. The performance of these organizations is monitored by a national or provincial agency which also sets general regulations in such areas as salary scales and staff densities. Other than these restrictions, these organizations enjoy considerable autonomy within their own geographical jurisdictions. Staff members in these organizations are mostly recruited locally and spend their career within one location. Furthermore, the organizations operate and pay their staff salaries by collecting water fees directly from farmers. These conditions induce the staff members to develop local identification and serve the farmers well. Within the irrigation systems, farmers form their own irrigation groups at the watercourse level and are responsible for water allocation and maintenance within their groups.

In conclusion, the unfortunate experiences of many bureaucratic irrigation systems in India, Pakistan, and Sri Lanka show that the mere presence of a government bureau, backed by coercive power, does not necessarily solve all of the dilemmas faced by irrigators. On the other hand, as demonstrated by examples in Taiwan and South Korea, government or quasi-government agencies can play an effective role in constructing, regulating, and governing irrigation systems if appropriate institutional arrangements are in place and farmers are properly involved in the operation and maintenance processes.

The Role of Irrigators in Bureaucratic Irrigation Systems

While irrigators themselves can play a significant role in operating and maintaining irrigation systems built by government agencies, examples exist where local communities have been able to pool together substantial amounts of local resources to build and govern their own irrigation systems without involving any external political authority (e.g., Lando, 1979; Martin and Yoder, 1986; Bacdayan, 1980; Coward, 1980). Irrigators in these communities frequently devise ingenious institutional arrangements that provide incentives for individuals to coordinate with one another in mutually productive ways.

In light of the successful experiences of many indigenous irrigation communities and the involvement of farmers in irrigation associations in East Asia, development agencies and governments in developing countries have devoted more attention to the potential contributions of farmers in operating and maintaining bureaucratic irrigation systems. These governments and agencies have begun to emphasize the organization of farmers at the watercourse level. Unfortunately, they often mandate the creation of "farmer organizations" as central directives without considering the incentives and capabilities of the farmers (see Hunt, 1985; Merrey and Wolf, 1986). Douglas Merrey documents such a problem in Pakistan:

> New legislation was adopted in each province, ostensibly enabling the establishment of water users associations but in fact strengthening the power of the state over the watercourse. Farmers are obliged to carry out maintenance themselves or repay the costs if the government does it for them.... Government officials delegated to project areas by the Provincial Government retain control of water and other resources and continue to respond to directives from the provincial capital rather than to the demands of local farmers. All of these activities are directed at trying to impose state wishes at the local level, but they do not address the fundamental organizational issues in Pakistan's irrigation management structure (Merrey and Wolf, 1986: 23-4).

Merrey indicates that after these kinds of measures have been implemented, serious allocation and maintenance problems still persist in many watercourses.

Robert Hunt (1985) also has warned against using the crude analogy between community irrigation systems and water users associations within bureaucratic irrigation systems. He argues that community irrigation systems are self-contained entities that are sustained by a set of mutually supportive institutional arrangements, while water users associations are units within a larger bureaucratic environment, the proper functioning of which requires careful communication and coordination across different organizational interfaces. Farmers' participation in bureaucratic irrigation systems will be successful only if both the organizational problems of the bureaucratic machinery and the structures of incentives facing the irrigators are corrected. For example, if the supply of water to a watercourse is highly unpredictable and depends entirely on the arbitrary decision of the officials operating at the system level, it would be hard to expect farmers to organize among themselves to undertake operation and maintenance at the watercourse level.

Farmers may be involved in decision making and organization in a bureaucratic irrigation system in numerous ways. In some cases, they may be responsible for making operational decisions at the tertiary canal or watercourse level only. In other cases, they may participate in making operational and collective decisions at both the watercourse and system level. Depending on the extent to which farmers are involved in an irrigation system and the institutional arrangements that structure their participation, the system may perform differently.

Government Assistance to Community Irrigation Systems

While it is a major policy concern in countries such as India, Pakistan, and Sri Lanka to involve farmers in operating and maintaining bureaucratic irrigation systems, government assistance to community irrigation systems is an important policy area in countries such as Nepal and the Philippines where community irrigation systems cover large amounts of irrigated farmland. Some observers argue that the performance of many community irrigation systems could be improved by various kinds of external assistance such as financial or material resources to strengthen or extend existing diversion structures and water delivery channels (Pradhan, 1988).

In countries such as Nepal and the Philippines, specialized government programs and agencies have been established to assist farmers in community irrigation systems. In Nepal, for example, various public and development agencies such as the Department of Irrigation, the Department of Agriculture, the Ministry of Panchayat and Local Development (MPLD), and the Agricultural Development Bank (ADB) recently have been involved in assisting community irrigation systems. These government interventions have met with mixed results. In some cases, farmers benefited from the assistance; in other cases, the assistance created additional conflict and collective problems among farmers.

Potential pitfalls exist for government intervention in community irrigation systems. A common pitfall is the failure to recognize the conditions that make indigenous institutions viable. In the "Proposal for Decentralization Program Support in Nepal", Elinor Ostrom writes:

> Indigenous institutions rely upon shared understandings of rights and duties to enforce compliance with their rules about who is authorized, permitted, or required to take what action. If these arrangements are not understood by public officials and public officials begin to take charge, such as has occurred over the past 25 years in the areas of forestry and irrigation, then the viability of the indigenous institution is challenged (Decentralization Finance and Management Project, 1988: 2-3).

Many examples exist in Nepal where once external government funding for construction and maintenance was made available to a community irrigation system, farmers in the system soon developed an expectation that repair and maintenance jobs would be done with government funding. Entrepreneurial energy in the irrigators' community was directed toward getting money or construction contracts from the government agency instead of organizing operation and maintenance activities among the irrigators themselves. Irrigators no longer undertook their own maintenance work and conflict developed among them (see Fowler, ed., 1986).

Very often government agencies have their own priorities in terms of funding to various irrigation systems, which may not match the actual conditions of individual community irrigation systems. In many cases, the level of funding is too low to solve the kinds of problems encountered by farmers in these systems. Sometimes, agency officials pay more attention to initial construction and rehabilitation than subsequent maintenance of the irrigation works. In other cases, the agency has it own budgetary cycle; funding for rehabilitation and maintenance activities is frequently released at times such as planting periods when farmers are least able to utilize it effectively (see Fowler, ed., 1986).

Given the importance of community irrigation systems in many countries, it is important to examine how farmers in these systems organize themselves and what factors motivate them to cooperate in their investment and water allocation activities. Only after policy makers have acquired these kinds of knowledge would they be able to design rules and processes of intervention that can achieve desirable results.

Research Questions

Although farmers can play a significant role in solving their collective problems in both community and bureaucratic irrigation systems, potential pitfalls exist if insufficient attention is paid to the incentive features of different institutional arrangements. The research questions to be addressed in this study are (1) what factors affect the structures of incentives facing irrigators in different collective action situations and (2) how do irrigators respond to these structures of incentives? These research questions can be addressed by using a theoretical framework derived from the fields of institutional analysis and transaction costs economics. According to this framework, collective action problems in an irrigation system could be alleviated by various institutional arrangements which, in conjunction with the physical and community features of the system, shape the structure of incentives faced by the participants. In Chapter 2, I discuss this framework and factors that can affect the performance of an irrigation system.

CHAPTER 2

AN INSTITUTIONAL ANALYSIS OF IRRIGATION SYSTEMS AND TRANSACTION COSTS

Institutional arrangements can facilitate or impede the problem solving capabilities of participants in irrigation systems. In order to learn from empirical studies of the performance of various institutional arrangements in different irrigation systems, it is necessary to develop a theoretical framework that identifies the key attributes shared by collective action situations in a wide diversity of irrigation systems. These attributes should be treated as variables that take on different values according to their specific circumstances. Relationships among these variables then can be explored by reference to experiences in varied settings. Knowledge of this kind can help us diagnose potential problems in specific situations and design institutional arrangements to attenuate them.

Drawing on literature in political science, economics, anthropology, game theory and law, scholars have developed a general framework of institutional analysis that identifies the key working parts of typical situations facing participants in various social circumstances (Kiser and Ostrom, 1982; Oakerson, 1986; E. Ostrom, 1986). The focal point of the institutional analysis framework is the action situation in which individuals adopt actions or strategies. Depending on such factors as the number of participants involved, the types of choices available to participants, and the incentives faced by the participants, different outcomes may result from interactions among participants. Many collective action problems in irrigation systems resemble situations where individuals trying to advance their interests end up producing unintended and harmful consequences for themselves as well as for others. One example discussed in the introductory chapter was the water allocation problem where every farmer tries to be a "free-rider" and ends up worse off than if everyone cooperates in the water allocation process.

Like the institutional analysis framework, transaction costs economics adopts transactions, which resemble the concept of an action situation, as the fundamental unit of analysis (Williamson, 1975; 1985).[1] Both transaction costs economics and institutional analysis are concerned with identifying appropriate institutional arrangements that can counteract perverse incentives inherent in various transaction situations. While transaction costs economics approaches the problem by examining the characteristics of different transaction situations, the institutional analysis framework explicitly identifies a higher level of analysis by delineating the contextual attributes that shape various action situations. At the contextual level of analysis, one examines how rules, physical attributes, and attributes of community produce various action situations.

In this chapter, I first highlight the basic theoretical premises of transaction costs economics. Then, I discuss how the institutional analysis framework helps develop more specific arguments about conditions that induce irrigators to develop and sustain institutional arrangements that enable them to operate and maintain an irrigation system and what forms such arrangements may take.

Transaction Costs and Institutional Arrangements

As has been shown in the introductory chapter, there are situations related to irrigation where it is in everyone's interest to do one thing, but frequently they end up doing something else. In such situations, each person pursuing his or her own short term interests ends up producing suboptimal outcomes. Empirically one finds that farmers in some irrigation systems are able to change the structures of these situations so as to ameliorate the perversity while others are not. In an attempt to explain this variance in behavior and outcomes, an analyst needs to adopt an analytical approach to explain both the presence and absence of cooperative behavior. To do this, it is necessary to posit a consistent model of the individual that one can use to generate predictions about likely behavior given the structure of incentives and opportunities facing an individual.

An individual's choice of action in any particular situation depends on how the individual weighs the benefits and costs of various alternatives and their likely outcomes. Rationality, however, is bounded: in an attempt to pursue benefits, an individual is constrained by his limited information processing ability. In many economic models, for the sake of simplification, an individual is assumed to be able to process all the information relevant to a decision situation. The individual is assumed to be able to undertake all necessary computations to reach a decision that could maximize his expected utilities. This assumption has been challenged by many authors. Herbert Simon, for example, argues that human behavior is "intendedly rational but only limitedly so"(Simon, 1961: xxiv). Organizations, Simon argues, compensate for this human limitation by assigning each individual a limited task environment and standard operating procedures. Institutions that regulate ways of undertaking activities can also be thought of as stores of acquired knowledge. In the words of Langlois:

> institutions have an information-support function. They are, in effect, interpersonal stores of coordinative knowledge; as such, they serve to restrict at once the dimensions of the agent's problem-situation and the extent of the cognitive demands placed upon the agent." (Langlois, 1986: 237).

In order to develop mutually beneficial arrangements in irrigation, participants need rudimentary information about the physical and technological characteristics of the water flow and water delivery facilities, as well as the respective interests of the participants related to the irrigation system. Their existing information and their ability to gain further information affect their ability to develop appropriate institutional arrangements to tackle their problems in water allocation and maintenance.

The long-term viability and performance of a set of institutional arrangements also depends on whether the arrangements can help individuals to process and use information necessary for effective operation and maintenance. Hayek (1948) argues that a major problem of any economic system is the continuous utilization of information about circumstances of specific time and place. In irrigation, effective water allocation and maintenance require knowledge about the topology, soil types, or crop patterns of the particular area. It is important to ensure that these kinds of information are utilized when making decisions in relation to water allocation and maintenance.

Opportunism, defined as "self-interest seeking with guile", is another important attribute of individuals that affects collective action in irrigation systems (Williamson, 1985: 47). Opportunism, in conjunction with bounded rationality, creates difficulties for both negotiating and enforcing institutional agreements. In the process of negotiation, individuals may try to hide their true preferences from one another in order to secure a better deal, thus making the negotiation process more difficult. After individuals have entered into some form of mutually agreed contract, disputes may arise as to the proper interpretation of the contract when novel situations appear or new individuals are involved. This is especially the case because it is impossible to devise rules that take into account all possible contingencies in the future. Furthermore, individuals who have entered into a contract with others may still be inclined to take advantage of their fellow-contractors if circumstances allow them to do so.

Transaction costs economics focuses on the potential disputes that may arise when individuals, who are characterized by bounded rationality and opportunism, enter into contractual relationships (Williamson, 1975; 1985). Contrary to the assumption of "legal centralism" that the resolution of these disputes requires adjudication by an external authority, most disputes can be avoided by recognizing "potential conflict in advance and [devising] governance structures that forestall or attenuate it" (Williamson, 1985: 29). These governance structures represent institutional arrangements that participants voluntarily adopt in order to facilitate recurrent transactions among themselves. The organizational imperative emerging from considering bounded rationality and opportunism, Williamson argues, is: "Organize transactions so as to economize on bounded rationality while simultaneously safeguarding them against the hazards of opportunism" (1985: 32).

The transaction costs economics literature studies contractual problems mostly in relation to the exchange of private goods (i.e., goods that are characterized by the ease of exclusion and subtractibility of resource units) such as labor and machinery (see Joskow, 1988; Putterman, ed., 1986). Williamson (1985) distinguishes three principal dimensions of a transaction that are related to different organizational problems. First, some transactions are characterized by asset specificity which "refers to durable investments that are undertaken in support of particular transactions, the opportunity cost of which investments is much lower in best alternative uses or by alternative users should the original transaction be prematurely terminated" (Williamson, 1985:55). Transactions that involve durable and transaction-specific assets experience "lock in" effects on which account unified ownership (vertical integration) is commonly more preferable to autonomous trading in the open market.

Second, some transactions are subject to uncertainty caused by their environments and their participants' opportunistic behavior. This uncertainty, if accompanied by significant amounts of transaction-specific assets, induces the participants to devise institutional arrangements capable of sequential adaptation. Third, transactions are undertaken with different frequencies. If a certain kind of transaction is needed only infrequently, it may not be cost-effective to establish elaborate institutional arrangements to handle the transactions even if transaction-specific assets are involved. On the other hand, specialized institutional arrangements will be more cost-effective if large transactions of a recurring kind are involved.

Among the three dimensions, Williamson suggests, asset specificity is the most important for transaction cost economics. He writes:

> asset specificity is the big locomotive to which transaction cost economics owes much of its predictive content. Absent this condition, the world of contract is vastly simplified; enter asset specificity, and nonstandard contracting practices quickly appear" (Williamson, 1985: 56).

In irrigation, highly transaction-specific assets are involved: once constructed, irrigation facilities such as dams or canals can hardly be relocated or redeployed for other uses. In some arid areas, farmland is a highly transaction-specific asset whose value depends on the effective functioning of an irrigation system. If an irrigation system is used by multiple individuals, one individual's opportunistic behavior can affect the others considerably. Since it is difficult to redeploy one's investment once it is made in relation to an irrigation system, specific institutional arrangements are essential to ensure that no one would "free-ride" on others regarding investment and water allocation.

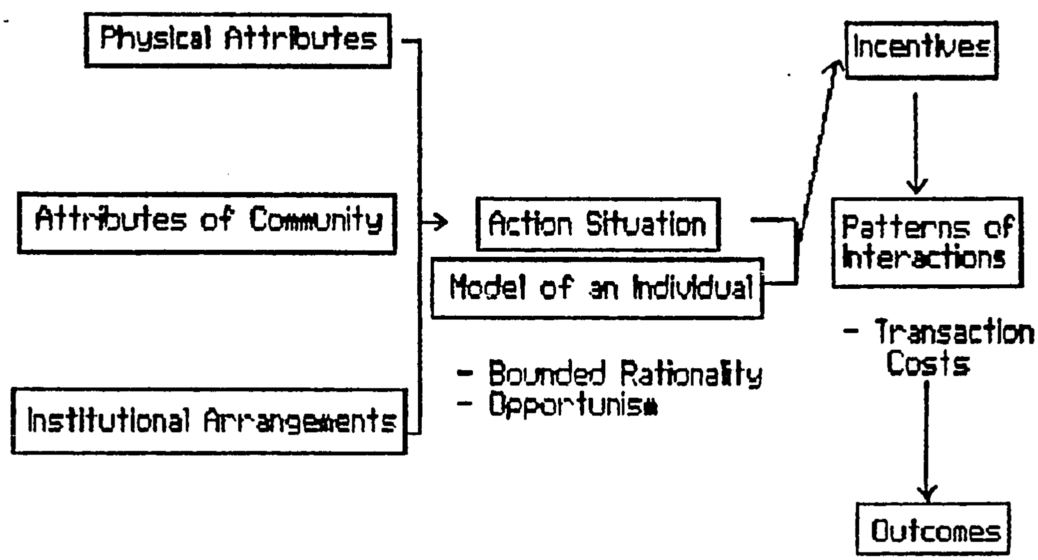
While most irrigation systems involve specific assets, farmers in different irrigation systems face different problems. In order to identify the causes of these problems, it is necessary to analyze systematically the contextual attributes that shape various collective action situations. Three sets of contextual attributes structure the action situation facing participants in an irrigation system: (1) physical attributes of the irrigation system; (2) attributes of the community of participants; and (3) the set of institutional arrangements in use by the participants (see Kiser and Ostrom, 1982). These three sets of attributes combine to create different incentives and constraints for participants. Participants, who are characterized by bounded rationality and opportunism, will react differently according to the incentives and constraints inherent in the situations they face. The strategic interactions among participants in an action situation produce different outcomes (see Figure 2.1).

Outcomes for participants in irrigation systems include: (1) whether the water supply in the system meets the water requirements of the crops in the established fields served by the system; (2) whether most participants follow rules-in-use in the system; (3) whether the water diversion and delivery facilities are well-maintained; and (4) whether some participants have been consistently disadvantaged in relation to the system.[2] These outcomes are influenced by the extent to which participants cooperate in the operation and maintenance of a system. In some situations, however, outcomes may be beyond the immediate control of the participants. The volume of water flow in a river at any particular moment, for example, is frequently a result of physical and meteorological factors that are not amenable to immediate human control.

Different outcomes may be related to different action situations faced by participants. Outcomes of one action situation may become contextual attributes for another situation. The level of water supply in a system may be partly a result of the way participants

Figure 2.1

A Framework for Institutional Analysis



constructed the system in the first place. Once constructed the amount of water supplied by the system, as will be discussed in Chapter 4, becomes a physical attribute of the system that affects irrigators' incentives to cooperate in maintaining the system.

Individuals in different situations may evaluate these outcomes differently. For example, irrigators in general are likely to regard adequate water supplies and good maintenance as the most important. Different communities, however, may evaluate the fourth outcome (i.e., whether some participants have been consistently disadvantaged) differently, depending on the concept of fairness shared by members of the community. Government and international development agencies frequently rate this outcome relatively high when designing their irrigation projects. Evaluations of the second outcome (i.e., whether most participants follow rules-in-use) also differs among participants, depending on whether they regard the rules-in-use as legitimate in the first place.

In the remaining part of this chapter, I first discuss how physical and community attributes affect collective action in an irrigation system. Then, I examine how institutional arrangements affect structures of incentives faced by participants and ways they relate to one another.

Physical and Community Attributes

As discussed in Chapter 1 and earlier in this chapter, most irrigation systems are characterized by "difficulties of exclusion", "subtractibility of resource units", and "asset specificity". These are physical attributes that affect collective action situations among irrigators in most irrigation systems. Besides these three, other physical attributes including the size of the irrigation system, the pattern of water supply, and the availability of alternative water sources affect interactions among irrigators. Community attributes such as irrigators' sources of incomes and the presence or absence of social, economic, cultural, and locational differences among irrigators also affect irrigators' incentives to cooperate with one another.[3] Either by itself or in combination with other attributes, each of these attributes potentially affects collective action and outcomes in an irrigation system. The constraints and opportunities created by these attributes have to be taken into account when designing institutional arrangements for an irrigation system.

Farmers' Degree of Dependency on an Irrigation System

Farmers' degree of dependency on an irrigation system may affect their incentives to cooperate with one another in fairly complex and counter-intuitive ways. Farmers are dependent on an irrigation system in two different senses: (1) they may depend on the system as a major source of their incomes, (i.e., their incomes come mostly from cultivating crops irrigated by the system); and (2) they may depend on the system as a major source of water for irrigation.

How much farmers depend on an irrigation system as a major source of income may have different effects on their incentives to participate in collective action. In most situations, the more irrigators depend on an irrigation system, the more likely they are willing to expend substantial amounts of private resources to operate and maintain the system. Irrigators without other job obligations are also more likely to be able to participate in collective activities in an irrigation system.

In other situations, if most farmers do not have other sources of income, it may be harder for them to develop new cooperative ventures that require substantial capital investment or sacrifice before producing benefits to the investors. It may, for example, require a substantial reduction in the rate of water withdrawal to replenish a deteriorating water basin. If most farmers rely entirely on water from the basin to irrigate their crops and have no alternative source of income, it would be difficult for them to agree to and enforce cooperative efforts to cut back on the rate of withdrawing water in an attempt to save the basin. Depending on the circumstances, farmers' dependency on an irrigation system as a major source of income may either facilitate or impede collective action.

By the same token, the availability of alternative water sources may increase or decrease farmers' incentives for cooperation, depending on the specific situations. In some situations, the availability of an alternative source of water may reduce tension among irrigators when water flow in the system is scarce, thus facilitating their long-term cooperation. In other situations, irrigators with access to an alternative source of water may be less willing to contribute to operating and maintaining the system than those without, thus inhibiting their long-term cooperation.

Water Scarcity and Uncertainty

Farmers' vulnerability to scarcity and uncertainty in water supply and its effects on their incentives for collective action have drawn special attention in the irrigation literature. Wickham and Valera (1979), for example, in a study of irrigation projects in the Philippines observe that in order to induce farmers to cooperate in managing their watercourses, an effective system-wide management program is a prerequisite. In other words, farmers have less incentive to organize if they do not have a predictable or sufficient flow of water into their watercourses in the first place. This observation seems to contradict that of Wade (1988) who, drawing upon experiences in South India, argues that the greater scarcity and uncertainty of the water supply, the greater the likelihood that a community of cultivators will develop collective arrangements to govern their watercourse.

Although these two arguments appear to be directly contradictory, they may be consistent when presented in a more general context. Irrigators' vulnerability to scarcity and uncertainty in water supply may be related to their incentives for cooperation in a curvilinear manner (see Uphoff, 1986a: 84). Farmers have to be sure of at least some minimal availability of water in the first place before they are willing to make any investments in collective efforts in water allocation and maintenance. If the water supply is really abundant, however, investments in water allocation and maintenance would make little sense as water would be available even without the investments. But under conditions of moderate scarcity, keeping regular water allocation and maintenance schedules may strongly affect the quantity of water that gets to the farmers' fields. Therefore, one may expect little collective action by the farmers under conditions of either extreme abundance or scarcity; most collective activities will happen in situations where water is barely sufficient or moderately scarce and farmers believe that their collective efforts can improve their chance of getting a more reliable supply of water.[4]

An inadequate supply of water, however, could increase coordination costs among farmers. As the supply of water decreases, the temptation for free-riding in water acquisition increases; efforts in monitoring and sanctioning have to be increased to enforce discipline in water allocation. Further, more conflicts are likely to arise among irrigators as they are competing for a scarce source of water. In some situations, farmers may be able to increase the flow of water to their fields by damaging, for example, the canal embankment. This again increases the difficulty for maintaining the irrigation system. All of these could increase the costs for organizing collective action in irrigation.

Therefore, in situations between extreme abundance and extreme scarcity, farmers expect both potential benefits and costs in their participation in collective action. On the one hand, if they are successful in collective action, they will receive a more adequate and reliable supply of water; there is a "demand" for collective action. On the other hand, the potential costs created by water scarcity make their cooperation with one another more difficult, thus inhibiting the "supply" of collective action. One may expect that in the real world many irrigation systems fall within this middle range; whether farmers in these systems will be successful in governing and maintaining their systems depends on the balance between the benefits and costs they face.

Irrigated Area and Number of Irrigators

Even if individual irrigators are willing to contribute to collective endeavors, they have to expend resources to organize among themselves to assign responsibilities and undertake water allocation and maintenance jobs. Both the size of the irrigation system and the number of users of the system may affect farmers' actions. Many authors argue that, all other things being equal, information-gathering, communication, decision-making, and monitoring costs increase as the size of a resource increases. By the same token, various kinds of transaction costs increase as the number of irrigators increases (Field, 1986; Buchanan and Tullock, 1962). These two arguments imply that, all other things being equal, it will be easier to organize collective action in irrigation systems of smaller sizes and with smaller numbers of users.

Although it is more costly to organize collective action in large irrigation systems, this does not mean that large systems are doomed to fail. In many circumstances, in order to take advantage of a large source of water, it is more economical to develop a system that irrigates extensive areas and serves many farmers. Depending on the kinds of institutional arrangements adopted, coordination problems in large systems can be solved in various manners.

The type of institutional arrangement that is needed to overcome the problem of organizing large scale irrigation has long been of interest to social scientists. Wittfogel's thesis that large scale irrigation (hydraulic agriculture) requires the discipline and direction by an external authority is probably the most famous theory about irrigation known to a general social science audience.[5]

Wittfogel wrote:

> A large quantity of water can be channeled and kept within bounds only by the use of mass labor; and this mass labor must be coordinated, disciplined, and led. Thus a number of farmers eager to conquer arid lowlands and plains are forced to invoke the organizational devices which -- on the basis of premachine technology -- offer the one chance of success: they must work in cooperation with their fellows and subordinate themselves to a directing authority (Wittfogel, 1981: 18).

Wittfogel further argued that the need to direct and enforce cooperation in constructing and operating major hydraulic works induced the development of highly centralized bureaucratic regimes in many parts of the world.

This thesis, however, has been contradicted by many examples where farmers or local communities have been able to assemble and discipline large amounts of local labor and other resources to construct and sustain irrigation systems with command areas of over several hundred hectares (e.g. Lando, 1979; Siy, 1982; Pradhan, 1983). These systems are not governed by any single, unified bureaucratic machinery. Instead, some forms of federated arrangements are adopted such that the entire system is governed by multiple levels of farmers' organizations. As will be discussed later in this chapter, this kind of multi-level arrangement can reduce transaction costs and facilitate coordination and problem solving in large irrigation systems.

Differences among Irrigators

Irrigators may be different from one another in: (1) their cultural and social characteristics such as ethnicity, caste, race, clan, or religion; (2) the amounts of irrigated land or water shares they hold; or (3) the locations of their plots within the system.

These differences are important contextual attributes that affect collective action in irrigation.

If a community of irrigators is divided by ethnic, clan, racial, caste, or religious differences that inhibit communication, the costs of organizing collective action within the community will be higher than within those without divisions. In some situations, the divisions among irrigators may be great enough to inhibit any form of cooperation among them. There are, however, situations where communities with ethnic, caste, or other divisions are able to overcome these obstacles, and develop and sustain long-term cooperative efforts. In these situations, high levels of potential disagreements and conflicts among irrigators still exist. Institutional arrangements that can mitigate and resolve potential conflicts among farmers and ensure a more equitable sharing of benefits and burdens among irrigators are important for the survival of their cooperative efforts.

Some collective action literature suggests that a collective good is more likely to be provided if a few individuals have disproportionate interests in the good, since these individuals have more to gain from the good and may find it in their own interests to provide the good by themselves or expend resources to organize other potential beneficiaries to provide the good (e.g. Olson, 1965). In irrigation, this means that the presence of individuals with disproportionate landholdings or shares of the water flow facilitates collective efforts in water allocation and investment. Contrary to this argument, some authors argue that highly unequal distribution of landholdings inhibits local cooperation in operating and maintaining irrigation facilities (e.g. Palanisami and Easter, 1986). Farmers with disproportionate wealth and influence may be reluctant to cooperate with poorer farmers; or if they do, they expect more privileges and benefits (Harriss, 1977). In order to ensure a mutually-productive relationship among all farmers in this kind of situation, institutional arrangements that ensure a fair share of costs and benefits among participants are important.

Different irrigators may have unequal access to the flow of water. This difference among irrigators also affects their incentives for cooperation. In most canal irrigation systems, headenders have a natural advantage in their access to water over tailenders. As documented by many authors, unless irrigation systems are well organized, headenders tend to take more water than is necessary for the growth of their crops to the detriment of tailenders (Bromley, 1982; Chambers, 1977). The temptation to "overuse" water is especially great for the cultivation of rice. Rice is believed by many farmers to be very sensitive to the shortage of water but tolerant to large amounts of water.[6] Standing water is also an important means to control the growth of weeds. For many farmers, to maintain as much water as possible in their rice field is a good way to reduce the risk of lower yields and the amount of labor required to clear weeds (see Abel, 1977). Because of their more favorable position relative to tailenders, headenders may have little incentive to cooperate with tailenders in water allocation.

The position of headenders is, of course, not invulnerable. Tailenders may go upstream and destroy their banks, gates, or valves and thus hurt the headenders if no one sanctions them. The possibility of the destruction of their diversion works is an inducement for headenders to cooperate with tailenders to a certain extent. On the other hand, when both headenders and tailenders implement a set of enforceable allocation rules, headenders are probably in a better position to negotiate a more favorable share of the water because of their proximity to the source of water.

The situation is different in irrigation systems where most farmers cultivate plots in both head and tail areas. In such kind of system, most of the farmers have vested interests in ensuring that enough water is delivered to the tail area; this pattern of plot distribution frequently facilitates cooperation among farmers. In some irrigation systems, specific rules exist to make sure that every farmer cultivates plots both in the head and tail areas (Coward, 1979).

Conclusion

While many physical and community attributes of an irrigation system affect situations faced by farmers, most of these attributes do not have any deterministic effects on the success or failure of collective action. In most cases, institutional arrangements can mitigate the perverse effects of situations created by these attributes.

Institutional Arrangements

From a policy perspective, institutional arrangements are the most important among the three contextual attributes underlying action situations faced by irrigators. Institutional arrangements are rules that "are potentially linguistic entities that refer to prescriptions commonly known and used by a set of participants to order repetitive, interdependent relationships" (E. Ostrom, 1986: 22). In a rule-structured situation, individuals select specific actions from a large set of allowable actions in light of the incentives existing in the situation in an attempt to further their interests. Rules as social artifacts are subject to human design and intervention. By identifying the capabilities and limitations inherent in different institutional arrangements, one can anticipate different patterns of social outcomes. By changing rules, it is possible to intervene to change the structure of incentives faced by participants and the way they relate to one another. Such interventions may enhance or reduce irrigators' capabilities to allocate water and maintain an irrigation system effectively.

Operational Rules

Operational rules define who can participate in which situations, what the participants may, must, or must not do, and how they will be rewarded or punished. Operational rules facilitate coordination among participants if the participants share a common knowledge of these rules and are willing to follow them. In a world of rapidly expanding knowledge and changing circumstances, rules have to be able to create enough predictability among individuals yet permit enough flexibility to deal with various contingencies (V. Ostrom, 1989). In irrigation systems, four kinds of operational rules are particularly important for farmers to solve their collective action problems.[7]

Boundary Rules

The existence of a set of boundary rules that limits the number of individuals who have rights to withdraw resource units is a key precondition for successful collective action in common pool resources (Ostrom, 1985; Schlager and Ostrom, 1987). Without a well-defined set of rights holders, it will be difficult for actual and potential users to negotiate and enforce a common set of rules coordinating various water allocation and investment activities. Arthur Maass and Raymond Anderson, for example, argue, "The strength and coherence of local irrigation organizations in developed regions appears to be correlated with an irrigation community's success in limiting or stabilizing growth, thereby gaining security for its members" (Maass and Anderson, 1986: 368).[8] The existence of a closed set of rights holders also distinguishes a common property resource from an open access resource (Bromley, 1984). Norman Uphoff suggests that because the resource and the users are more definite in the area of irrigation, water user associations tend to perform better than other local organizations responsible for resources such as forests and grazing lands (Uphoff, 1986b: 27-28).

Several boundary requirements are frequently used in irrigation systems: (1) ownership or leasing of land within a specified location; (2) ownership or leasing of shares in water delivery facilities; (3) ownership or leasing of shares to a certain proportion of the water flow; (4) payment of certain entry fee; and (5) membership in an organization. A boundary rule may consist of only one requirement or a combination of requirements.

Although limiting the number of users of an irrigation system is a way to ensure the long-term viability of an irrigation system, serious resource misallocation occurs if individuals who could benefit from an irrigation system are excluded. This may happen, for example, in situations where the irrigation system has an abundant supply of water, but the rights to appropriate water are rigidly tied to plots within a certain area. Excess water will be wasted if farmers who cultivate plots outside the area are excluded from the system.

There are, however, boundary requirements that tend to encourage efficient uses of water. It is, for example, argued by a number of authors that transferable water rights, independent of land, provide incentives for individuals to use water efficiently. Transferable rights also enable the trading of water shares such that water can be obtained by individuals that can make the most productive use of it (Martin and Yoder, 1986; Anderson, 1983). Some others, however, argue that independently transferable rights arrangements generally require more technological and organizational control, and may not be feasible in all kinds of situations (Glick, 1970).

Allocation Rules

Allocation rules prescribe the procedure for withdrawing water from an irrigation system; they are important especially when the supply of water is inadequate to meet the crop requirements of all cultivators simultaneously. If allocation rules are effectively enforced, they can reduce uncertainty and conflict among irrigators in relation to water withdrawal. Three types of procedures -- fixed percentage, fixed time slots, and fixed order -- are frequently used in water allocation. Each of these procedures may be based on different premises such as amount of land held, amount of water needed for cultivation, number of shares held, historical pattern of use, location of fields, or official discretion. For example, an allocation rule may require each irrigator to withdraw water in specific time slots. The length of the slot an irrigator is entitled to may be determined by the amount of land he holds, e.g., the larger amount of land he holds, the longer the time period he is entitled to. As shown in Table 2.1, there are many possible combinations of water distribution procedures and bases.[9]

Depending on such diverse attributes as the degree of water scarcity, length and structure of the water carrying facilities, the types of crops cultivated, and the monitoring devices available, different allocation rules may be appropriate under different situations. Among them, the degree of water scarcity deserves some specific discussion. The degree of water scarcity affects the type of allocation rules required to coordinate water appropriation activities. In systems that have an abundant supply of water all year round, no specific allocation rule may even be needed. For many other irrigation systems, the volume of water supply as a whole may be adequate for the requirement of all the crops cultivated by its members; demands for water however may exceed the amount available during certain time periods of the year. This situation happens frequently in dry seasons or in specific growth stages of crops when larger amounts of water are needed.

Two different responses to such a situation are possible. One possible response is to impose a more restrictive set of allocation

Table 2.1
Allocation Rules: Procedures by Bases

	Land/Needs	Shares	Historical Use Pattern	Location	Official Discretion
Fixed Percentage					
Fixed Time Slots					
Fixed Order					

rules: more restrictive turns or time schedules may be adopted or officials may begin to exercise discretion in allocating water among farmers. In order to enforce this more restrictive set of rules, the irrigation institutions and officials have to be able to command sufficient respect and confidence from the irrigators. Otherwise, pressure from irrigators, especially the more influential ones, may undermine the ability of the institutions and officials to govern the system. Another possible response to decreases in water supplies is to suspend or relax restrictions on water allocation. This response may lessen pressure on the institutions and officials. However, unless irrigators have other alternative sources of water, conflict may develop among them. Furthermore, tailenders are likely to suffer more than headenders in the absence of allocation arrangements.

Input Rules

Input rules prescribe the types and amounts of resources required of each cultivator. In systems that are owned and run entirely by irrigators, irrigators have to raise their own resources to finance their own organization and to develop and maintain the water delivery works. In large-scale, government-built irrigation systems, human and material resources from irrigators could also be effective and reliable inputs for developing and maintaining the system. There are four major types of inputs an irrigator may be required to contribute: (1) regular water tax; (2) labor for regular maintenance; (3) labor for emergency repair; and (4) labor, money, or materials for major capital investment. Each of these input requirements may be based on one of two kinds of premises -- equal or proportional. Equal rules simply require equal contribution from all irrigators. Proportional rules require contributions from irrigators roughly in proportion to the benefits each gets from the system, e.g., proportional to one's share of the system, to the amount of land cultivated, or to the amount of water needed (see Table 2.2).

Some scholars argue that if farmers are required to contribute labor to maintenance, the inputs required of a farmer should be proportional to the benefits he or she receives. Chambers (1977), for example, argues that in order to have effective maintenance, inputs required of an irrigator should be proportional to the benefits he or she receives. Chambers writes:

> Communal labor is most likely to be effective where the community will benefit directly and where labor obligations are proportional to expected benefits.... Conversely, where there is no direct link between the work done and the benefits gained, communal maintenance will be much more difficult (Chambers, 1977: 354).

According to this principle, proportional input rules should be more effective for maintenance than equal input rules. There are, however, exceptions to this principle. First, if an irrigation system only requires relatively small amounts of labor inputs for regular maintenance every year, the costs of implementing proportional rules could be more than their potential benefits. Only for systems that require large amounts of labor inputs could the gains from proportional rules be higher than the costs of enforcing them. Second, if an important structure, such as the diversion dam, of an irrigation system is destroyed and requires emergency repair, it may be easier to implement equal contribution rules than proportional rules. The prospect of losing the entire source of water may provide

Table 2.2
Input Rules: Requirements by Bases

	Equal	Proportional (e.g., shares, land, Needs)
Regular Water Tax		
Regular Labor		
Emergency Labor		
Major Capital Investment		

enough incentives for everyone to devote their efforts in repairing the structure.

Penalty Rules

In most cases, rules will be ineffective unless there are penalty rules to punish rule-breakers. Some possible penalties against rule-breakers include community shunning, fines, temporary or permanent loss of rights to water, and incarceration. Which of these penalties is more effective in detering rule-breakers depends on the features of the community of irrigators and the monitoring mechanisms available. In a closed and homogeneous community, community shunning may be sufficient to deter rule-breakers. In a more diverse and heterogeneous community, more substantial penalties such as fines are necessary. More serious penalties such as loss of rights to water and incarceration may not be suitable for every irrigation community because these kinds of penalties may induce a high level of conflict among irrigators. Unless these penalties are backed by an external authority with legal power for imposing coercion, they may be difficult to enforce.

Collective Choice Arrangements

Operational rules establish constraints that, if properly designed and followed, facilitate cooperation among participants in various collective action situations in irrigation. Operational rules, however, are not self-generating nor self-enforcing. In most cases, institutional arrangements have to be established to adjudicate conflicts, enforce decisions, and formulate and modify operational rules. These institutional arrangements represent a second order set of rules -- collective choice rules. The study of processes used to create, enforce, and modify collective choice rules is a different level of institutional analysis -- the constitutional level (V. Ostrom, 1987; 1989).

Collective choice arrangements for determining, enforcing, and altering operational rules are especially important in view of participants' bounded rationality and opportunism. Due to bounded rationality, it is impossible to devise operational rules that anticipate all kinds of contingencies; disputes among participants as to the proper meanings and scopes of operational rules could arise frequently. Collective choice arrangements structure the processes by which disputes among participants can be settled. Given opportunism, individuals are inclined to take advantage of their fellow-contractors; collective choice arrangements that sanction against rule-breaking behavior are important for sustaining mutually-productive relationships among the participants. Furthermore, in a world of changing knowledge and environments, operational rules adopted at one time may become obsolete at another; institutional arrangements that facilitate the adoption and modification of rules enable participants to respond to these changes.

Multiple Levels of Collective Choice Entities

Different sets of collective choice rules and different communities of participants may be involved in collective choice situations. Depending on attributes such as the size and the number of users of the irrigation system, different collective choice entities could 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 by reference 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 some other irrigation systems, the collective choice entity is constituted solely by the irrigators who adopt and enforce their own collective choice and operational rules.

Sometimes, a community of irrigators may be subject to multiple sets of operational rules adopted by different collective choice entities. For example, irrigators in large irrigation systems may be simultaneously subject to 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.[10] Collective choice entities at the sub-system level, constituted by the farmers themselves, are important for the effective operation and maintenance of large irrigation systems for two major reasons. First, what kinds of water allocation and input rules are the most effective and how these rules should be implemented depend much on such specific attributes as the soil type, field typology, cropping patterns, 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 changes such as the volume of water flow, climate, and the growth stage of plants. In many large irrigation systems, different watercourses vary in these attributes. If there is only one collective choice entity to create and enforce one uniform set of operational rules for an entire system, it is unlikely that the set of 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 "information of specific time and place" in formulating and enforcing appropriate operational rules and choices.

Second, collective choice entities at the sub-system level involve irrigators in the formulation of their own rules. 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 various informal mechanisms such as social shunning to enforce their own rules, mechanisms which are not available to any external officials.

While collective choice entities at the sub-system level facilitate adaptation to the specific needs of various irrigation units, a collective choice entity at the system level is necessary to deal with broader collective problems such as the allocation of water among watercourses and the maintenance of the diversion work for the entire system. The collective choice entities at the sub-system level, however, can still maintain their autonomy in relation to water allocation and maintenance activities within their respective areas. By constituting different levels of collective choice entities to deal with collective action problems of different scopes, many coordination and control problems associated with large irrigation bureaucracies, as discussed in the introductory chapter, can be avoided.

Collective Choice Rules

Individuals may have little incentive to comply to rules unless they believe that their non-compliance will result in substantial punishment. Long-term cooperation among a large group of individuals depends on arrangements that help monitor and sanction against non-compliance (see Hechter, 1987). Mutual monitoring among irrigators can be a means of rule enforcement. It may be effective in situations where (1) only a small group of individuals is involved, (2) an individual's activities can be easily observed by others, and (3) each individual has an incentive to monitor others' activities in an attempt to protect his or her own rights. When large numbers of individuals are involved, however, the provision of monitoring is itself subject to the free-riding problem because an individual may have incentives to save the time and energy for monitoring others' activities, hoping that other individuals will do the monitoring job for him. Specialized officials may be needed to enforce rules. Many cooperative activities in irrigation benefit from the involvement of specialized officials.

Officials vested with special prerogatives in rule formulation and enforcement, however, are frequently in a position to interpret rules to their own advantage or demand favor from irrigators when adjudicating their disputes or distributing their water shares. This potential opportunistic behavior of the officials is a permanent danger in any collective choice entity. The design of institutional arrangements that can ensure the accountability of irrigation officials has been a major concern of the literature in irrigation organization and management (Hunt, 1985; Coward, 1980).

In order to ensure the responsiveness of irrigation officials to irrigators, rules are needed to stipulate how irrigation officials are selected and removed, to whom they have to report, and how they are compensated for their services. These collective choice rules affect the structures of incentives faced by these officials and their services to irrigators. These officials are more likely to be responsive to the needs of irrigators if (1) their tenures are subject to periodic votes by the irrigators; (2) they have to report to irrigators in general meetings or hearings periodically; and (3) their salaries depend on direct contributions from the irrigators.

In some irrigation systems, incentives for officials come more from their private interests in the operation and maintenance of the system than from their official salaries. If the officials themselves, for example, cultivate lands in the tailend of a system, it would be in their personal interests to ensure that the water allocation and maintenance schedules are being followed by all irrigators such that their fields can get a sufficient and predictable supply of water. In this situation, personal interests are sufficient incentives for the officials to work for the common interests of the collective entity.

Conclusion

In irrigation, no single form of institutional arrangement is good for all circumstances. Different operational and collective choice rules, in combination with the physical and community attributes of an irrigation system, may create different incentive structures that induce cooperation or conflict among participants.

Research Agenda

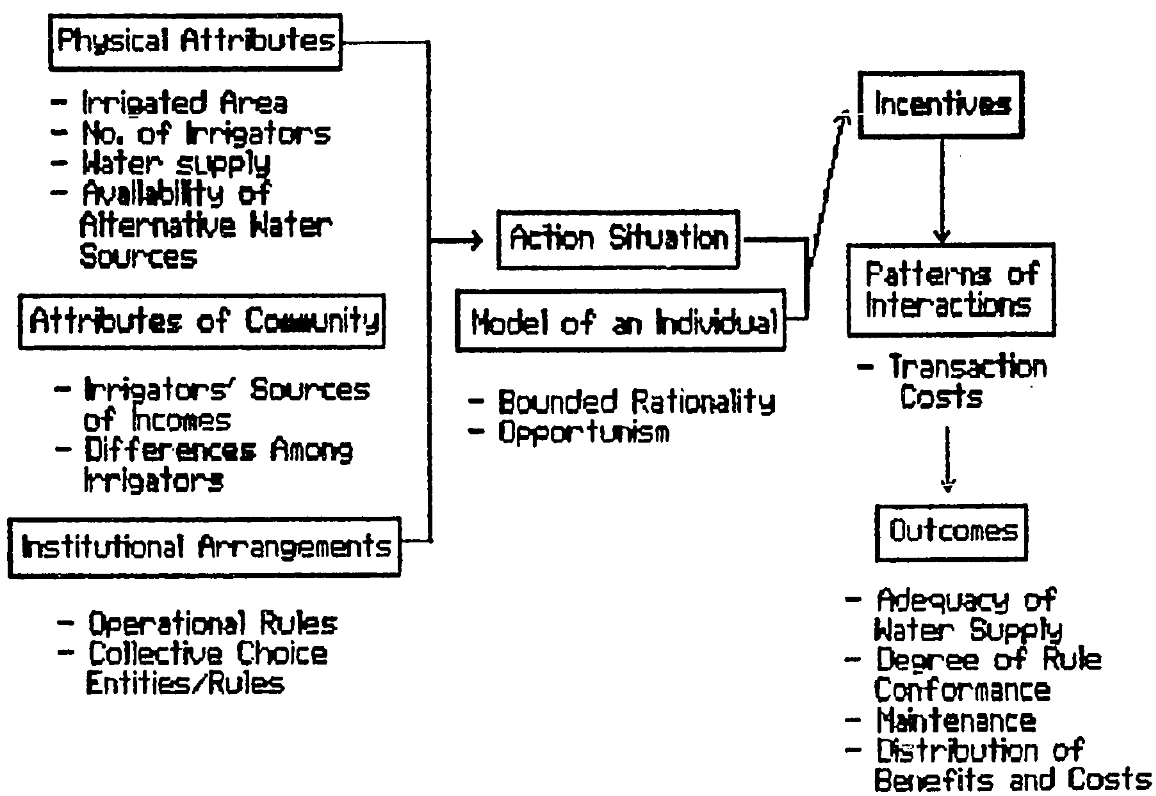
Various physical, community, and institutional attributes may affect collective situations in irrigation. These attributes usually combine in a configurational manner rather than a simple additive manner (see Kiser and Ostrom, 1982; E. Ostrom, 1986). To know the effect of one attribute, it is usually necessary to know what other attributes are also in effect. A change in one attribute may alter the way the entire configuration operates, thus creating quite a different action situation. This implies that when one tries to explain or predict outcomes for various irrigation situations, one has to be aware of the interrelationships among the contextual attributes involved.

The discussion of collective action problems by reference to transaction costs in this chapter enables us to specify several behavioral assumptions and contextual attributes that potentially affect the outcomes in an irrigation system. Figure 2.2 shows how these assumptions, attributes, and outcomes are related to one another within the institutional analysis framework.

In Chapter 4, I examine the pattern of collective outcomes as they are found in case studies of irrigation systems. I also analyze how these outcomes are related to various physical and community attributes. In Chapter 5, I examine some major operational and collective choice rules found in the case studies. Then, I analyze

Figure 2.2

Research Agenda



the factors that lead to the emergence or adoption of these arrangements and how these arrangements affect the patterns of outcomes under various circumstances.

In Chapter 3, I discuss the research method used for the study, some terminological problems in relation to irrigation, and the profiles of the case studies used. In Chapter 6, the concluding chapter, I summarize the major findings of the study and discuss their practical implications. I also suggest some directions for future research.

Notes

1. The concept "action situation" is broader than "transaction" because the former deals with all kinds of social situations while the latter concerns specific exchanges between or among people.

2. Other outcomes such as cropping intensities and agricultural productivities are important too. I do not focus on them in this dissertation because information about them is generally absent in case studies on irrigation systems. For a more extensive list of "objectives in irrigation management" see Uphoff, 1986a: 20-21.

3. This is only a partial list of physical and community attributes that may affect collective action in irrigation systems. Other attributes such as meteorological conditions and irrigators' cosmological views are also important variables to consider. They are not discussed in this study because most cases do not provide detailed information about these attributes.

4. In some situations, water abundance may be a problem by itself and requires collective action for its solution. For example, if the water flow is so abundant as to create drainage problems or threaten the physical integrity of the water diversion or delivery works, these kinds of situations could induce farmers to undertake intensive collective efforts to keep their system in a working condition.

5. Wittfogel distinguished between two types of irrigated agriculture -- hydroagriculture and hydraulic agriculture. Hydroagriculture refers to small scale agriculture for which "strictly local tasks of digging, damming, and water distribution can be performed by a single husbandman, a single family, or a small group of neighbors, and in this case no far-reaching organizational steps are necessary" (Wittfogel, 1981: 18). Hydraulic agriculture, on the other hand, deals with large amounts of water and requires elaborate organizational discipline to work.

6. Researchers, however, have discovered through experimentation that rice does not require a continuous stand of water during the growth period and that continuous flow of water through the field is unnecessary. If farmers could follow a rotational schedule for distributing water, a larger area could be cultivated by the same amount of water (Abel, 1977).

7. There are, of course, other kinds of operational rules. I do not focus on them because they are in general less important than the four I am discussing here. I will discuss other operational rules whenever relevant.

8. It is possible that individuals who control a water resource use their control to jack up the price of the crops they raise using that resource. This situation, however, would happen only in isolated communities that do not have any connections with other marketing networks. In locations that have regular connections with other marketing networks, individuals monopolizing a water source could not have much influence on the price of the crops they raise.

9. In the irrigation literature a distinction is often made between "water allocation" and "water distribution". Martin and Yoder, for example, argue that "Water allocation is the assignment of entitlement to water from a system, both identifying the fields and farmers with access to water from the system and the amount and timing of the water to be delivered to each. Water distribution refers to the physical delivery of water to the fields and may not conform to the water allocation" (Martin and Yoder, 1986:2). "Water allocation" as defined by Martin and Yoder is analogous to what is called "bases" in this dissertation; "water distribution" is analogous to water delivery "procedures".

10. In larger irrigation systems, three or even more levels of collective choice entities may exist.

CHAPTER 3

RESEARCH METHOD

A way to ascertain how various physical, community, and institutional attributes affect the performance of an irrigation system is to examine their pattern of interactions in natural settings.[1] In the past two decades, extensive in-depth case studies on irrigation systems in various parts of the world have been written by scholars in disciplines such as anthropology, sociology, agricultural economics, and political science. These cases vary from extremely simple settings, where a temporary diversion dam diverts water from a stream to a small, homogeneous group of farmers to cases involving huge networks of canals delivering water to diverse groups of people and hundreds of thousands of hectares of farmland. Although some of these studies focus on certain selected aspects of an irrigation system, they do represent in many instances excellent accounts of how different physical, community, and institutional attributes affect the process of organizing various types of collective action related to irrigation systems. Information from some of these case studies will be used to examine arguments discussed in Chapter 2.

In this chapter, I first introduce some basic terminology essential for classifying and comparing irrigation systems. Then, I describe how case studies on irrigation systems have been collected and used for analysis in the subsequent chapters of this dissertation.

Simple Versus Complex Irrigation Systems

How the boundaries of an irrigation system are defined determines the specification of such important variables as the size of the system, number of irrigators, and the institutional arrangements related to the system. Unless definitions are used consistently, the validity of any comparative studies will be in doubt.[2] One way of conceptualizing the boundaries of an irrigation system is to consider the water delivery processes within the system. These processes can be divided into four stages -- production, distribution, appropriation, and use (see Plott and Meyer, 1975).[3] These four stages may occur in four distinct parts of an irrigation system -- the production resource, distribution resource, appropriation resource, and use resource. The production of water for irrigation involves making water available at locations and times when it does not naturally occur in the form of precipitation and immediate runoff. Water is produced, for example, by holding back the flow of a river by a dam and releasing it during irrigation seasons. A dam or any other form of headwork is the "production resource" of the irrigation system. From the production resource, the water may be distributed through a large aqueduct or canal to the irrigated area; the aqueduct or canal is the "distribution resource". In the irrigated area, farmers may appropriate water from the local canals, tanks, or pumps; these works are the "appropriation resource". The water appropriated by farmers is then used to irrigate the crops in the fields; the fields and crops together constitute the "use resource".[4]

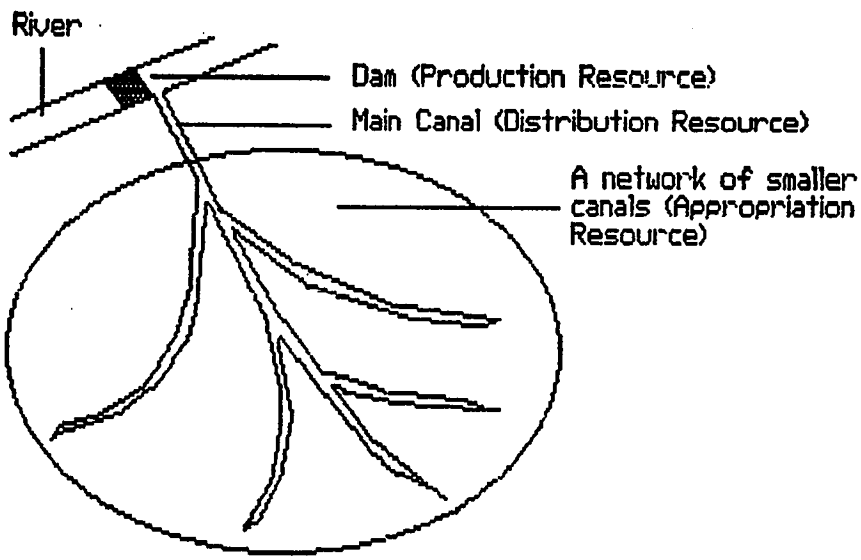
While appropriation resources can be distinguished from production and distribution resources in many irrigation systems, in some other systems the appropriation and distribution resources may be contained in the same boundary. For example, if water is diverted to the fields immediately after it leaves the headwork, the network of canal connected to the headwork can be considered as both the distribution and appropriation resources. In this case, the distribution and appropriation resources are identical.

With this distinction among production, distribution, and appropriation resources, two general types of irrigation systems -- simple and complex -- can be identified. In a simple irrigation system, the production and distribution resources supply water to only one appropriation area. In a complex irrigation system, the production and distribution resources deliver water to multiple appropriation areas (see Figure 3.1).[5] Simple irrigation systems are usually easier to analyze because the entire network of canals usually constitutes the appropriation resource and the organizational activities of all irrigators center around it. Serious analytical problems arise, however, in relation to complex irrigation systems where the entire system is divided into many smaller watercourses (i.e., appropriation areas). Although problems at the system level would certainly affect various appropriation areas within the system, each appropriation area has its own set of collective action problems.

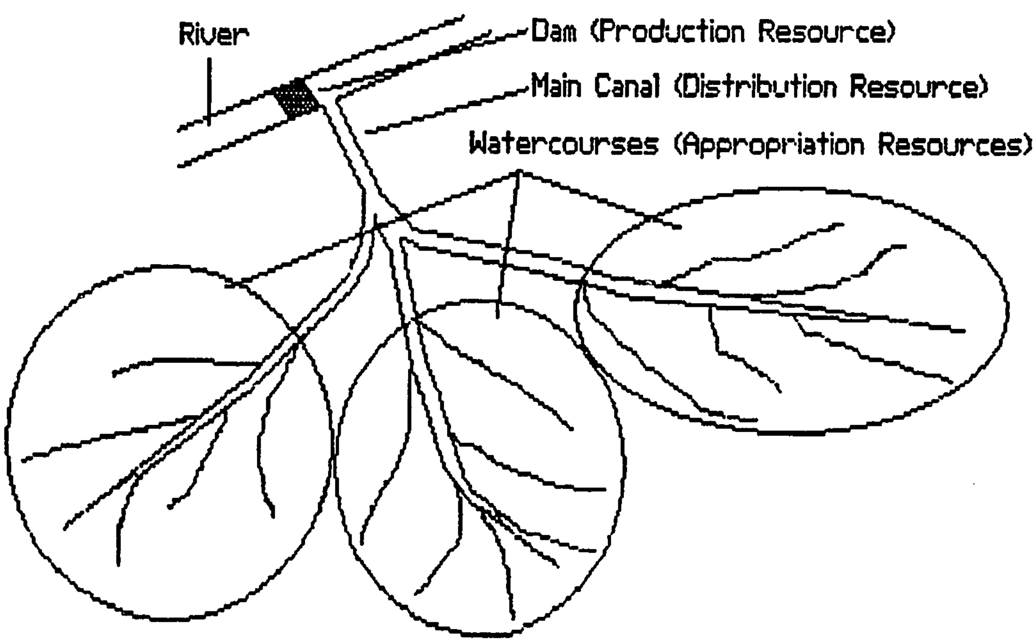
In this dissertation, I focus primarily on the appropriation stage of the water delivery process because no matter what institutional arrangement an irrigation system takes, irrigators will be involved in the appropriation stage. It is also at this stage that

Figure 3.1
Simple and Complex Irrigation Systems

A. A Typical Simple System



B. A Typical Complex System



most water allocation and maintenance problems arise. In subsequent chapters, I analyze activities and attributes related to the entire appropriation resource of a simple irrigation system and selected appropriation areas (i.e., watercourses) within a complex system. Activities and attributes related to production and distribution resources are discussed whenever they are closely related to activities within the appropriation area under discussion.

Organizational Forms

An irrigation system may be governed by one or more collective choice entities. A collective choice entity may be constituted by (1) a national or regional government agency or enterprise, (2) a local government unit, (3) a communal enterprise or an irrigators' association, or (4) any other kind of organization such as a profit-making, private enterprise. In some irrigation systems, one collective choice entity governs the production, distribution, and appropriation resources simultaneously. In some other systems, a separate collective choice entity governs each of the three resources. An irrigation system can be classified by reference to what kinds of collective choice entities are involved in governing which resources of the system.

In this dissertation, I concentrate on two kinds of irrigation systems -- bureaucratic irrigation systems and community irrigation systems. A bureaucratic irrigation system refers to a system whose production resource is governed by a national or regional government agency or enterprise. In some bureaucratic systems, the same government agency or enterprise may also govern the distribution and appropriation resources of the system. In others, different collective choice entities, such as irrigators' associations, may be involved in governing activities in the distribution or appropriation resources.[6]

A community irrigation system refers to a system whose production resource is governed either by communal enterprises or irrigators' associations. In almost all community irrigation systems, the distribution and appropriation resources are also governed by either communal enterprises or irrigators' associations. Systems that are not governed by any formal collective choice entity are also considered as community irrigation systems since only irrigators are involved in their operation.

Nature of the Evidence

A research project, "Towards an Institutional Theory of Collective Action", headed by Professor Elinor Ostrom at Indiana University, has served as a major source of data for this dissertation. A part of the research project has been to undertake a systematic analysis of in-depth case studies on common pool resources including irrigation systems, fisheries, forests, and grazing lands. Members of the research project have developed a series of in-depth coding forms, containing mostly close-ended questions, to capture key physical, community, and institutional attributes of an appropriation area in each irrigation system and general information about production and distribution resources when they are separated geographically and organizationally from the appropriation resource.

Forms that are relevant to this dissertation include the following:

1. Location Form -- examines the major geographic and demographic features of the location where an appropriation resource (of an irrigation system) is located.

2. Appropriation Resource From -- examines the boundaries and physical characteristics of an appropriation resource.

3. Operational Level Form -- examines the types of situations faced by participants, the level of information available to them, their potential actions and levels of control, their patterns of interactions, and outcomes they obtain. Each operational level form reports a "time slice" during which the actions of the appropriators are relatively consistent. By "relatively consistent", it is meant that the rules governing the appropriation resource, the community of appropriators, and the physical characteristics of the resource are the same throughout the period. When any one of these attributes changes, another operational level form is coded for a new "time slice". Therefore, there will be more than one case for each irrigation system if more than one operational level form is coded.

4. Subgroup Form -- examines the stakes and resources, potential actions and levels of control, and strategies of participants in a subgroup. There will be more than one subgroup and more than one subgroup form has to be filled out if the participants in an appropriation resource are not relatively symmetrical in their legal rights to appropriate water, their withdrawal rate from the resource, their exposure to variation in water supply, their level of dependency on water from the resource, and how they use the water.

5. Operational Rule Form -- examines the kinds of boundary, authority, scope, information, payoff, and aggregation rules used in an appropriation resource.

6. Collective Choice Form -- examines the collective choice entities that govern an irrigation system.

7. Organizational Structure Form -- examines the structure and process of a collective choice entity. Multiple organizational structure forms have to be filled out if more than one collective choice entity is involved in governing an appropriation resource.

Most of the variables discussed in Chapter 2 are contained in these seven forms. I have used these forms to code data provided by in-depth case studies in irrigation. These case studies have been published in various manners, including books, dissertations, journal articles, monographs, occasional papers, and conference papers. Sometimes information about one irrigation system appears in several sources by different authors.

Since the original coding forms were designed to code cases about different kinds of common pool resources, the wordings of some of the questions presented in subsequent chapters are slightly changed from the original versions in the coding forms so that they can fit the present context of the discussion. The meanings of the questions, however, remain unchanged.

The values for some variables are also changed. Some variables in the original coding forms consist of four or five values. In this study, because of the limited number of cases available, the number of values for some variables is reduced to two. In the original coding form, for instance, the variable about the supply of water has five values: (1) extreme shortage; (2) moderate shortage; (3) apparently balanced; (4) moderately abundant; and (5) quite abundant. In this study, values (1) and (2) are coded as "inadequate;" (3), (4), and (5) are coded as "adequate." The coded values of individual variables for each case are reported in the subsequent chapters so that readers will have an opportunity to check the validity of my coding.

Forty-seven cases were coded and the data have been entered into a micro-computer database system, R:Base 5000. These forty-seven cases were selected from several hundred documents collected by the research project. Only cases that contain relatively good information about the physical, community, and institutional attributes of an appropriation resource of an irrigation system were selected for coding. The profiles of these cases are shown in Tables 3.1, 3.2, and 3.3. Twenty-nine of these cases are community systems; fourteen are bureaucratic systems; and four are systems governed by local governments. Twenty-nine of the cases are simple systems; eighteen are complex ones. Forty-one out of the 47 cases are located in Asia. The sizes of the systems range from 3 hectares (Cadchog, a community system) to 628000 hectares (Area One, a bureaucratic system). The major irrigated crop in most of the systems is rice.

The reader may notice that some of the cases bear similar names, such as San Antonio (1) and San Antonio (2), Tanowong (T) and Tanowong (B), and Lurin Sayoc (1) and Lurin Sayoc (2). San Antonio (1) and San Antonio (2) correspond to two different operational periods -- time slices -- of an irrigation system that was built by the National Irrigation Administration of the Philippines in San Antonio. San Antonio (1) stands for the period when there was a watertender to oversee water allocation; San Antonio (2) stands for the period when the position of watertender no longer existed. Tanowong (B) is different from Tanowong (T) in that the former corresponds to a period when the appropriation resource had access to an additional source of water. Lurin Sayoc (1) is different from Lurin Sayoc (2) in that the former stands for a period when the resource is governed by some barrio-wide rural political officials and the latter stands for a period when the resource is governed by municipal officials.

Since these 47 cases are the basic evidence of this study, the generalizations derived from the study pertain to what has been reported in the cases studies. While these case studies may focus on only a few selected aspects of an irrigation system, they are

Table 3.1
Cases Coded: Community Systems (N = 29)

Country	Name	Type	Command Area (in hectares)	Major Crop	Documents
Bangladesh	Nabagram	Simple	29	MIC	Coward & Badaruddin (1979)
Indonesia	Bondar Parhudagar	Simple	4	Rice	Lando (1979)
Indonesia	Takkapala	Simple	95	Rice	Hafid & Hayami (1979)
Indonesia	Saebah	Simple	100	Rice	Hafid & Hayami (1979)
Indonesia	Silean Banua	Simple	120	Rice	Lando (1979)
Iran	Deh Salm	Simple	300	Other grains	Spooner (1971, 1972 & 1974)
Iran	Nayband	Simple	MIC	Rice	Spooner (1971, 1972 & 1974)
Nepal	Raj Kulo	Simple	94	Rice	Martin & Yoder (1983a, 1983b & 1986)
Nepal	Thulo Kulo	Simple	39	Rice	Martin & Yoder (1983a, 1983b & 1986)
Nepal	Char Hazar	Simple	200	Rice	Fowler (1986)
Nepal	Chhahare Khola	Simple	20	Other grains	Water & Engineering Commission (1987)
Nepal	Naya Dhara	Simple	55	Rice	Water & Engineering Commission (1987)
Philippines	Agcuyo	Simple	9	Rice	de los Reyes (1980)
Philippines	Cadchog	Simple	3	Rice	de los Reyes (1980)
Philippines	Calaoaan	Simple	150	Rice	de los Reyes (1980)
Philippines	Mauraro	Simple	15	Rice	de los Reyes (1980)
Philippines	Oaig-Daya	Simple	100	Rice	de los Reyes (1980)
Philippines	Sabangan Bato	Simple	94	Rice	de los Reyes (1980)
Philippines	Silag-Butir	Simple	114	Rice	de los Reyes (1980)

to be continued...

Table 3.1 (continued)
Cases Coded: Community Systems (N = 29)

Country	Name	Type	Command Area (in hectares)	Major Crop	Documents
Philippines	San Antonio (1)	Simple	23	Rice	de los Reyes & Borigdan (1980)
Philippines	San Antonio (2)	Simple	7	Rice	de los Reyes & Borigdan (1980)
Philippines	Tanowong (T)	Simple	MIC	Rice	Bacdayan (1980)
Philippines	Tanowong (B)	Simple	MIC	Rice	Bacdayan (1980)
Philippines	Pinagbayanan	Simple	20	Rice	Cruz (1975)
Tanzania	Kheri	Simple	260	Other Grains	Gray (1963)
Thailand	Na Pae	Simple	64	Rice	Tan-Kim-Yong (1983)
Philippines	Zanjera Danum Sitio	Complex	45/1500*	Rice	Coward (1979)
Switzerland	Felderin	Complex	19/MIC	Meadow	Netting (1974 & 1981)
Thailand	Chiangmai	Complex	MIC/MIC	Rice	Potter (1976)

MIC = Missing in Case
* command area of the appropriation resource/command area of the entire system

Table 3.2
Cases Coded: Bureaucratic Systems (N = 14)

Country	Name	Type	Command Area (in hectares)	Major Crop	Documents
India	Kottapalle	Complex	500/MIC*	Rice	Wade (1985 & 1988)
India	Sananeri	Complex	173/1172	Rice	Meinzen-Dick (1984)
India	Dhabi Minor Watercourse	Complex	21/MIC	Other Grains	Gustafson & Reidinger (1971) Reidinger (1974 & 1980) Vander Velde (1971 & 1980)
India	Area Two Watercourse	Complex	33/229000	Other Grains	Bottrall (1981)
Indonesia	Area Three Watercourse	Complex	115/33000	Rice	Bottrall (1981)
Iraq	El Mujarilin	Complex	307/208820	Other Grains	Fernea (1970)
Lao	Nam Tan Watercourse	Complex	100/2046	Rice	Coward (1980b)
Pakistan	Dakh Branch Watercourse	Complex	152/MIC	Other Grains	Mirza (1975)
Pakistan	Gondalpur Watercourse	Complex	200/628000	Rice	Merrey & Wolf (1986)
Pakistan	Punjab Watercourse	Complex	98/MIC	Rice	Lowdermilk, Clyma & Early (1975)
Pakistan	Area One Watercourse	Complex	50/628000	Other Grains	Bottrall (1981)
Thailand	Kaset Samakee	Complex	28/12000	Rice	Gillespie (1975)
Thailand	Amphoe Choke Chai	Complex	125/12000	Rice	Gillespie (1975)
Taiwan	Area Four Watercourse	Complex	150/67670	Rice	Bottrall (1981)

MIC = Missing in Case
* command area of the appropriation area/command area of the entire system

Table 3.3
Cases Coded: Other Systems* (N = 4)

Country	Name	Type	Command Area (in hectares)	Major Crop	Documents
Peru	Hanan Sayoo	Simple	MIC	Other Grains	Mitchell (1976 & 1977)
Peru	Lurin Sayoc (1)	Simple	MIC	Other Grains	Mitchell (1976 & 1977)
Peru	Lurin Sayoc (2)	Simple	MIC	Other Grains	Mitchell (1976 & 1977)
Mexico	Diaz Ordaz Tramo	Complex	2/150**	Other Grains	Downing (1974)

* The production resource of Lurin Sayoo (1) is governed by barrio-wide rural political officials.
The production resources of the other three cases are governed by municipal governments
MIC = Missing in Case
** command area of the appropriation resource/command area of the entire system

invaluable in that they provide a wide diversity of experiences from which to analyze institutions and collective action in irrigation systems. No other source of evidence describes in detail the experiences of irrigation systems in such diverse physical, community, and institutional settings. This contrasts with most other studies of irrigation systems which make generalizations based on experiences of one or two irrigation systems. An analysis of these 47 cases enables us to identify how various collective outcomes are associated with different configurations of physical, community, and institutional attributes of irrigation systems.

Notes

1. Another method is to set up laboratory experiments that resemble typical action situations faced by irrigators and examine how participants in the experiments respond to different structures of incentives induced by the designer of the experiment (see Gardner, Ostrom, and Walker, 1989).

2. There is however no easy solution as to how the boundaries of an irrigation system can be defined. Hunt, for example, argued at one point that an irrigation system refers to the area receiving water from a single point on a natural water source. He later admitted the limitation of that definition because some irrigation systems do receive water from more than one source (Hunt, 1979).

3. Potentially there is a fifth stage, drainage. Since most of the case studies do not contain information about drainage activities and arrangements, I will not deal with them in this dissertation.

4. In some irrigation systems, especially those in Africa, government or parastatal bodies are responsible for both irrigation and cropping patterns in state farms (see Thornton 1976: 149). In these irrigation systems, the "use resource" is an integral part of the systems. In most of the cases examined in this dissertation, "use resources" belong to private individuals. I do not discuss this particular resource in this dissertation unless it is related to some other resources or collective activities within an irrigation system.

5. This distinction between simple and complex irrigation systems is different from that suggested by Spooner (1974) who uses the level of technological sophistication to distinguish simple irrigation systems from complex ones.

6. Chambers (1977) calls the latter kind of systems bureaucratic-communal irrigation systems.

CHAPTER 4

COLLECTIVE OUTCOMES AND PHYSICAL AND COMMUNITY ATTRIBUTES

As discussed in Chapter 2, cultivators' cooperative efforts in investments and water allocation in an irrigation system affect the level of water supply, degree of rule conformance, maintenance, and distribution of benefits and costs among cultivators in the irrigation system. These outcomes are related to one another in a recursive manner. On the one hand, rule conformance and maintenance may act as independent variables affecting the level of water supply. Cultivators' cooperative efforts in maintaining an irrigation system, for instance, can increase the level of water supply in the system. After cultivators have utilized an appropriation resource for several years and are able to enforce a suitable set of water allocation rules, they can estimate the usual amount of water available and plan the amount and types of crops to be cultivated accordingly. On the other hand, the level of water supply may act as an independent variable affecting the degree of rule conformance and maintenance: whether the amount of water available from the appropriation resource meets the water requirements of the crops affects cultivators' incentives to cooperate in water allocation and maintenance.

The collective outcomes in an irrigation system are also related to various physical and community attributes of the system. Cultivators' degree of dependency on an irrigation system may affect their incentives to cooperate with one another. After individual cultivators have realized the potential benefits of cooperating with one another, they have to expend resources to organize among themselves and to assign responsibilities to undertake actual water allocation and maintenance. The size of the irrigated area, the number of cultivators involved, the distribution of wealth, and the presence or absence of cleavages among cultivators affect the coordination costs among cultivators and their abilities to develop and sustain institutional arrangements that can solve their problems.

In this chapter, I first discuss the collective outcomes as they are found in the cases. Within the sample of cases, these collective outcomes occur in a specific pattern. An analysis of the pattern enables me to draw inferences about how these outcomes are related to one another. Then, I examine how various physical and community attributes are associated with different outcomes. Some of these physical and community attributes tend to be associated with inferior outcomes. Others attributes are indeterminate in their effects on outcomes; they may affect outcomes in either a positive or negative direction, depending on the configuration of other contextual variables.

Water Supply, Rule Conformance, and Maintenance

The performance of an irrigation system can be measured in different ways. On the technical side, one may measure the marginal productivity of the water used for irrigation or the proportion of water loss through seepage during the conveyance process. Since time-consuming and technical surveys have to be undertaken to obtain these measurements, these measurements are absent in most case studies. Notwithstanding this lack of technical information, most cases do report information related to the relative adequacy of water supply, level of maintenance, and degree of rule conformance among cultivators in an irrigation system. These outcomes can serve as rough measures of the relative performance of an irrigation system.[1]

The evidence presented in relation to these outcomes varies from case to case. In some cases, the author discusses the outcomes specifically; in others, one has to draw inferences from other related discussions in the cases. Three questions were used to identify these outcomes in a case.

1. **ADEQUACY**: At the end of this period, does the amount of water available in the appropriation resource meet the water requirements of the crops in the established fields served by the resource?

Since the principal objective of any irrigation system is to supply water for agriculture, an important outcome of an irrigation system is whether the system has enough water to meet the needs of crops planted by appropriators of the system. The following excerpts are examples of the authors' assessment of the relative adequacy of water supply in some case studies:

Examples of cases where the supply of water is "adequate":

I. Raj Kulo: "there have been significant improvements made in the canal, and the amount of water supplied to the command area has increased considerably in the past 25 years, but there has been little increase in the area that is irrigated.... Whereas they once had to use a rotation system of distribution and go out to irrigate at night, now the water flows continuously to all fields, and much of the time, excess water is diverted to a drain" (Martin & Yoder, 1983a: 24-25).

II. Cadchog: "our informants claim that their system's water supply is always sufficient for the irrigation needs. They explain that they can always obtain adequate irrigation in spite of their being situated at the downstream portion of the creek because the upstream dams do not divert all the creek's water" (de los Reyes, 1980: 85)

Examples of cases where the supply of water is "inadequate":

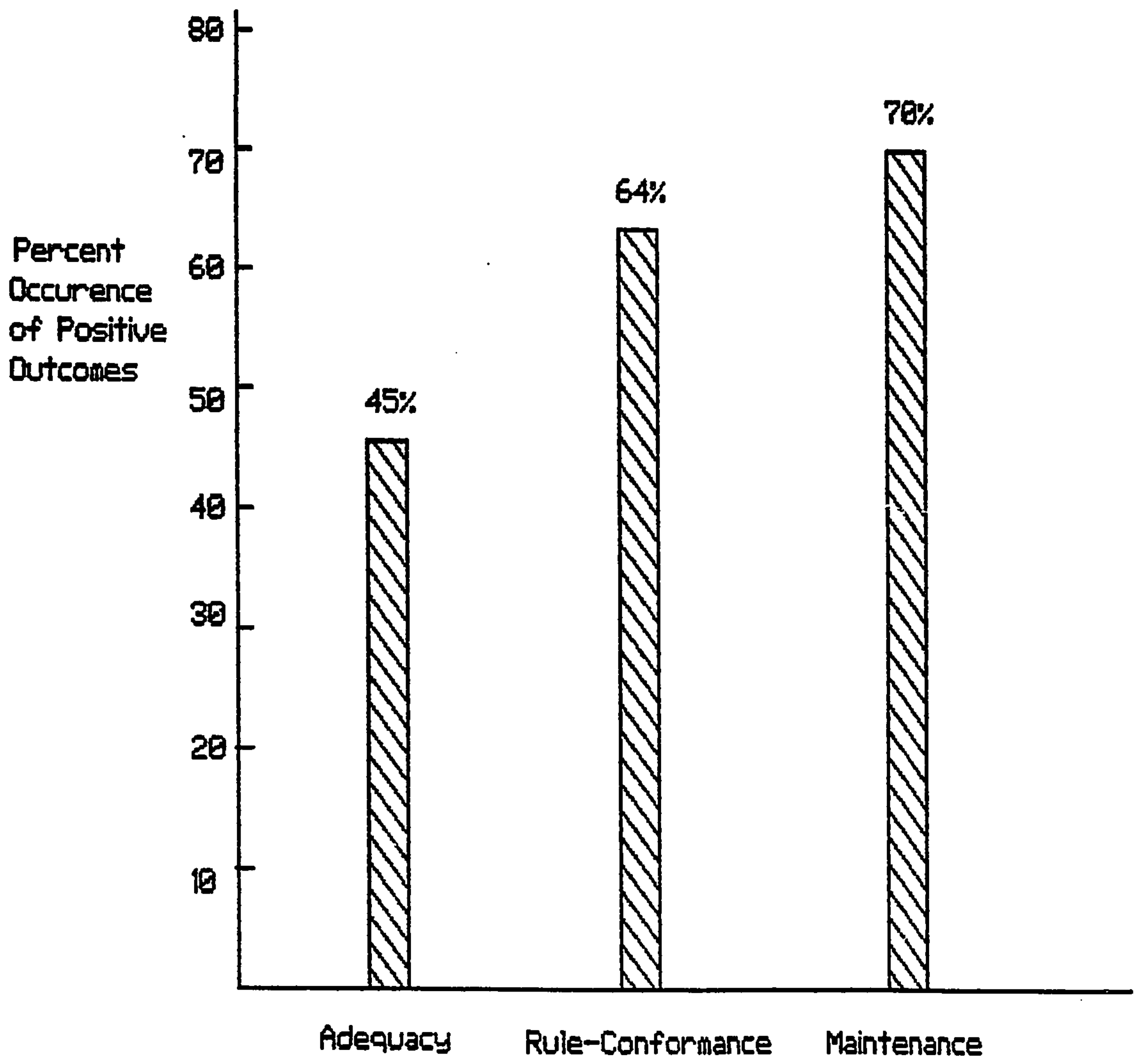
> III. Tanowong (T): "Over the years the inadequacy of the original irrigation sources became more and more of a problem for three reasons: (1) the expansion and increase in the number of terraces on the original site, (2) the construction of new terraces along and below the irrigation ditch which necessarily diverted water permanently, and (3) the denuding through careless cutting and frequent fires of the pine forest of the mountains in the environs of the streams which served as the source of irrigation water. Gradually, therefore, more and more of the original rice terraces, particularly those located in the lowest tiers, were not adequately watered and thus became increasingly unproductive, leading to their conversion to the growing of sweet potatoes" (Bacdayan, 1980: 177).

> IV. Dhabi Minor: "The total amount of water available to each farmer is severely limited; each season most farmers can irrigate only about one-third of their land included in the canal service area.... canal-irrigation supplies have at least three types of uncertainty or unreliability with which the farmer must contend: the timing of water supplies during the season, the quantity of water to be received at various times during the season, and in total, and the timing and quantity of water received at various locations. This uncertainty is in direct contrast to the farmer's allocated turn to receive water..." (Reidinger, 1980: 269 & 281-283).

As shown by these examples, elements such as the quantity of water available from the source, the amount and types of crops cultivated, and the timeliness and reliability of the water supply schedules jointly determine whether there is an adequate supply of water from an irrigation system. Twenty-one or 45 percent of the cases indicate an adequate supply of water (see Figure 4.1).

The coding on the level of water supply is affected by how an irrigation system is defined in the first place. In some cases, irrigators in an appropriation resource have access to water derived from a separate water system. This separate water system, when combined with the original irrigation system, may provide sufficient water for irrigators for cultivation. The water supply from the original irrigation system is considered "inadequate", however, if the

Figure 4.1
Results for Three Outcomes



original system alone does not provide sufficient water for cultivation. In Sananeri Tank, for example, farmers rely primarily on water from the surface irrigation system. In times of water scarcity, they have access to ground water through pumpsets that are owned and operated privately by individual farmers. Since these pumpsets are operated and governed separately from the surface irrigation system, they are not considered parts of the surface system. The level of water supply from Sananeri Tank is considered "inadequate" because farmers can not have enough water for cultivation without supplements from the ground. Besides Sananeri Tank, there are two other cases in the sample -- Char Hazar and Amphoe Choke Chai -- where farmers are able to get sufficient water for cultivation from water sources other than the original irrigation systems. In these two cases, the levels of water supplies from the original systems are still considered "inadequate." The presence or absence of alternative sources of water affects farmers' incentives to cooperate with one another. The relationships between alternative water sources and collective action are discussed in a later section in this chapter.

2. RULE-CONFORMANCE: Do most irrigators follow local operational level rules-in-use related to the appropriation process from this appropriation resource in years other than extreme shortage?

Operational rules are important means of coordinating water allocation and maintenance activities among appropriators. Whether most appropriators are regularly following these rules reflects the viability of these rules as coordinating devices. The following are examples of evidence for these outcomes in some case studies:

An example of a case where most appropriators follow operational level rules-in-use:

I. Pinagbayanan: "In the dry season, the members paid their obligations in cash rather than in kind.... The total collection amounted to P5971.... The association was then able to repay its P10000 loan from the rural bank of Pila. This was a remarkable achievement and it attests to the members' concern for living up to their commitments in a cooperative way" (Cruz, 1975: 255).

An example of a case where substantial numbers of appropriators fail to follow operational level rules-in-use:

II. Char Hazar: "the indigenous farmers' irrigation organization has begun to deteriorate. Traditional rules and regulations are no longer followed, and maintenance tasks are not performed as well as in previous years" (Fowler, ed., 1986: 59).

Thirty or 64 percent of the cases indicate that most appropriators follow operational rules-in-use.

3. **MAINTENANCE:** At the end of this period, is the appropriation resource well-maintained?

Besides the care taken by the appropriators, a wide diversity of elements affects the maintenance of an irrigation system. These factors may include the initial construction and physical environments of the system, and the financial and technological capabilities of the irrigators. One has to take these elements into account when determining whether an appropriation resource is well-maintained. Examples of evidence for this outcome from specific case studies are as follows:

An example of a case where the appropriation resource is "well-maintained":

I. Na Pae: "Because the canal bank is strong and built firmly with rocks, Na Pae members seldom have maintenance problems. However, in some sandy areas where the bank easily slips, there has been trouble before the bank was repaired with concrete.... Since the irrigation system is small and has never been threatened by a natural catastrophe, it requires relatively little work; one good maintenance effort a year is able to keep the system in good working condition.... A few locations along the canal have persistent problems of sand slides and leaking, but when people repair the canal bank with cement the problem is permanently solved" (Tan-Kim-Yong, 1983: 209 & 217-218).

An example of a case where the appropriation resource is "poorly-maintained":

II. Godaplur: "At the time of the study (1976-77), the level of maintenance of all the branches on the watercourse was extremely poor.... for some years after the installation of the tubewell, there was no perceived shortage of water. According to informants this led to a decrease in maintenance efforts, astrophying the already weak sanctions enforcing participation in watercourse cleaning.... The watercourse on all branches was choked with grass, bushes, and trees; leaked through rat holes, thin banks, and at junctions; and water remained standing in many low sections after irrigation" (Merrey and Wolf, 1986: 35).

Thirty-three or 70 percent of the cases indicate that the appropriation resource is well-maintained.

Pattern of Outcomes

The level of water supply, degree of rule conformance, and maintenance are closely related to one another. An adequate supply of water encourages a high degree of rule conformance and maintenance activities, and vice versa. Within the sample of cases, these three outcomes are associated with one another in a pattern that resembles a Guttman scale. In a Guttman scale, the component items can be arranged in a systematic and cumulative fashion so that there will be "a continuum that indicates varying degree of the underlying dimension" (Nachmias and Nachmias, 1987: 475). By employing this property of Guttman scales, one may predict the sequence of collective outcomes generated in irrigation systems.

The Guttman scale as shown in Table 4.1 can be interpreted in two complimentary ways. One interpretation is that the outcomes can be arranged cumulatively along a continuum of increasing degree of

Table 4.1
Three Outcomes Arranged According to a Guttman Scale

Good Maintenance	Rule Conformance	Adequate Water	No. of Cases
yes	yes	yes	21
yes	yes	no	8
yes	no	no	4
no	no	no	13
no	yes	no	1
			Total = 47

CR (Coefficient of Reproducibility) = 1 - 1/47X3 = 0.99

difficulty. Some outcomes are more difficult to attain than others: a case that is characterized by a difficult outcome will usually be characterized by a less difficult outcome, but not vice versa. Within the sample of cases, an adequate supply of water is the most difficult to attain. The degree of difficulty is followed by a high degree of rule conformance and good maintenance. Forty-six out of 47 cases conform to the scalable pattern perfectly. The coefficient of reproducibility, which measures the degree of conformity to a perfect scalable pattern, is 99 percent.

If the scalable pattern is perfect, an irrigation system with a high degree of rule conformance must also be well-maintained; a case with an adequate supply of water must have both a high degree of rule conformance and good maintenance. All 21 cases with adequate supplies of water are characterized by both high degrees of rule conformance and good maintenance (see Table 4.2). Among these 21 cases, the three outcomes tend to reinforce one another. On the one hand, an adequate supply of water encourages appropriators to cooperate in water allocation and maintenance. On the other hand, a high level of rule conformance and good maintenance enable irrigators to further develop and preserve their water supplies.

The Guttman scale also shows that even in cases characterized by good maintenance and a high degree of rule conformance, the supply of water may still be inadequate. Out of the 29 cases with a high degree of rule conformance and good maintenance, eight of them are characterized by an inadequate supply of water (see Table 4.2). These eight cases show that even if appropriators cooperate in rule enforcement and maintenance, an appropriation resource may still have

Table 4.2
RULE-CONFORMANCE/MAINTENANCE by ADEQUACY

	Adequate Water Supply	Inadequate Water Supply	(Total)
Positive in both RULE-CONFORMANCE & MAINTENANCE	100% (21)	31% (8)	(29)
Negative in either RULE-CONFORMANCE or MAINTENANCE, or both	0% (0)	69% (18)	(18)
(Total)	100% (21)	100% (26)	(47)

Percentage Difference = 69%
Chi-Square with continuity correction factor = 20.7
D.F. = 1 P < 0.0001

an inadequate supply of water. Water scarcity may be a result of other constraining factors than appropriators' failure to enforce rules and maintain appropriation resources.

Nayband, for example, is an oasis on the Iranian Plateau where there is plenty of land but a limited supply of water from nearby springs. Water inadequacy is an environmental constraint beyond the irrigators' immediate control. Other examples are Kottapalle, Sananeri, and Nam Tan Watercourse, all of which are located in complex bureaucratic irrigation systems. In these systems, the amount of water available to an appropriation area is affected by such factors as the location of the area within the larger system and decisions by the officials who are responsible for releasing water from the main canal to the area. These factors are beyond the immediate control of the irrigators withdrawing water from the appropriation area. In some situations the level of water supply may not be a pertinent indicator of the success or failure of collective action by the appropriators. In these situations, the adequacy of water supply can be treated as a contextual attribute that affects the structure of incentives facing the appropriators.

Another way to interpret the Guttman scale in Table 4.1 is that problems in irrigation systems are arranged cumulatively along a continuum of increasing severity. If a more severe problem is present the less severe ones are usually also present, but not vice versa. In other words, problems in irrigation systems usually appear in a specific sequence: first, the water supply is scarce or poorly matched to the crops planted by the farmers; then, more and more irrigators fail to follow allocation and maintenance rules; and the maintenance of the appropriation resource begins to deteriorate. If an appropriation resource has an adequate supply of water, it usually will not have problems in rule conformance nor maintenance. If problems do happen in an appropriation resource, water scarcity is usually the first kind to emerge; if additional problems follow, those will be in the areas of rule conformance and maintenance.

Within the sample, all 18 cases with problems in rule conformance or maintenance are also characterized by an inadequate supply of water (see Table 4.2). Although one cannot infer from the pattern that all problems in rule conformance and maintenance are caused directly by water scarcity in an appropriation resource, water scarcity appears to be a major cause of these problems in many individual cases. In these individual cases, water scarcity is the first problem that emerges. The problem subsequently induces conflict among appropriators, thus affecting their willingness to follow allocation and maintenance schedules. A case in point is San Antonio of the Philippines where water shortage created a high level of conflict among appropriators and eventually reduced the ability of the irrigation association to enforce its allocation and maintenance rules. Another example is Mauraro of the Philippines where farmers routinely pierced the canal embankment to increase the flow of water to their field, thus increasing the difficulty for maintaining the irrigation system.

According to the Guttman scale, cases with an inadequate supply of water may or may not have problems in maintenance and rule conformance. In eight of the 26 cases with inadequate supplies of water, most irrigators still follow operational rules-in-use and maintain their appropriation resources well (see Table 4.2). This shows that irrigators may be able to overcome obstacles for collective action created by water inadequacies. Indeed, Wade (1988) found that the more scarce and uncertain the water supply is in South India, the greater the likelihood that a community of cultivators will develop collective arrangements to manage their watercourse. One of the reasons why cultivators in South India will organize under a situation of water scarcity is that they can influence the amount of water available in their village by concerted actions such as bribing officials and intimidating upstream-stealers. Water scarcity, in this particular case, acts as an additional incentive for cultivators to get organized.

On the other hand, if the farmers do not have much chance of increasing their water supply, an inadequate supply of water may reduce their incentives to organize for allocation and maintenance. This is probably the case in the Philippine irrigation system which Wickham and Valera (1979) refer to when they argue that in order to induce farmers to cooperate in managing their watercourses, an effective system-wide management program is a prerequisite. Their arguments imply that if farmers do not have much influence on the amount of water that flows into their watercourse, they have less incentive to cooperate with others than if they do have a reliable and adequate flow of water into their watercourse in the first place.

Regardless of which interpretation of the Guttman scale one adopts, the pattern of outcomes identified in the sample indicates that the chance of having a high degree of rule conformance and good maintenance is smaller in systems with inadequate supplies of water than those with adequate supplies of water. While irrigators' failure to organize water allocation and investment may adversely affect the level of water supply in an appropriation resource, an inadequate supply of water may hinder collective action among irrigators.[2]

Distribution of Benefits and Costs

An additional indicator of the performance of an irrigation system is the distribution of benefits and costs among its appropriators. One question was used to identify this outcome in a case:

1. **DISADVANTAGED:** Are there any appropriators who have been consistently disadvantaged in this period?

Few irrigation systems benefit all irrigators equally because different irrigators may cultivate different amounts of land. Instead of asking whether every irrigator gets an equal amount of water, one may inquire whether there are groups of irrigators who consistently get a disproportionately lesser amount of water to cultivate their crops or pay a disproportionately larger amount of inputs than others. Fourteen or 38 percent out of 37 cases indicate that some appropriators have been consistently disadvantaged in this sense (see Table 4.3).

A group of appropriators could be consistently disadvantaged in two major ways. One has to do with a common problem in most canal irrigation systems where headenders have a natural advantage in their access to water over tailenders. If the supply of water in the appropriation resource is limited and most appropriators fail to follow allocation procedures and to maintain the water delivery facilities, tailenders are likely to get less water than headenders.

Table 4.3
DISADVANTAGED
by RULE-CONFORMANCE/MAINTENANCE

	Positive in both RULE-CONFORMANCE & MAINTENANCE	Negative in either RULE-CONFORMANCE or MAINTENANCE, or both	
Without Disadvantaged Groups	83% (20)	23% (3)	(23)
With Disadvantaged Groups	17% (4)	77% (10)	(14)
(Total)	100% (24)	100% (13)	(37)

Percentage Difference = 60%
Chi-Square with continuity correction factor = 10.6
D.F. = 1   P < 0.01

Ten out of 14 cases that report the presence of a disadvantaged group of appropriators appear to fall into this category (see Table 4.3). All ten cases are characterized by an inadequate supply of water and problems in rule conformance or poor maintenance. Lowdermilk, et al., for example, describe the situation in Punjab Watercourse as follows:

> Given the present system with losses resulting from seepage, dead storage, countless leaks and spills along watercourses at improper elevation along unlevel fields, there is actually a built-in mechanism creating mini-type economic dualism between watercourse users located at the head and tail positions. The farmers who own land at the tail are always at a disadvantage for canal water (Lowdermilk, et al., 1975: 27).

If the problem with water supply, rule conformance, and maintenance in these watercourses are alleviated, the position of the tailenders will be improved considerably.

In some irrigation systems, some irrigators are consistently disadvantaged as a result of institutional arrangements instead of problems in water supply, rule conformance, or maintenance. Four out of the 14 cases that report the presence of a disadvantaged group of appropriators fall into this category (see Table 4.3). One example is Kheri in Tanganyika -- presently Tanzania -- where appropriators were divided into four groups. Two hereditary groups had absolute priority to irrigation water. The other two groups had to purchase water rights from the two hereditary groups. One of the hereditary groups was responsible for managing the irrigation system and, at the same time, acted as "the political rulers of the village with powers to issue orders and constitute themselves a court of law" (Gray, 1963: 164). It appears that water privileges and political powers in the village reinforced each other.

Another example is Felderin in the Swiss Alps where water allocation is based on specific time slots owned by different individuals. In this system, "there are gross inequalities in amount of water available per unit of land" (Netting, 1974: 73). Netting argues that these inequalities are results of subdivisions of properties through inheritance and sale, which at times led to exchanges and reapportionment of water rights. Netting writes:

> A rationalized system of water sharing is resisted by those who derive advantage from the current arrangement. Convenient watering periods during the day are valued, and owners are reluctant to accept other times. Though everyone recognizes that some unfairness of distribution is perpetuated by the existing system, large owners claim (1) that their water is as much a possession as the land and is subject to similar inequalities in tenure, (2) that any reorganization would be dreadfully complicated, and (3) such a project would inevitably arouse suspicion and animosity in all concerned (Netting, 1974: 73).

Some commentators are concerned that indigenous organizations tend to perpetuate inequalities among farmers. They argue that the the decision making processes in many of these communities are dominated by the elite in the communities. The poor and less influential farmers are usually disadvantaged in their access to common pool resources in the communities. An examination of the sample, however does not support this contention. Only four out of 23 community irrigation systems in the sample are characterized by institutional arrangements that are specifically designed to favor one group of irrigators over another.

Most bureaucratic irrigation systems are designed to supply water to whoever cultivate crops in a particular area. No one is supposed to be discriminated against by design. However, problems in water supplies, rule conformance, and maintenance in many of these systems put some of their irrigators, especially the poorer ones who cultivate only lands located in the tail portion of a watercourse, in consistently disadvantaged positions.

Dependency on an Appropriation Resource

Irrigators frequently have to invest their private resources or forgo some immediate, short-term benefits to follow and enforce allocation and maintenance rules. Their incentives to contribute to these investments may be affected by their degree of dependency on the resource. Two questions in our coding forms are indicators of farmers' relative dependency on an appropriation resource:

1. **FAMILY-INCOME**: For most of the appropriators, how dependent are they on this appropriation resource as a major source of family income? (i.e., do most of the appropriators' family incomes come directly from cultivating crops irrigated by the resource?)

2. **ALTERNATIVES**: Do most appropriators have access to an alternative source of water for irrigation?

In about one-half of the cases, most irrigators derive most of their income directly from cultivating crops irrigated by the resource. In the other half, most irrigators have other sources of incomes. These alternative sources of incomes include cultivating crops irrigated by other water sources, raising livestock, and jobs outside the agricultural sector. In 40 percent of the cases, most appropriators have access to alternative sources of water for irrigation. These sources include ground water basins and other appropriation resources where irrigators can get water for irrigation.

Within the sample, neither the availability of alternative sources of incomes nor the availability of alternative sources of water appear to be related to rule conformance and maintenance (see Tables 4.4 & 4.5). These results suggest either (1) that farmers' degree of dependency on an appropriation resource does not affect rule conformance nor maintenance or (2) that their effects could be either positive or negative depending on other contextual factors.

Some of the case studies do illustrate how appropriators' degree of dependency on an appropriation resource affects their incentives for cooperation in various circumstances. Near Char Hazar in Nepal, for example, a new irrigation system was constructed and water leaked from this new system to the Char Hazar system. Farmers in Char Hazar gradually became dependent on the leakage water. Now, most farmers are no longer willing to follow traditional rules and maintenance schedules. The experiences of Char Hazar show that if farmers believe they will get enough water from an alternative source without any extra effort, they will have less incentive to cooperate with others in water allocation and maintenance.

The presence or absence of alternative water sources also affects farmers' strategies in various water zones within the Lam Pra Plerng Irrigation Project -- a bureaucratic irrigation system -- in Thailand (Gillespie, 1975). Zone One (Kaset Samakee), located at the headend of the system, had a reliable supply of water and no alternative source of water. Most farmers in the zone followed water allocation schedules and participated in maintaining ditches in their zone. This is contrasted with the other six zones of the system that were plagued by problems of water allocation and maintenance. In two of these zones, located at the tailend of the system, farmers were also dependent on water from the system, but the supply reaching the zones

Table 4.4
RULE-CONFORMANCE/MAINTENANCE by FAMILY-INCOME

	Most of Family Income from Resource	Half or less of Family Income from Resource	(Total)
Positive in both RULE-CONFORMANCE & MAINTENANCE	68% (15)	58% (11)	(26)
Negative in either RULE-CONFORMANCE or MAINTENANCE, or both	32% (7)	42% (8)	(15)
(Total)	100% (22)	100% (19)	(41)

Percentage Difference = 10%
Chi-Square with continuity correction factor = 0.13
D.F. = 1 P > 0.5

Table 4.5
RULE-CONFORMANCE/MAINTENANCE by ALTERNATIVES

	With Alternative Water Supply	Without Alternative Water Supply	(Total)
Positive in both RULE-CONFORMANCE & MAINTENANCE	53% (9)	58% (14)	(23)
Negative in either RULE-CONFORMANCE or MAINTENANCE, or both	47% (8)	42% (10)	(18)
(Total)	100% (17)	100% (24)	(41)

Percentage Difference = 5%
Chi-Square with continuity correction factor = 0.001
D.F. = 1 P > 0.5

was both erratic and limited. In the other four zones, located at the middle part of the irrigation system, farmers usually received sufficient water from the natural flooding of rivers and did not depend entirely on water from the system. In the words of Gillespie:

> With the introduction of the new irrigation system, Zone One received a dependable supply of water. The farmers took advantage of this and began planting paddy. The higher incidence in Zone One of farmers cleaning their farm ditches when water is scarce may therefore be related to their comparative dependence on irrigation water, since they have no alternative sources. Moreover, the generally porous nature of the soil necessitates the distribution of water as quickly as possible, for the longer it takes to distribute the water the more is lost by seepage, for the water can not flow easily through the ditches because of silt or weeds, the farmers are compelled to keep them clean (Gillespie, 1975: 7).

It appears that the absence of alternative water sources, in combination with a reliable supply of water and extra efforts required to keep the water flowing in the resource, created powerful incentives for farmers in Zone One to cooperate in water allocation and maintenance. As shown by the two tailend zones in the system, farmers dependent on water from an appropriation resource may not have incentives to organize in water allocation and maintenance if they do not have a rather reliable supply of water in the first place. The four zones located in the middle part of the system show that if farmers have access to an inexpensive, alternative source of water, they may not have much incentive to cooperate in governing and maintaining their appropriation resource.

Sananeri in India is another case where the availability of an alternative source, well water, appears to have both positive and negative effect on farmers' incentives to govern their surface water system (Meinzen-Dick, 1984: 62-72). On the one hand, irrigators' potential access to well water encourages them to cooperate in maintaining and securing more water for their surface system. Since it is relatively expensive to extract water from the ground, irrigators have incentives to keep the field channels clean and in good repair in order to move the high-value well water through these channels as efficiently as possible. The availability of well water also helps to ease tension among appropriators when the water supply in the surface system is scarce. On the other hand, the presence of groundwater also creates a potential conflict of interests among irrigators. Well owners would like to ask the irrigators' association to use its resources to lobby for more frequent water issues from government officials. Those irrigators without wells may be unwilling to share those expenses from which they receive little direct benefit. In spite of this negative effect, the existence of an alternative water source, on the balance, facilitates cultivators' cooperation in governing Sananeri.

The experiences of these cases suggest that farmers' degree of dependency on an irrigation system does not directly affect their collective action in irrigation systems. A high degree of dependency on an irrigation system may increase or decrease farmers' incentives for cooperation, depending on the configuration of other contextual factors.

Irrigated Area and Number of Irrigators

Although the information-gathering, communication, decision-making, and monitoring costs for governing a resource tend to increase as the size of the resource increases, large resources are not doomed to failure. Depending on the geographical and hydraulic environments, it may be more economical to develop irrigation systems and watercourses that serve large numbers of fields and irrigators. By adopting appropriate kinds of institutional arrangements, coordination problems in large irrigation systems and appropriation resources can be solved.

Three questions in our coding forms are used to assess this dimension of a case:

1. APPROPRIATION-SIZE: At the end of this period, how many hectares of fields are irrigated by the appropriation resource?

2. NUMBER: At the end of this period, what is the number of appropriators utilizing the appropriation resource?

3. SYSTEM-SIZE: How many hectares of fields are irrigated by the entire irrigation system including production, distribution and appropriation resources?

As discussed in Chapter 3, a simple irrigation system consists of only one appropriation resource. For this kind of case, APPROPRIATION-SIZE and SYSTEM-SIZE are the same. A complex irrigation system consists of multiple appropriation resources. For this kind of case, APPROPRIATION-SIZE and SYSTEM-SIZE are different.

Within the entire sample of cases, the amount of land and number of irrigators served by an appropriation resource fail to show a strong and significant relationship with the level of rule conformance and maintenance in the resource (Table 4.6). Within the sample of complex cases, the total amount of land served by a system also fails to show a significant relationship with the degree of rule conformance and maintenance in its appropriation resource (Table 4.7). Even coordination costs tend to increase as the numbers of fields and

Table 4.6
Logit Estimates of Relation Between RULE-CONFORMANCE/MAINTENANCE and Measures of Appropriation Resources

Variables	Coefficient	t-score
Depedent:		
RULE-CONFORMANCE/MAINTENANCE +		
Independent:		
Hectares of field irrigated by the appropriation resource	0.0036	1.70*
Number of appropriators utilizing the appropriation resource	-0.0006	0.54**
No. of Cases = 37		
R-Square = 0.096		
Adjusted R-Square = 0.04		

\+ Positive in both RULE-CONFORMANCE and MAINTENANCE = 1
Negative in either RULE-CONFORMANCE and MAINTENANCE, or both = 0

* P > 0.05
** P > 0.5

Table 4.7
Logit Estimates of Relation Between RULE-CONFORMANCE/MAINTENANCE and SYSTEM-SIZE Among Complex Systems

Variables	Coefficient	t-score
Dependent: RULE-CONFORMANCE/MAINTENANCE +		
Independent: Hectares of field irrigated by the entire irrigation system	-0.0000	-0.93*
No. of Cases = 12		
R-Square = 0.38		
Adjusted R-Square = 0.31		

+ Positive in both RULE-CONFORMANCE and MAINTENANCE = 1
Negative in either RULE-CONFORMANCE or MAINTENANCE, or both = 0

* P > 0.1

appropriators increase, appropriators are still capable of overcoming these costs and successfully organize their water allocation and maintenance activities in irrigation systems and appropriation resources of substantial sizes. Kottapalle in India, for example, is an appropriation resource that serves about 500 hectares of land and 800 irrigators. Another example is El Mujarilin in Iraq that serves more than 300 hectares of land; the irrigation system in which El Mujarilin is located serves more than 200,000 hectares of land.

Social and Cultural Divisions

If a community of irrigators is divided by ethnic, cultural, clan, racial, caste, or other social differences that inhibit communication, the costs of organizing collective action within the community will be higher than those without divisions. One question was used to identify this attribute:

> 1. CLEAVAGES: Are there any ethnic, cultural, clan, racial, caste, or other differences among appropriators that may affect their capacities to communicate with one another effectively?

In the sample, seven cases (two community and five bureaucratic cases) are reported to have divisions among irrigators that inhibit their communication with one another. The two community cases are characterized by both a high degree of rule conformance and good maintenance; the five bureaucratic cases are characterized by both a low degree of rule conformance and poor maintenance.

Chiangmai is an appropriation resource located in a complex community irrigation system in Thailand. Farmers within the Chiangmai village are divided into two major factions. Although this division has created numerous conflicts among farmers in the village, farmers are able to cooperate with one another in relation to irrigation matters.

In Deh Salm, a community irrigation system in the Iranian Plateau, six brothers from outside of the village purchased water shares of the system and financed the improvement of the qanat (tunnel) that diverts water to the appropriation area. Since then, they gained rights to cultivate land in the village. Later "some of the brothers have sold out, and others or their heirs have settled on one side of the village and become resident cultivators, performing some, if not all, of their own cultivation" (Spooner, 1974: 53). Although these people have become residents in the village, they are not considered members of the community. The division between "members" and "non-members" in the village does not undermine the functioning of the system because the operation and maintenance of the system usually do not require much active involvement and contributions by the irrigators. Unless the qanat is damaged by extreme circumstances, the entire irrigation system does not require much maintenance. Water is allocated according to water shares that correspond to specific time slots in a distribution cycle. This allocation arrangement is self-enforcing because every share holder has incentives to guard his own time slots. As long as the qanat requires no major repair, the irrigation system remains viable in spite of the social division in the village.

Five of the bureaucratic cases (Area Two Watercourse, Gondalpur Watercourse, Dakh Branch Watercourse, Dhabi Minor Watercourse, and Punjab Watercourse), all located in either India or Pakistan, are reported to have communication problems due to social divisions among their participants. In many parts of India and Pakistan, farmers are divided into various caste and subcaste groups, which are further subdivided into kinship or brotherhood groups (Merrey and Wolf, 1986; Lowdermilk, Clyma & Early, 1975). Although these divisions may not inhibit communication and cooperation among farmers in every irrigation system in the two countries, they do make cooperation among irrigators in the five cases more difficult. All these five cases are characterized by inadequate supplies of water, poor maintenance, and low levels of rule conformance among irrigators.

The cleavages among biradaris (kinship groups) in some Pakistani communities are reinforced by the cultural concept of _izzart_ (Merrey and Wolf, 1986). Izzart may be translated variously as "honor", "esteem", or "face". People regard the izzart game as zero-sum in nature, meaning that one acquires izzart only at someone else's expense; "the success of one person is a threat to all the other players, a characteristic that generates competition and jealousy" (Merrey and Wolf, 1986: 38). The concept of izzart may be applied at both an individual and a group level. Many disputes in the Gondalpur, for example, stem from izzart games among biradaris. There is a feeling that the izzart of a biradari must be protected. If the izzart of a member is hurt by a person from a different biradari, other close kinsmen are obliged to be united against the offender. The concern for izzart hinders cooperation among irrigators:

> men oppose or support decisions and programs based on their perceptions of their competitors' position. For example, even though all farmers suffered the exactions of a corrupt tubewell operator, they did nothing because, informants explained, if one man or group proposed petitioning for his removal, others would oppose. This would be done not out of love for the tubewell

> operator but to prevent the others from gaining some advantage from the issue or to pursue some long-standing grudge. This can be carried further: the non-cooperative behavior of [a biradari] on branch A during the watercourse reconstruction was interpreted by informants as based on a desire to prevent others from benefiting -- even if it means foregoing their own potential benefits (Merrey and Wolf, 1986: 39).

Before the British rule, these kinds of conflict were mostly avoided by organizing social activities in small groups. Ancestors of the Gondalpur farmers were cattle herders and part-time farmers. The society was characterized by relative mobility of individuals and families; people moved around in small groups. This dispersion of the population helped to avoid conflict which otherwise would be rampant in larger groups. After the irrigation system was constructed under the British rule, people began to settle down and became full-time farmers. The irrigation system creates situations that require cooperation among substantial numbers of farmers. Traditional cleavages among them, however, become obstacles for their cooperation.

In some other cases, institutional arrangements are developed to mitigate potential conflict in larger groups. In Punjab Watercourse, for instance, informal water turn schedules within the watercourse are adjusted to follow family lines in order to minimize disputes (Lowdermilk, Clyma & Early, 1975: 40). Other cooperative ventures such as the ownership and operation of jalars -- persian wheels used for lifting water from a shallow depth -- within the watercourse are usually organized among kinship members. Although there are occasional exchanges of water turns among kinship groups, their cleavages remain a potential obstacle for cooperative actions of a larger scale.

Distribution of Wealth

The distribution of wealth among irrigators may affect their collective action in water allocation and maintenance. One question was used to identify this attribute:

1. **INCOME-VARIANCE:** What is the variance of the average annual family income across families among appropriators?

In the sample of cases, a low variance of the average annual family income among irrigators tends to be associated with a high degree of rule conformance and good maintenance: seventy two percent more of the cases with low income variance are characterized by both a high degree of rule conformance and good maintenance than of the cases with high income variance (Table 4.8).

This result, however, has to be treated cautiously. Few cases in the sample specifically discuss how the distribution of wealth affects cooperation among irrigators. Only 27 of the cases provide enough information for us to estimate roughly the degree of income variance among the irrigators. Because of the limited number of cases available and the sketchy nature of the information, the test of relationship between income variance and rule conformance and maintenance is merely suggestive. Further, the relationship probably cannot be attributed to income variance alone because the five cases with both high income variance and problems in rule conformance and maintenance are all bureaucratic cases that are also characterized by other features unfavorable to collective action. High income variance is probably one factor among others that create collective action problems in these systems. The limited number of cases available,

Table 4.8
RULE-CONFORMANCE/MAINTENANCE by INCOME-VARIANCE

	Low Income Variance	Moderate Income Variance	High Income Variance	(Total)
Positive in both RULE-CONFORMANCE & MAINTENANCE	89% (8)	75% (9)	17% (1)	(18)
Negative in either RULE-CONFORMANCE or MAINTENANCE, or both	11% (1)	25% (3)	83% (5)	(9)
(Total)	100% (9)	100% (12)	100% (6)	(27)

Chi-Square = 9.1
D.F. = 2 $P < 0.05$

however, prevents us from assessing the relative importance of these factors.

Locational Differences

Locational differences are a major source of collective action problems in many irrigation systems. As discussed earlier, locational differences in conjunction with an inadequate supply of water, a low degree of rule conformance, and poor maintenance may put some irrigators in consistently disadvantaged positions. The influence of locational differences on farmers' collective action in irrigation is documented in some individual cases.

Depending on how plots are distributed along the main canal in a watercourse, irrigators face different incentives for cooperation. Mirza and Merrey (1979) in a study of ten watercourses in Pakistan find that a watercourse is more likely to be better maintained if there is a concentration of power and influence at the tail or at the tail and middle of the watercourse. This is because the powerful and influential people have incentives to help organize water allocation and maintenance activities in the watercourse so that sufficient water can reach their fields located in the middle and tail portions of the watercourse.

In Kottapalle in India, the fields of any one household tend to be scattered about the appropriation resource (Wade, 1988). This pattern of scattered plots is especially prevalent among farmers with large holdings. While the pattern is partly a result of partible inheritance, it is also a way to minimize risk. Land in the area is extremely variable: "in soil type, sub-surface drainage, slope, susceptibility to flash floods, and micro-climate" (Wade, 1988: 47). The possession of fields scattered throughout the village insures against the possibility of losing all crops at the same time. Scattered holdings also enhance collective action in irrigation: since a farmer with land in the headend of the canal may have another plot near the tailend; this creates a common interest in rules that facilitate water allocation throughout the entire appropriation resource.

In some community irrigation systems, irrigators' associations specifically adopt rules to ensure that members have fields in the head, middle, and tail portions of the major canals. For instance, within each watercourse in Zanjera Danum in the Philippines, land along a lateral canal is divided into several blocks perpendicular to the source of water (Coward, 1979). The blocks thus represent differential distance from the water source: some are near the headend of the canal, some near the tailend. Each of the blocks is further divided into several parcels. Each share in the irrigation system is tied to one parcel in each block, so that each share holder has to cultivate parcels of various distances from the water source. This arrangement creates an interest among all irrigators to help deliver water throughout the entire watercourse. When there is not enough water to irrigate an entire watercourse, decisions could be made to discontinue irrigating some of the blocks. In this way, the burden of water scarcity is borne by all irrigators proportionally.

Further, in Zanjera Danum, one or more parcels at the tailend portion of each watercourse are reserved for the watercourse's irrigation leaders. These leaders are allowed to farm these parcels as a compensation for their services to the irrigators. This arrangement encourages the irrigation leaders to work diligently to deliver water efficiently from the head to the tail of the watercourse.

Summary

The pattern of outcomes found in the sample of cases suggests that an inadequate supply of water is a more common problem in irrigation than a low degree of rule conformance and poor maintenance. Although the failure to organize water allocation and maintenance causes water scarcity in some cases, there are also cases where water scarcity results from factors other than a low degree of rule conformance or poor maintenance. Water scarcity in some cases is caused by various environmental and organizational problems that are beyond the immediate control of irrigators. In these cases, the level of water supply in an appropriation resource can be viewed as a contextual variable that affects irrigators' incentives to follow water allocation and maintenance schedules. The chance of having a high level of rule conformance and good maintenance is higher in systems with adequate supplies of water than those with inadequate supplies of water. Extra coordination costs caused by water scarcity appear to be a major factor affecting collective action in some irrigation systems.

An inadequate supply of water, low degree of rule conformance and poor maintenance affect the distribution of benefits among irrigators in some irrigation systems. In these systems, irrigators who cultivate only land at the tail portion of an appropriation resource usually get a disproportionately lesser amount of water than the headenders. Active cooperation among all irrigators is important for ensuring that no irrigator is consistently disadvantaged.

In the sample of cases, high income variance and the presence of substantial social cleavages among appropriators appear to be conducive to low degrees of rule conformance or poor maintenance. This result, however, has to be treated cautiously because (1) a rather small percent of the cases report the presence of these two attributes and (2) all the cases that are characterized by this combination of attributes and outcomes happen to be bureaucratic cases that are also characterized by other features unfavorable for collective action. These two attributes are probably factors among others that impose substantial constraints on irrigators' attempts to organize collective action.

Other physical and community attributes including farmers' degree of dependency on an appropriation resource, size of the irrigated area, and number of irrigators may affect the structures of incentives irrigators face and the kind of institutional arrangement that is needed to coordinate irrigators' activities. Within the sample of cases, these attributes fail to show any significant effect on the level of rule conformance and maintenance in an appropriation resource. Individual cases, however, have documented how some of these attributes are combined with other factors to affect the level of cooperation among irrigators. The lack of strong and significant associations between these attributes and certain outcomes in irrigation systems does not necessarily mean that these attributes are irrelevant for collective action in irrigation systems. These attributes may produce opposite effects, depending on the configuration of other contextual factors.

Tables 4.9, 4.10, and 4.11 show the configurations of outcomes and physical and community attributes of all the 47 cases discussed in this chapter. One may observe from these tables that a wide diversity of configurations of physical and community attributes are represented in the sample of cases. Cases sharing similar physical and community attributes may be characterized by very different outcomes. For instance, Mauraro has a pattern identical to that of Nabagram in terms of their source of family income, lack of alternative water sources, absence of social cleavages, and moderate income variance (see Table 4.9). The outcomes of the two cases, however, are very different.[3]

In conclusion, physical and community attributes create the settings in which irrigators make choices and take actions in an attempt to improve their welfare. Individuals are capable of shaping outcomes in an irrigation system by constituting their own terms of cooperation that take into account the constraints and opportunities created by these attributes. The experiences of some of the cases, such as the one that requires farmers to cultivate fields in the head, middle, and tail portions of the major canals, demonstrate how institutional arrangements may be established to counter potential perverse incentives created by some of these physical and community attributes.

Table 4.9
Outcomes and Physical and Commuity Attributes in Community Irrigation Systems (N = 29)

NAME	ADEQ	RULE	MAIN	DISA	INCO	ALTE	CLEA	VARI	SIZE	NUMB
Mauraro	no	no	poor	yes	h./l.*	no	no	moderate	15	26
Chhahare Khola	no	no	poor	-	-	no	-	-	20	250
Naya Dhara	no	no	poor	-	-	yes	no	-	55	400
Char Hazar	no	no	poor	no	most	yes	no	-	200	-
San Antonio (1)	no	no	poor	yes	h./l.	yes	no	-	23	16
San Antonio (2)	no	no	poor	yes	h./l.	yes	no	-	7	5
Oaig-Daya	no	no	good	no	h./l.	no	no	low	100	86
Silag-Butir	no	yes	good	yes	h./l.	yes	no	-	114	35
Tanowong(T)	no	yes	good	no	h./l.	no	no	-	-	200
Sabangan Bato	no	yes	good	no	h./l.	yes	no	-	94	97
Nayband	no	yes	good	no	h./l.	no	no	low	-	40
Calaoaan	yes	yes	good	-	h./l.	yes	no	-	150	71
Felderin	yes	yes	good	yes	h./l.	-	no	moderate	100/-	75
Kheri	yes	yes	good	yes	most	no	no	moderate	260	130
Raj Kulo	yes	yes	good	yes	most	-	no	low	94	159
Saebah	yes	yes	good	-	-	-	no	-	100	90
Chiangmai	yes	yes	good	no	most	yes	yes	high	-/-	167
Zanjera Danum Sitio	yes	yes	good	no	most	no	no	moderate	45/150	23
Tanowong (B)	yes	yes	good	no	h./l.	no	no	-	-	200
Pinagbayanan	yes	yes	good	no	h./l.	yes	no	moderate	20	17
Thulo Kulo	yes	yes	good	no	most	-	no	low	39	105
Takkapala	yes	yes	good	-	-	-	no	-	95	125
Deh Saim	yes	yes	good	-	most	no	yes	moderate	300	80
Bondar Parhudagar	yes	yes	good	no	-	yes	no	low	4	-
Nabagram	yes	yes	good	no	h./l.	no	no	moderate	29	61
Na Pae	yes	yes	good	no	most	no	no	low	64	80
Agcuyo	yes	yes	good	no	most	no	no	-	9	50
Cadchog	yes	yes	good	no	most	no	no	-	3	200
Silean Banua	yes	yes	good	no	most	yes	no	-	120	206

ADEQ = ADEQUACY (adequacy of water supply)
RULE = RULE-CONFORMANCE (most appropriators follow rules)
MAIN = MAINTENANCE (maintenance of appropriation resource)
DISA = DISADVANTAGED (any appropriators being consistently disadvantaged)
INCO = FAMILY-INCOME (famiy income derived directly from cultivating crops irrigated by appropriation resource)
ALTE = ALTERNATIVES (access to alternative sources of water for irrigation)
CLEA = CLEAVAGES (cultural or social differences among appropriators)
VARI = INCOME-VARIANCE (variance of the average annual family income across appropriators)
SIZE = APPROPRIATION-SIZE/SYSTEM-SIZE (size of appropriation resource in ha/size of irrigation system in ha)
NUMB = NUMBER (number of appropriators utilizing appropriation resource)

- Missing in case
* half or less of family income

Table 4.10
Outcomes and Physical and Community Attributes in Bureaucratic Irrigation Systems (N = 14)

NAME	ADEQ	RULE	MAIN	DISA	INCO	ALTE	CLEA	VARI	SIZE	NUMB
Gondalpur Watercourse	no	no	poor	yes	most	yes	yes	high	200/628000	95
Area One Watercourse	no	no	poor	yes	most	no	-	high	50/628000	50
Area Two Watercourse	no	no	poor	yes	most	no	yes	high	33/229000	10
Dakh Branch Watercourse	no	no	poor	yes	most	yes	yes	high	152/-	56
Dhabi Minor Watercourse	no	no	poor	yes	-	no	yes	high	21/-	60
Punjab Watercourse	no	no	poor	yes	most	yes	yes	moderate	96/-	41
Amphoe Choke Chai	no	no	poor	no	h./l.*	yes	no	-	125/12000	85
Area Three Watercourse	no	yes	poor	yes	most	no	no	moderate	115/33000	460
Kottapalle	no	yes	good	no	most	no	no	moderate	500/-	800
Nam Tan Watercourse	no	yes	good	no	most	-	no	low	100/2046	40
Sananeri	no	yes	good	-	most	yes	no	moderate	173/1172	150
Area Four Watercourse	no	yes	good	no	h./l.	yes	no	low	150/67670	300
Kaset Samakee	yes	yes	good	no	most	no	no	-	28/12000	34
El Mujarilin	yes	yes	good	no	h./l.	no	no	moderate	307/208820	38

ADEQ = ADEQUACY (adequacy of water supply)
RULE = RULE-CONFORMANCE (most appropriators follow rules)
MAIN = MAINTENANCE (maintenance of appropriation resource)
DISA = DISADVANTAGED (any appropriators being consistently disadvantaged)
INCO = FAMILY-INCOME (family income derived directly from cultivating crops irrigated by appropriation resource)
ALTE = ALTERNATIVES (access to alternative sources of water for irrigation)
CLEA = CLEAVAGES (cultural or social differences among appropriators)
VARI = INCOME-VARIANCE (variance of the average annual family income across appropriators)
SIZE = APPROPRIATION-SIZE/SYSTEM-SIZE (size of appropriation resource in ha/size of irrigation system in ha)
NUMB = NUMBER (number of appropriators utilizing appropriation resource)

- Missing in case
* half or less of family income

Table 4.11
Outcomes and Physical and Community Attributes in Other Irrigation Systems (N = 4)

NAME	ADEQ	RULE	MAIN	DISA	INCO	ALTE	CLEA	VARI	SIZE	NUMB
Hanan Sayoc	no	no	good	-	h./l.*	no	no	-	-	600
Lurin Sayoc (1)	no	no	good	-	h./l.	no	no	-	-	400
Lurin Sayoc (2)	no	no	good	-	h./l.	no	no	-	-	400
Diaz Ordaz Tramo	yes	yes	good	no	most	no	-	low	2/150	-

ADEQ = ADEQUACY (adequacy of water supply)
RULE = RULE-CONFORMANCE (most appropriators follow rules)
MAIN = MAINTENANCE (maintenance of appropriation resource)
DISA = DISADVANTAGED (any appropriators being consistently disadvantaged)
INCO = FAMILY-INCOME (family income derived directly from cultivating crops irrigated by appropriation resource)
ALTE = ALTERNATIVES (access to alternative sources of water for irrigation)
CLEA = CLEAVAGES (cultural or social differences among appropriators)
VARI = INCOME-VARIANCE (variance of the average annual family income across appropriators)
SIZE = APPROPRIATION-SIZE/SYSTEM-SIZE (size of appropriation resource in ha/size of irrigation system in ha)
NUMB = NUMBER (number of appropriators utilizing appropriation resource)

- Missing in case
* half or less of family income

Notes

1. Another outcome, the distribution of benefits and costs among cultivators, will be discussed in a later section in this chapter.

2. In the original coding form, the variable about the level of water supply has five values: (1) extreme shortage; (2) moderate shortage; (3) apparently balanced; (4) moderately abundant; and (4) quite abundant. Table 4.12 shows how these five values are related to rule conformance and maintenance. Since no case has been coded as "quite abundant," it is not possible for me to examine the argument, mentioned in Chapter 2, that there will be little collective action by farmers when the supply of water is abundant.

3. The two systems, however, differ in terms of institutional arrangements (see Table 5.17 in Chapter 5).

Table 4.12
RULE-CONFORMANCE/MAINTENANCE by ADEQUACY (in five values)

	Extreme Shortage	Moderate Shortage	Apparently Balanced	Moderately Abundant	Quite Abundant	(Total)
Positive in both RULE-CONFORMANCE & MAINTENANCE	65% (2)	32% (6)	100% (19)	100% (2)	(0)	(29)
Negative in either RULE-CONFORMANCE or MAINTENANCE, or both	35% (5)	68% (13)	0% (0)	0% (0)	(0)	(18)
(Total)	100% (7)	100% (19)	100% (19)	100% (2)	(0)	(47)

CHAPTER 5

INSTITUTIONAL ARRANGEMENTS

Although physical and community attributes may affect collective action in an irrigation system, they seldom dictate its success or failure. As discussed in Chapter 2, the long-term viability of an irrigation system depends on rules that can help to accommodate bounded rationality and safeguard against opportunistic behavior. Cultivators in some irrigation systems are able to shape the structure of the situation they face by constituting rules that take into account the constraints and opportunities created by various physical and community attributes.

Diverse types of institutional arrangements have been documented in the cases. Although the case authors describe the institutional arrangements using different terminologies, information about these institutional arrangements can be translated into a form that one can use to compare the structures of institutions across cases. As discussed in Chapter 2, institutional arrangements can be conceptualized as rules that are distinguishable at least at two levels: operational and collective choice levels.[1] Operational rules stipulate who can participate as appropriators and providers, what the participants may, must, or must not do, and how they will be rewarded and punished. A second set of rules -- collective choice rules -- stipulates the conditions for adopting, enforcing, and modifying operational rules. The distinction between these two levels of rules can serve as a starting point for deciphering information about institutional arrangements discussed in the case studies. By examining rule configurations at each level, one can identify essential differences and similarities underlying various action situations in irrigation systems.

A systematic examination of information contained in the sample of cases reveals the richness and diversity of rule configurations existing in the real world. In this chapter, I discuss some common operational and collective choice rules found in the cases. I also examine how these rules affect outcomes in an irrigation system under various circumstances and some of the factors that lead to the emergence or adoption of these rules.

Operational Rules

Depending on their physical and community attributes, various irrigation systems may pose different types of problems for cultivators. For instance, cultivators in irrigation systems with inadequate supplies of water and poor construction face serious collective action problems in water allocation and maintenance. Four types of operational rules -- boundary, allocation, input, and penalty rules -- are important means of coordinating irrigators in water allocation and maintenance in these irrigation systems.

Boundary Rules

Boundary rules prescribe the requirements individuals have to meet before appropriating water from an appropriation resource. They define the groups of individuals whose actions will affect one another due to their common relationship to an appropriation resource. Four boundary requirements appear most frequently in the case studies:

1. **LAND**: ownership or leasing of land within a specified location.

2. **SHARE**: ownership or leasing of shares, transferable independently of land, to a certain proportion of the water flow or water delivery facilities.

3. **MEMBERSHIP**: membership in an organization.

4. **FEE**: payment of certain entry fee each time before withdrawing water.

Except for a few cases that do not contain enough information to determine, all cases in the sample are characterized by some forms of boundary requirements. As shown in Table 5.1, uniformity exists among bureaucratic irrigation systems and systems governed by local governments: they all adopt land as the sole boundary requirement.[2] There is, however, a great diversity of boundary requirements among community irrigation systems.

Land Versus Other Boundary Requirements

A boundary rule will facilitate cooperation among irrigators if it can limit the number of appropriators to a point where the demand for water does not far exceed the supply. This is because, as discussed in Chapter 4, water scarcity is a major source of conflict in many irrigation systems. Collective action problems may be aggravated if more cultivators or fields are entitled to receive water than the appropriation resource can support. Many irrigation systems that use land as the sole boundary requirement appear to fail to keep the number of irrigators within limits. As shown in Tables 5.2a and 5.2b, a higher percent of the cases that use land as the sole boundary requirement are characterized by an inadequate supply of water, a low

Table 5.1
Boundary Rules in All Cases

REQUIREMENTS	COMMUNITY SYSTEMS	BUREAUCRATIC SYSTEMS	OTHER SYSTEMS
Shares to Resource or Flow	Deh Salm Felderin Nayband Thulo Kulo		
Shares + Membership	Pinagbayanan		
Land	Char Hazar * Chhahare Khola * Chiangmai Mauraro * Naya Dhara * San Antonio (1) * San Antonio (2) * Tanowong (T) Tanowong (B)	Amphoe Choke Chai * Area One Watercourse * Area Two Watercourse * Area Three Watercourse * Area Four Watercourse Dakh Branch Watercourse * Dhabi Minor Watercourse * El Mujarilin Gondalpur Watercourse * Kaset Samakee Kottapalle Nam Tan Watercourse Punjab Watercourse * Sananeri	Diaz Ordaz Tramo Hanan Sayoc * Lurin Sayoc (1) * Lurin Sayoc (2) *
Land + Other Requirements (e.g. membership, fees, shares)	Calaoaan Na Pae Oaig-Daya * Sabangan Bato Zanjera Danum Sitio		
Different Requirements Applied to Different Subgroups	Bondar Parhudagar Kheri Nabagram Raj Kulo Silag-Butir Silean Banua		

Cases with an * are either negative in RULE-CONFORMANCE or MAINTENANCE, or both.
Cases without an * are positive in both RULE-CONFORMANCE and MAINTENANCE

Table 5.2a
ADEQUACY by Boundary Rules

	Land as the sole boundary requirement	Other types or combinations of boundary requirements	(Total)
Adequate Water Supply	22% (6)	75% (12)	(18)
Inadequate Water Supply	78% (21)	25% (4)	(25)
(Total)	100% (27)	100% (16)	(43)

Percentage Difference = 53%
Chi-Square with continuity correction factor = 9.4
D. F. = 1 P < 0.005

Table 5.2b
RULE-CONFORMANCE/MAINTENANCE by Boundary Rules

	Land as the sole boundary requirement	Other types or combinations of boundary requirements	(Total)
Positive in both RULE-CONFORMANCE & MAINTENANCE	37% (10)	94% (15)	(25)
Negative in either RULE-CONFORMANCE or MAINTENANCE, or both	63% (17)	6% (1)	(18)
(Total)	100% (27)	100% (16)	(43)

Percentage Difference = 57%
Chi-Square with continuity correction factor = 11.0
D. F. = 1 P < 0.001

degree of rule conformance, and poor maintenance than cases that adopt other combinations and types of boundary requirements.

In many of the cases that use land as the sole boundary requirement, water is supposed to be available to all plots within a defined command area. While this boundary requirement has the effect of making water available to more individuals, the problem is that more irrigators are often included than the source of water can support. A formal policy goal of many bureaucratic irrigation systems in South Asia is to deliver water to as many farmers and as much land as possible. The official command areas in many of these irrigation systems, however, are much larger than can be supported by the sources of water (Palanisami, 1982). Irrigators in these systems face a high degree of water scarcity and various water allocation and maintenance problems.

In some bureaucratic cases, the government agencies involved may not even have accurate information about their own systems. As documented by Wade (1984), government officials in India have incentives to misrepresent data about their irrigation systems. Officials in the Revenue Department like to report a smaller irrigated area in order to justify a smaller amount of revenue they have to collect from farmers. Those in the Irrigation Department like to report a larger area in order to boast about the amount of work they do. If policy makers cannot have accurate data about the actual volume of water flow in an irrigation system nor the actual amount of land it irrigates, it is difficult for them to deliver adequate amounts of water to cultivators.

Transferable Shares

A theoretically interesting boundary requirement is the ownership or leasing of shares to the water flow or to the physical resource that can be transferred independently of land. The system of independently transferable water shares encourages efficient use of water. Martin and Yoder (1986), for example, compare two community irrigation systems -- Thulo Kulo and Raj Kulo -- in Nepal. Irrigators in Thulo Kulo have a transferable water share system. Farmers who want water are free to purchase water shares from other farmers. Water is likely to go to those who can use it in the most productive manner. In Raj Kulo, water rights during the monsoon rice season are restricted to individuals who cultivate land in a certain part of the village. Even though the supply of water has increased considerably in the past decade, other farmers in need of water cannot benefit from the increased water supply because water rights are tied to particular plots within the original command area and are not independently transferable. Due to this inflexible boundary requirement, excess water is diverted to a drain instead of being used to cultivate crops outside the original command area.

In spite of the efficient feature of transferable water rights, only a few cases in the sample report the use of transferable water rights. In four cases, transferable shares are the sole boundary requirement; in another case, transferable shares are used in conjunction with membership as the boundary requirement (see Table 5.1). There are two possible reasons for the absence of this form of institutional arrangement. One possibility is that transferable water rights are feasible only under very special circumstances. Glick

(1970), for example, argues that more technological control is usually needed to enforce the transferable right system. The cases in the sample, however, do not appear to support this argument: the share arrangements in Deh Salm, Nayband, and Felderin work effectively with little technological and organizational control. In all three systems, each water share corresponds to a fixed time slot in a distribution cycle. Since all share owners know their own time slots, they are supposed to divert water to their own fields from certain outlets during their time slots.

In Thulo Kulo, a somewhat more sophisticated system is at work. The water right arrangement is accomplished through the use of saachos -- beams with several notches of equal depth but varying widths cut into the top. A saacho is "installed in a canal such that all the water flows through the notches causing the flow to be divided proportionally relative to the ratio of the widths of the notches" (Martin and Yoder, 1983a: 14). By adjusting the size of the notch, water can be distributed to individual farmers according to the amounts of water rights they hold. Although such an arrangement is more sophisticated than those in Deh Salm, Nayband, and Felderin, it requires only very simple construction and operating procedures.

The second possible reason why only a few cases report the presence of transferable water rights is that some case authors may have failed to recognize the property right arrangements in some of the irrigation systems. Coward writes:

> The simple technology of traditional irrigation works and the apparent casualness with which they operate often mislead outsiders into assuming that little of value exists. The untrained observer can easily fail to extract from the rude weirs

> and rough canal structures the sometimes intricate property relations which such prior investments have created (Coward, 1986a: 226).

To identify property rights in irrigation systems is difficult not only for "the untrained observer", it is also difficult for experienced researchers. Robert Yoder, for example, indicated that he was not aware of the water share system in Thulo Kulo until after spending six months in the village.[3] Unless careful observation has been made, the detailed property right arrangements in an irrigation system may not be readily apparent.

Allocation Rules

While boundary rules prescribe the requirements one must fulfill before taking water from an appropriation resource, allocation rules stipulate the procedures and bases by which individuals can withdraw water from an appropriation resource. Allocation rules determine how much water one can get and when one can get it. A wide diversity of water allocation rules can be found in the cases. Three types of procedures -- fixed percentage, fixed time slots, and fixed orders -- are frequently used in water allocation. Each of these procedures may be based on different premises such as amount of land held, amount of water needed to cultivate existing crops, number of shares held, location of field, or official discretion. An allocation rule, for instance, may require each irrigator to appropriate water in specific time slots. The length of the slot assigned to each irrigator may be determined by the number of water shares he or she holds, e.g., the greater the number of shares one holds, the longer the time slot one is entitled to.

Most of the cases, except three, in the sample have some form of allocation rules. Although the presence of allocation rules does not guarantee success, the three cases -- Mauraro, Chhahare Khola, and San Antonio (2) -- that lack allocation rules face various kinds of water allocation and maintenance problems. All the three cases have an inadequate supply of water and conflicts arise frequently among appropriators in the absence of any allocation rules.[4]

Fixed Time Slots Versus Other Allocation Procedures

In an irrigation system, more than one set of allocation rules may be used for different occasions. In many irrigation systems, a more restrictive set of allocation rules is used during certain periods in a year and a less restrictive set of allocation rules is used during other periods. Table 5.3 shows the most restrictive sets of rules that are used in the sample of cases. Among the three types of procedures, fixed time slots are the most commonly used. Assigning irrigators fixed time slots may be an economical way of distributing water. As discussed earlier, this method of distributing water is successful in Deh Salm, Nayband, and Felderin. In these systems, all irrigators know their own time slots, each irrigator will show up and divert water to his own plots from certain outlets when his time slot begins.

This water distribution procedure, however, has its potential problem: if the water flow is erratic, an irrigator owning a share for a particular time slot is still uncertain about his or her supply of water. Dhabi Minor Watercourse, for example, is located in a

Table 5.3
The Most Restrictive Allocation Rules in All Cases

	Land/Needs	Shares	Location	Official Discretion	Other
Fixed Percentage	"Raj Kulo"	"Na Pae" "Thulo Kulo" "Zanjera Danum Sitio"		San Antonio (1) *	
Fixed Time Slots	Oaig-Daya * Naya Dhara [Area One Watercourse] * [Area Three Watecourse] * [Area Four Watercourse] [Dhabi Minor Watercourse] *	Doh Saim Felderin Nayband	Calaoaan	Chiangmai Kheri "Na Pae" Pinagbayanan Hanan Sayoc * Lurin Sayoc (2) * [Amphoe Choke Chai] * [Area Two Watecourse] * [Area Three Watercourse] * [Kaset Samakee] [Nam Tan Watercourse]	Lurin Sayoc (1) * [Punjab Watercourse] * [Gondalpur Watercourse] *
Fixed Order	Sabangan Bato [Kottapalle] [Sananeri]		Cadchog Char Hazar Silag-Butir "Zanjera Danum Sitio"	Tanowong (T) Tanowong (B) "Thulo Kulo" "Raj Kulo"	Agouyo Nabagram
NO RULE					Chhahare Khola * Mauraro * San Antonio (2) *

Cases with an * are negative in either RULE-CONFORMANCE or MAINTENANCE, or both.
Cases without an * are positive in both RULE-CONFORMANCE and MAINTENANCE.

Bureaucratic cases are in brackets.

Cases that use more than one allocation rule include: Na Pae, Raj Kulo, Thulo Kulo, and Zanjera Danum Sitio.
These cases are in qoutations

bureaucratic irrigation system where irrigators are assigned time slots in different water distribution cycles within a watercourse. At the system level, water supplies to various watercourses are determined by yet another water distribution cycle. 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.

Forty-five percent more of the cases using fixed time slots as the sole distribution procedure are characterized by problems in rule-conformance or maintenance than those using other types or combinations of distribution procedures (see Table 5.4). 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 without considering whether it is compatible with other institutional and physical attributes of the appropriation resource. The example of Dhabi Minor Watercourse just mentioned is a case in point. Within the sample, this kind of incompatibility appears to happen mostly in bureaucratic irrigation systems: out of the 12 cases that use fixed time slots as the sole distribution procedure and have problems in rule-conformance or maintenance, eight are bureaucratic cases.

Adjusting Water Allocation Rules to Changes in Water Supplies

In some irrigation systems, demands for water may temporarily

Table 5.4
RULE-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	48% (11)	93% (14)	(25)
Negative in either RULE-CONFORMANCE or MAINTENANCE, or both	52% (12)	7% (1)	(13)
(Total)	100% (23)	100% (15)	(38)

Percentage Difference = 45%
Chi-Square with continuity correction factor = 6.5
D. F. = 1 $P < 0.05$

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 light of the changes in the balance between the supply of and demand for water. Within the sample, 19 cases are reported to have two sets of allocation rules. All of them, except one, have more restrictive rules during times of water scarcity than during times of abundance.

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 Cadchog in the Philippines, for example, water flows from the canal to the plots through various take-off points. During the wet season, all the take-off points are kept open most of the time. Water is allowed to reach as many plots as the available water flow can reach. During the dry season when water is scarce, water is distributed in a certain order. The entire irrigated area is divided into four sections, each of which takes turns in obtaining water.

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. In Tanowong of the Philippines, for example, irrigators are allowed to withdraw water freely from the system during the rainy season when water is abundant. During the dry season from February to April, eight to twelve water distributors are selected by appropriators to "take over the task of systematically distributing the water as fairly as they can to the different fields" (Bacdayan, 1980: 176). The involvement of officials in water allocation is a way to reduce conflicts or chances of rule violations among irrigators. Provided that water distributors are held accountable to irrigators, irrigators can be relieved of the trouble of having to spend time and energy guarding their own water allotments against theft.

In Sananeri Tank in India, allocation rules are relaxed at times of extreme water scarcity. Sananeri Tank is located in a large bureaucratic irrigation system. A water users association exists to govern water appropriation activities from the tank. During most of the year, appropriators are allowed to withdraw water from the tank freely. In the dry season, six "water spreaders" appointed by the association take over the water allocation job. These water spreaders, however, stop distributing water whenever the water level in the tank is too low to irrigate the entire appropriation area. They will notify the cultivators of the fact. After that, cultivators may take any available water for their own use. In this situation, cultivators with fields near the tank have an advantage in obtaining water over those with fields farther away. Meinzen-Dick argues that this arrangement reflects the principle that those who receive water should pay for the costs of its acquisition:

> If tank water cannot be used to serve the entire ayacut, it would be unfair to those who did not receive water if common ayacut resources were used to distribute water to the head-enders. The switch from collective to individual distribution ensures that all cultivators in the ayacut receive roughly equal benefit from the water distribution activities of the organization. This also lifts the burden of expense and effort for applying water to the fields from the association (all cultivators) to those who receive additional water (Meinzen-Dick, 1984: 76).

This arrangement has not created too much conflict among irrigators in Sananeri because many irrigators have access to an alternative source of water -- private wells; those who do not own wells may purchase well water from those with electric pumpsets at an hourly rate.

These cases show that 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 one appropriation resource, allocation rules have to be adjusted from time to time to accommodate different degrees of water scarcity.

Input Rules

Input rules stipulate the types and amounts of resources required of each cultivator. There are four major types of inputs an irrigator may be required to contribute: (1) regular water tax; (2) labor for regular maintenance; (3) labor for emergency repair; and (4) labor, money, or materials for major capital investment. As shown in Table 5.5, while regular water taxes are required of irrigators in half of the community cases; they are required in almost all bureaucratic cases. The presence or absence of regular water taxes does not appear to have any definite effect on the outcomes of an irrigation system. With a few exceptions, almost all the cases require some labor inputs from the irrigators. Direct labor inputs from irrigators may or may not solve maintenance problems in an appropriation resource depending on whether the labor force is effectively organized and motivated to do the job.

While capital investments are required in most community cases, they are used in only half of the bureaucratic cases. It appears that irrigators in bureaucratic systems are more motivated to cooperate in water allocation and maintenance if they are involved in capital

Table 5.5
Input Rules in All Cases

NAME	Water Tax	Regular Labor	Emergency Labor	Capital Investment
COMMUNITY SYSTEMS				
Mauraro *	no	yes	no	no
Chhahare Khola *	no	yes	yes	yes
Naya Dhara *	no	yes	yes	yes
Char Hazar *	no	yes	yes	no
San Antonio (1) *	yes	yes	yes	yes
San Antonio (2) *	yes	yes	yes	yes
Oaig-Daya *	no	yes	yes	yes
Silag-Butir	yes	yes	yes	yes
Tanowong (T)	-	yes	yes	no
Sabangan Bato	no	yes	yes	-
Nayband	-	-	-	-
Calaoaan	no	yes	yes	yes
Felderin	no	yes	yes	yes
Kheri	yes	yes	yes	-
Raj Kulo	yes	yes	yes	yes
Saebah	-	yes	yes	yes
Chiangmai	yes	yes	yes	yes
Zanjera Danum Sitio	-	yes	yes	-
Tanowong (B)	-	yes	yes	yes
Pinagbayanan	yes	yes	yes	yes
Thulo Kulo	yes	yes	yes	yes
Takkapala	-	yes	yes	yes
Deh Salm	no	no	no	no
Bondar Parhudagar	yes	yes	yes	yes
Nabagram	yes	yes	yes	-

Cases with an * are either negative in RULE-CONFORMANCE or MAINTENANCE, or both.
Cases without an * are positive in both RULE-CONFORMANCE and MAINTENANCE.
- Missing in case

to he continued...

Table 5.5 (continued)
Input Rules in All Cases

Name	Water Tax	Regular Labor	Emergency labor	Capital Investment
COMMUNITY SYSTEMS				
Na Pae	no	yes	yes	yes
Agcuyo	–	yes	yes	no
Cadchog	no	yes	yes	–
Silean Banua	yes	yes	yes	yes
BUREAUCRATIC SYSTEMS				
Gondalpur Watercourse *	yes	yes	yes	no
Area One Watercourse *	yes	yes	yes	no
Area Two Watercourse *	yes	no	no	no
Dakh Branch Watercourse *	yes	yes	yes	no
Dhabi Minor Watercoures *	yes	no	no	no
Punjab Watercourse *	yes	yes	yes	no
Amphoe Choke Chai *	yes	yes	yes	yes
Area Three Watercourse *	yes	yes	yes	yes
Kottapalle	yes	no	no	yes
Nam Tan Watercourse	yes	–	–	no
Sananeri	yes	yes	yes	yes
Area Four Watercourse	yes	yes	yes	yes
Kaset Samakee	yes	yes	yes	yes
El Mujarilin	–	yes	yes	yes
OTHER SYSTEMS				
Hanan Sayoc *	–	yes	yes	–
Lurin Sayoc (1) *	–	yes	yes	–
Lurin Sayoc (2) *	–	yes	yes	–
Diaz Ordaz Tramo	yes	yes	yes	no

Cases with an * are either negative in RULE-CONFORMANCE or MAINTENANCE, or both.
Cases without an * are positive in both RULE-CONFORMANE and MAINTENANCE.
– Missing in case

investments in their own appropriation resources. Five out of the seven cases that require irrigators to contribute capital investments are characterized by both a high level of rule conformance and good maintenance. Only one out of the seven cases without requirements for capital investments are characterized by both a high level of rule conformance and good maintenance.

Bases For Labor Inputs

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 gets from the resource, e.g., proportional to one's share of the resource, to the amount of land cultivated, or to the amount of water needed for cultivation.

Complete information about rules for regular labor inputs is available in only 17 of the cases coded (see Table 5.6). A higher percent more of the cases using proportional rules are characterized by a high-degree of rule conformance and good maintenance than those using equal rules (see Table 5.7). The relationship, however, is insignificant (with a level of confidence equal to 0.47).

This result does not fully support the argument that labor obligations ought to be proportional to expected benefits in order to be effective (see Chapter 2). Although the insignificant result may be due to the limited number of cases available, one may consider an additional factor -- maintenance intensity -- that may make equal rules more effective than proportional rules in some circumstances. Maintenance intensity can be roughly measured by dividing the total

Table 5.6
Rules for Regular Labor Inputs in All Cases

Basis: PROPORTIONAL	Basis: EQUAL
Chiangmai	
Thulo Kulo	Cadchog
Raj Kulo	Calaoaan
Zanjera Danum Sitio	Na Pae
Oaig-Daya *	Chhahare Khola *
Mauraro *	Naya Dhara *
Diaz Ordaz Tramo	Hanan Sayoc *
	Lurin Sayoc (1) *
[Sananeri]	Lurin Sayoc (2) *
[Gondalpur Watercourse] *	

Cases with an * are negative in either RULE-CONFORMANCE or MAINTENANCE, or both.
Cases without an * are positive in both RULE-CONFORMANCE and MAINTENANCE.

Bureaucratic cases are in brackets.

Table 5.7
RULE-CONFORMANCE/MAINTENANCE by Rules for Regular Labor Inputs

	Proportional Rules	Equal Rules	(Total)
Positive in both RULE-CONFORMANCE & MAINTENANCE	67% (6)	38% (3)	(9)
Negative in either RULE-CONFORMANCE or MAINTENANCE, or both	33% (3)	62% (5)	(8)
(Total)	100% (9)	100% (8)	(17)

Percentage Difference = 29%
Chi-Square with continuity correction factor = 0.51
D. F. = 1   P > 0.1

number of person-days of labor per year mobilized to maintain the production, distribution, and appropriation resources by the total number of appropriators in an appropriation resource. Only eleven of the cases report information about both maintenance intensity and labor input rules for maintenance (see Table 5.8). 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 that have 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 and organizing various contributions from different appropriators. For systems that require only two or three days of work from each appropriator every year, the potential benefits of proportional rules could easily be offset by the costs for keeping records and implementing the proportional rules. Whereas for systems with higher maintenance intensity, the gain from the proportional rule could be higher than the administrative costs.

This argument is supported by the emergency labor rules found in the sample of cases (see Table 5.9). Within the sample, cases using proportional rules do not appear to be more likely to have a high degree of rule conformance and maintenance than those using equal

Table 5.8
Maintenance Intensity and Rules for Regular Labor Inputs

Cases	Basis for Regular Labor Input	Maintenance Intensity (Person-days of labor per cultivator per year)
Cadchog	Equal	4.0
Na Pae	Equal	3.5
Chhahare Khola *	Equal	2.0
Hanan Sayoc *	Equal	1.5
Lurin Sayoc (1) *	Equal	1.5
Lurin Sayoc (2) *	Equal	1.5
Naya Dhara *	Equal	2.0
(Average)		(2.3)
Chiangmai	Proportional	28.0
Thulo Kulo	Proportional	16.7
Raj Kulo	Proportional	11.0
Daig-Daya	Proportional	15.0
(Average)		(17.7)

Cases with an * are negative in either RULE-CONFORMANCE or MAINTENANCE, or both.
Cases without an * are positive in both RULE-CONFORMANCE and MAINTENANCE.

Table 5.9
Rules for Emergency Labor Inputs in All Cases

Basis: PROPORTIONAL	Basis: EQUAL
Chiangmai	Calaoaan
Zanjera Danum Sitio	Thulo Kulo
Naya Dhara *	Raj Kulo
Oaig-Daya *	Na Pae
	Chhahare Khola *
Diaz Ordaz Tramo	
	Hanan Sayoc *
[Sananeri]	Lurin Sayoc (1) *
[Gondalpur Watercourse] *	Lurin Sayoc (2) *

Cases with an * are negative in either RULE-CONFORMANCE or MAINTENANCE, or both.
Cases without an * are positive in both RULE-CONFORMANCE and MAINTENANCE.

Bureaucratic cases are in brackets.

rules (see Table 5.10). In eight of the cases, 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.

Penalty Rules

Individuals may have little incentive to follow allocation and input rules if rule-breakers are not liable to any penalty. Penalty rules can take many forms including incarceration, loss of appropriation rights, fines, and community shunning. Although no single set of penalty rules can guarantee cooperation among irrigators, the absence of penalty rules will make cooperation among irrigators difficult. As shown in Table 5.11, there are seven cases in the sample where none of these four penalties are in use. All these seven cases have problems in rule conformance or maintenance.

The effectiveness of a penalty rule in detering against rule-violations depends on various contextual attributes of an irrigation system. Incarceration, for example, is not a commonly used penalty in irrigation because its enforcement requires the involvement of law enforcement agencies which are not readily available in most irrigation systems. The use of incarceration as a penalty against rule-violators is reportedly used in two of the cases in the sample.

Table 5.10
RULE-CONFORMANCE/MAINTENANCE by Rules for Emergency Labor Inputs

	Proportional Rules	Equal Rules	(Total)
Positive in both RULE-CONFORMANCE & MAINTENANCE	57% (4)	50% (4)	(8)
Negative in either RULE-CONFORMANCE or MAINTENANCE, or both	43% (3)	50% (4)	(7)
(Total)	100% (7)	100% (8)	(15)

Percentage Difference = 7%
Chi-Square with continuity correction factor = 0.06
D. F. = 1 P > 0.5

Table 5.11
Penalty Rules in All Cases

NAME	Incarceration	Loss of Entry Rights	Fines	Community Shunning
COMMUNITY SYSTEMS				
Mauraro *	no	no	no	no
Chhahare Khola *	no	no	no	no
Naya Dhara *	no	no	no	no
Char Hazar *	no	no	yes	yes
San Antonio (1) *	no	no	no	no
San Antonio (2) *	no	no	no	no
Oaig-Daya *	no	yes	yes	yes
Silag-Butir	no	yes	yes	-
Tanowong (T)	no	no	yes	yes
Sabangan Bato	-	-	yes	-
Nayband	no	no	-	-
Calaoaan	-	no	yes	-
Felderin	no	no	no	-
Kheri	no	yes	yes	no
Raj Kulo	no	yes	yes	yes
Saebah	-	-	-	-
Chiangmai	no	no	yes	yes
Zanjera Danum Sitio	-	-	-	-
Tanowong (B)	no	no	yes	yes
Pinagbayanan	no	no	yes	yes
Thulo Kulo	no	no	yes	yes
Takkapala	-	-	-	-
Deh Salm	no	no	no	-
Bondar Parhudagar	no	no	-	yes
Nabagram	no	yes	no	yes

Cases with an * are either negative in RULE-CONFORMANCE or MAINTENANCE, or both.
Cases without an * are positive in both RULE-CONFORMANCE and MAINTENANCE.
- Missing in case

to be continued...

Table 5.11 (continued)
Penalty Rules in All Cases

Name	Incarceration	Loss of Entry Rights	Fines	Community Shunning
COMMUNITY SYSTEMS				
Na Pae	no	no	yes	yes
Agcuyo	no	no	yes	yes
Cadchog	no	no	no	yes
Silean Banua	no	no	yes	yes
BUREAUCRATIC SYSTEMS				
Gondalpur Watercourse *	no	no	no	no
Area One Watercourse *	no	no	-	-
Area Two Watercourse *	no	no	-	no
Dakh Branch Watercourse *	no	no	yes	no
Dhabi Minor Watercoures *	no	-	-	-
Punjab Watercourse *	-	no	yes	no
Amphoe Choke Chai *	no	no	no	no
Area Three Watercourse *	no	no	-	yes
Kottapalle	no	no	yes	yes
Nam Tan Watercourse	-	-	-	-
Sananeri	no	no	-	-
Area Four Watercourse	no	no	-	yes
Kaset Samakee	no	yes	no	no
El Mujarilin	yes	yes	-	yes
OTHER SYSTEMS				
Hanan Sayoc *	no	yes	yes	no
Lurin Sayoc (1) *	no	yes	yes	no
Lurin Sayoc (2) *	no	yes	yes	no
Diaz Ordaz Tramo	yes	no	-	-

Cases with an * are either negative in RULE-CONFORMANCE or MAINTENANCE, or both.
Cases without an * are positive in both RULE-CONFORMANE and MAINTENANCE.
- Missing in case

Incarceration in these cases is enforced and carried out by government authorities. It is used mostly as a potential threat instead of a regular punishment. In Diaz Ordaz in Mexico, for example, a local official called a Sindico is in charge of water distribution among different irrigation sections. The Sindico is the local representative of the state government. He shares responsibility with the local judges in adjudicating disputes among irrigators. If the Sindico considers a dispute especially serious, he may refer the case to the district court where the disputants may face heavy legal expenses and possible incarceration. This potential threat gives the Sindico great authority in settling disputes among irrigators.

Temporary loss of appropriation rights is a serious penalty for farmers who rely on irrigated agriculture as a major source of income. It is reportedly used as a penalty in ten cases in the sample. In most cases, it is used only under special circumstances. In Oaig-Daya in the Philippines, a farmer is required to pay a fine for being absence from a general meeting. If the farmer refuses to pay the fine, officials of the farmers' association will compel the farmer to pay the fine by depriving him of water. In Kaset Samakee, Raj Kulo, Hanan Sayoc, Lurin Sayoc (1), and Lurin Sayoc (2), a farmer will be denied irrigation water if he refuses to work in the periodic cleaning or pay a fine. In Nabagram in Bangladesh, one must have paid irrigation fees in advance before getting the initial water for land preparation and transplanting.

Fines are the most commonly used penalty within the sample of cases: it is reportedly used in 21 cases in the sample. In many of these cases, fines are used in some cases as a routine way of substituting for direct labor inputs. While this kind of arrangement helps ensure that no one can free-ride on others' contributions, it also allows those who have other obligations or dislike manual labor to bail out without undermining the cooperative arrangement among irrigators. In Thulo Kulo, for example, cash fines are levied against those who are absent from maintenance work. The fine for missing a day of ordinary maintenance is equivalent to the wage for a day of work. The fine for missing emergency maintenance is set higher to insure higher rate of attendance. The fine, however, is reduced if the member has some legitimate reasons like illness or being away from the village when the emergency is declared.

Community shunning is a more subtle form of punishing rule-breakers. Community shunning is reportedly used as a penalty against rule-breakers in 18 cases in the sample. Community shunning can be an effective penalty if appropriators have a high level of consensus about the legitimacy and the importance of the operational rules in use. If such a consensus is established, community shunning alone can be an effective check on free-riders. In Cadchog, for example, characterized by a high degree of rule conformance and adequate maintenance, community shunning is the only form of penalty that can be imposed on rule violators.

Collective Choice Arrangements

Operational rules are not self-generating nor self-enforcing. They depend on individuals who in coordination with one another formulate and enforce them. In situations where only small numbers of individuals are involved, individuals might be able to formulate and enforce rules without any explicit collective choice rules. In most cases, however, explicit collective choice rules are needed to formulate, modify and enforce operational rules. Whether participants in an irrigation system can develop and sustain an effective set of operational rules often depends on the kind of collective choice rules available. If properly constituted, collective choice rules enable participants to respond to changes by facilitating the rule adoption and alteration processes. Collective choice rules also help settle disputes among participants and sustain mutually-productive relationships among participants by monitoring and sanctioning against rule-violations and official abuses.

Explicit collective choice arrangements are absent in seven cases and present in forty cases of the sample. In this section, I first discuss the physical and community attributes of the cases without explicit collective choice arrangements and how these attributes affect outcomes in these cases. Then, I discuss the cases with explicit collective choice arrangements and how different types of collective choice arrangements affect outcomes in these cases.

Cases Without Explicit Collective Choice Arrangements

Although collective choice arrangements are usually needed to coordinate rule formulation and enforcement activities, irrigators in small-scale irrigation systems may be able to develop and sustain operational rules without recourse to explicit collective choice arrangements. Explicit collective choice arrangements are absent in seven of the community cases in the sample. Four of the cases are characterized by a high degree of rule conformance and good maintenance. None of them need extensive maintenance and irrigators in these systems are able to arrange to maintain their systems without specific leadership. The other three are characterized by a low degree of rule conformance and poor maintenance.

In the four cases -- Nayband, Felderin, Deh Salm, and Agcuyo -- that are characterized by a high degree of rule conformance and good maintenance, local irrigators have been able to develop and sustain operational rules without explicit collective choice arrangements. Mechanisms to coordinate their activities have evolved as a result of their mutual adjustment rather than conscious design. Felderin in the Swiss Alps is an example where rules have been evolved and sustained through time without affirmation nor enforcement by any explicit collective choice arrangement. Netting describes the evolution of the water share system in Felderin as follows:

> Little organized community activity was required to build the main channels, and as individuals extended the ditches into new meadow areas, they worked out limited and idiosyncratic agreements for water sharing. Though water rights accompany land, they are seldom specified in the elaborate deeds of land transfer that appear from the seventeenth century onward. It is reasonable to assume that inheritance and sale have subdivided properties and at times led to exchange and limited reapportionment of water rights (Netting, 1974: 73).

A similar kind of process appears to have happened in Nayband, Deh Dalm, and Agcuyo, all of which have effective operational rules governing their water allocation and maintenance activities.

These four cases share certain similar attributes. First, they involve either a small number of appropriators or a small irrigated area: Nayband has a population of around 80 families; Felderin irrigates 19 hectares of fields; both Agcuyo and Deh Salm serve 50 families. Because of the small number of individuals or the small area involved, irrigators can monitor one another. Second, the water allocation processes in these cases are self-regulative. Three of the cases -- Nayband, Deh Salm, and Felderin -- adopt water share arrangements that allocate water to share holders according to pre-specified time schedules. Share holders have incentives to monitor one another's activities in an attempt to protect their own water allotments. The water supply in Agcuyo is abundant during the wet season. During the dry months, farmers have to take turns in getting water but there is always sufficient water for all. Third, the four resources require only minimal maintenance. Nayband and Felderin can remain in good shape as long as appropriators use them with care; little maintenance work is required. In Agcuyo, farmers can coordinate in cleaning without specific leadership. In Deh Salm, the appropriation resource only requires limited maintenance. Even cleaning the main canals can be accomplished by individuals.

Although appropriators in these cases are able to manage the day-to-day operation of the irrigation system themselves without explicit collective choice arrangements, they may face serious problems when major challenges arise. A case in point is Deh Salm where water is delivered to the appropriation resource through a qanat (tunnel). Once the qanat is built, it can work for decades without maintenance. If the qanat collapses, however, substantial resources are needed to repair it. During the 1920s, the qanat was destroyed by an unusually heavy rainfall. People in Deh Salm were unable to organize themselves to repair the qanat. They had to rely on people from outside to do the job for them. By doing so, they had to give up some of their water shares to these outside people. If no outsider was interested in investing in the system, these farmers might have lost their entire irrigation system.

Although farmers in some small-scale irrigation systems might be able to govern and sustain their systems without explicit collective choice arrangements, there is no guarantee for success. In the other three cases that are not governed by any explicit collective choice entities -- Mauraro, Chhahare Khola, and Naya Dhara -- appropriators fail to coordinate their activities and face serious problems in water allocation and maintenance. Mauraro in the Philippines, for example, serves only 15 hectares of riceland cultivated by 26 farmers in the wet season. No organization exists to govern the water allocation and maintenance activities in the system. In order to get water, each farmer has to create his own take-off points along the canal and guard the setup against tampering by other farmers. Conflicts over water allocation arise frequently. While farmers are supposed to be responsible for cleaning and repairing parts of the system on or bordering their farms, they have developed no rules regarding maintenance of the entire system. The system as a whole is poorly maintained. This case shows that even in a small irrigation system involving a small number of irrigators, irrigators may fail to develop effective operational rules without recourse to explicit collective choice arrangements.

Cases With Explicit Collective Choice Arrangements

Forty of the cases in the sample have explicit collective choice arrangements that set the terms and conditions for the formulation, enforcement, and alteration of operational rules. Twenty-five of these cases are characterized by a high degree of rule conformance and good maintenance. The other fifteen have problems in rule conformance or maintenance.

As discussed in Chapter 2, whether a set of collective choice arrangements can help solve collective action problems in an appropriation resource depends on its ability to help formulate rules that meet the needs of appropriators, detect and sanction against rule-violations, and hold officials accountable to irrigators. These functions can be discharged by several collective choice arrangements. First, irrigators' direct involvement in making major collective decisions is important for ensuring that the decisions reflect their interests and needs. A way to achieve this is to allow all irrigators in an appropriation resource to participate in making major decisions concerning the resource.

Second, individuals will have little incentive to comply with a set of rules unless they believe their non-compliance will result in substantial punishment. To enforce operational rules, it is necessary to develop mechanisms that are capable of detecting and sanctioning against rule non-compliance. Mutual monitoring among irrigators may be effective in situations where only a small group of farmers is involved. If a larger group of farmers is involved, the provision of monitoring is itself subject to free-riding problems. Specialized officials or monitors have to be appointed to enforce rules.

Third, officials vested with special prerogatives in rule formulation and enforcement are in a position to abuse their powers by interpreting rules to their own advantage or demand favor from individual irrigators. Opportunistic behavior by officials is a potential danger in any collective choice entity. In order to ensure the accountability of irrigation officials, rules are needed to stipulate how irrigation officials are selected and removed, to whom they have to report, and how they are compensated for their services. Officials are likely to be responsive to the needs of irrigators if (1) their tenures are subject to periodic votes by the irrigators; (2) they have to report to the irrigators periodically; and (3) their salaries depend on direct contributions from the irrigators.

Within the sample of cases, collective choice entities governing most of the community cases are characterized by these collective choice rules. Government agencies in bureaucratic cases, on the other hand, are mostly characterized by collective choice rules that are unfavorable to effective rule formulation, rule enforcement, and official accountability. Among cases with explicit collective choice arrangements, 39 percent more of the community cases are characterized by a high degree of rule conformance and good maintenance than the bureaucratic cases (see Table 5.12). Differences in collective choice arrangements help explain why the bureaucratic cases are more likely to have inferior outcomes than the community cases in the sample.

Community Irrigation Systems

Collective choice entities 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 Bondar Parhudagar, for example, the irrigation organization's activities are confined to irrigation matters including

Table 5.12
RULE-CONFORMANCE/MAINTENANCE by Organizational Form in Cases with Collective Choice Arrangements

	Community System	Bureaucratic system	(Total)
Positive in both RULE-CONFORMANCE & MAINTENANCE	82% (18)	43% (6)	(24)
Negative in either RULE-CONFORMANCE or MAINTENANCE, or both	18% (4)	57% (8)	(12)
(Total)	100% (22)	100% (14)	(36)

Percentage Difference = 39%
Chi-Square with continuity correction factor = 4.2
D. F. = 1 P < 0.05

the collection of irrigation levies and maintenance of irrigation canals. In nine other cases, some village-wide or communal organizations that have other responsibilities besides irrigation are responsible for governing the irrigation systems. For instance, the council of elders in Kheri is responsible for governing irrigation matters in the village. It may also constitute itself as a court of law and in formal meetings function as the executive authority for the entire village.

In another case, Na Pae in Thailand, two collective choice entities are involved in governing one appropriation resource. The irrigation organization, headed by two leaders, is responsible for calling meetings, supervising the operation and maintenance of the irrigation facilities, and representing the organization to government agencies. Since all members of the irrigation organization are from a nearby village, the leader of that village can intervene both directly and indirectly in irrigation matters in Na Pae. The village leader is responsible for supervising the elections of the leaders of the irrigation organization which are held every four years in the village temple. He also helps to obtain assistance from government agencies and mobilize cash and labor for special repair and construction projects of the irrigation system.

Nineteen out of the 21 community cases are simple cases. Each of these 19 cases, except Na Pae mentioned above, is governed by one collective choice entity. The other two cases, Zanjera Danum Sitio and Chiangmai, are complex irrigation systems where multiple levels of collective choice entities are involved in governing the systems. Zanjera Danum Sitio, for example, is an appropriation resource within a larger irrigation system. Within a sitio, an irrigation leadership is selected by its own shareholders. The leadership is responsible for coordinating irrigation activities within the sitio. Above the sitio level, the irrigation system is divided into three major branches, each of which is governed by a branch headman who is selected by the total membership of the entire system and serves to coordinate irrigation activities within the branch. At the system level is an organization that deals with important external actors and coordinates activities within the system at both the branch and sitio levels. The leaders of this system-level organization are selected annually by the total membership of the entire irrigation system. These system-level leaders, together with those at the branch and sitio levels, "are able to act in a manner that considers both the location-specific conditions of an individual sitio and the corporate needs of several, or all, sitios" (Coward, 1979: 32).

Five questions about collective choice rules in the collective choice entities in these 21 community cases were asked in the coding form:

1. **GENERAL-MEETINGS**: Can appropriators participate in general meetings to express their needs and concerns to those officials of this organization who make collective choice decisions in relation to the resource?

2. **MONITORS**: Are specialized officials or monitors appointed by appropriators to enforce operational rules?

3. **EXECUTIVE-ELECTION**: Are the chief executives selected through direct or indirect elections by appropriators?

4. **EXECUTIVE-TENURE**: For how long can an individual serve as a chief executive?

5. **EXECUTIVE-PAY**: Are the chief executives paid?

In most of the community cases, major collective decisions concerning an appropriation resource are made in general meetings that involve most irrigators using the resource (see Table 5.13). In Thulo Kulo and Raj Kulo, for example, general meetings for the entire membership of the irrigators' organizations are held in mid-May. 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, a farmer is 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 cases. In Calaoaan in the Philippines, for example, the chairman and the board members of the irrigators' association are responsible for organizing maintenance works. In Nabagram in Bangladesh, 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 got 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,

Table 5.13
Collective Choice Rules in Collective Choice Entities in Community Cases

NAME	GENERAL-MEETINGS	MONITORS	EXECUTIVE-ELECTION	EXECUTIVE-TENURE	EXECUTIVE-PAY
Char Hazar *	yes	yes	yes	fixed +	yes
San Antonio (1) *	yes	yes	yes	fixed	no
San Antonio (2) *	yes	no	yes	fixed	no
Oaig-Daya *	yes	yes	yes	var. ++	no
Silag-Butir	yes	yes	yes	var.	yes
Tanowong (T)	yes	yes	yes	-	yes
Sabangan Bato	yes	no	yes	var.	yes
Calaoaan	yes	yes	yes	var.	no
Kheri	-	yes	no	life +++	yes
Raj Kulo	yes	yes	yes	var.	yes
Saebah	-	-	-	-	-
Chiangmai	yes	yes	yes	life	yes
Zanjera Danum Sitio	-	yes	yes	var.	yes
Tanowong (B)	yes	yes	yes	-	-
Pinagbayanan	yes	yes	yes	fixed	yes
Thulo Kulo	yes	yes	yes	var.	yes
Takkapala	-	-	-	-	-
Bondar Parhudagar	yes	yes	yes	fixed	yes
Nabagram	yes	yes	yes	-	-
Na Pae	yes	no	yes	fixed	yes
Cadchog	yes	no	yes	var.	no
Silean Banua	yes	yes	yes	fixed	yes

Cases with an * are either negative in RULE-CONFORMANCE or MAINTENANCE, or both
Cases without an * are positive in both RULE-CONFORMANCE and MAINTENANCE.
- Missing in case
+ fixed period of time, may be re-elected
++ variable subject to vote of confidence
+++ life term

his service helps reduce the chance of rule violations.

The chief executives in most of these collective choice entities are selected through direct or indirect elections by appropriators. The periods which the chief executives serve, however, vary from case to case. In some of the cases, officials are subject to re-election periodically. In Silean Banua, 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. In Calaoaan in the Philippines, the board of directors of the irrigators' association are selected by irrigators. Their term of office is unspecified. Their tenure ends only when they are incapable of exercising their duties or when they have committed major mistakes. A past chairman of the association, for example, had served for 13 years and resigned from the post because of old age.

The chief executives are compensated in most of the cases. Some of the commonly used compensation 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, 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.[5]

There are, however, a few exceptions where officials are not paid. In Diaz Ordaz Tramo, 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 land-holder within the appropriation resource, 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, the 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.

Bureaucratic Irrigation Systems

In a bureaucratic irrigation system, the production resource is governed by national or regional government agencies. In some bureaucratic systems, the same agencies may govern the distribution and appropriation resources of the systems. In others, different collective choice entities, such as irrigators' associations, are involved in governing activities in the distribution or appropriation resources. In six of the bureaucratic cases in the sample, the appropriation resources are governed solely by government agencies. In the other eight cases, the appropriation resources are governed by both government agencies and local collective choice entities constituted by appropriators.

Four questions about collective choice rules in a government agency were asked in the coding form:

1. FINANCIAL-SOURCE: What is the major financial source of the agency?

2. REPORT-TO-HIGHER-AUTHORITY: Do the administrators who make major operating decisions for the appropriation resource report to any external or higher level authority?

3. OFFICIAL-NEAR-RESOURCE: Do the administrators who make major operating decisions for the appropriation resource reside in or near the resource?

4. **GENERAL-MEETINGS**: Can appropriators participate in general meetings to express their needs and concerns to the administrators who make major operating decisions for the appropriation resource?

Collective choice rules used in most government agencies in the sample are not conducive to rule formulation, rule enforcement, nor holding officials accountable to irrigators. As shown in Table 5.14, the major financial source of all these agencies, with the exception of Area Four 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 appropriation resources 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.

The Provincial Irrigation Department that governs Gondalpur Watercourse in Pakistan, for example, receives funding for recurrent and operational expenditures through Provincial Finance Department allocations. 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

Table 5.14
Collective Choice Rules in Government Agencies in Bureaucratic Cases

NAME	FINANCIAL-SOURCE	REPORT-TO-HIGHER-AUTHORITY	OFFICIAL-NEAR-RESOURCE	GENERAL-MEETINGS
Gondalpur Watercourse *	government	yes	no	no
Area One Watercourse *	government	yes	no	no
Area Two Watercourse *	government	yes	no	no
Dakh Branch Watercourse *	government	yes	no	no
Dhabi Minor Watercourse *	government	yes	no	no
Punjab Watercourse *	government	yes	no	no
Amphoe Choke Chai *	government	yes	yes	yes
Area Three Watercourse *	government	yes	yes	no
Kottapalle	government	yes	no	no
Nam Tan Watercourse	-	yes	yes	no
Sananeri	government	yes	no	no
Area Four Watercourse	irrigators	yes	yes	no
Kaset Samakee	government	yes	yes	yes
El Mujarilin	government	yes	yes	no

Cases with an * are either negative in RULE-CONFORMANCE or MAINTENANCE, or both.
Cases without an * are positive in both RULE-CONFORMANCE and MAINTENANCE.

- Missing in Case

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).

As shown in Table 5.14, in most of the cases, officials who make major decisions for watercourses reside in places far away from the appropriation resources they serve. These officials would 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 appropriation resources also prevent them from acquiring timely and accurate information about different needs of various appropriation resources. In all but two cases, officials do not convene any general meetings with irrigators. Irrigators themselves usually have little formal channels to articulate their interests and grievances to officials.

Robert Wade (1988), in his study of Kottapalle in India, describes how the Irrigation Department's Supervisor and Assistant Engineer relate to farmers there. These officials live and work far away from the village, but have control over the level of water supply to the village. They may visit the village occasionally. During their visit, they will stay mostly with their local contact, a contractor in the village who works regularly for the Irrigation

Department. Rather than helping farmers to solve their irrigation problems, the object of their visit is usually to negotiate the bribe to be paid for assured water supplies to the village. At times when the water supply is exceptionally scarce, farmers in the village even have to send their representatives to the Irrigation Department in the town to get more water for the village through bribery. One, of course, can not generalize from this case that every irrigation bureaucracy is corrupt. The case, however, shows that irrigation officials, if not properly motivated and monitored, may create difficulties for farmers, instead of helping them.

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 the six cases that are governed solely by government agencies are characterized by both a low degree of rule conformance and poor maintenance (Table 5.15). 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 to develop "extra-legal" rules to suit their own circumstances. Merrey, for example, discusses the difference between informal, farmer-established, rotations versus formal rotations established by the Irrigation Department in Gondalpur Watercourse. He writes:

> 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.

Table 5.15
RULE-CONFORMANCE/MAINTENANCE by Local Collective Choice Entity in Bureaucratic Cases

	With Local Collective Choice Entity	Without Local Collective Choice Entity	(Total)
Positive in both RULE-CONFORMANCE & 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)	

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

More time is also allowed for filling long sections of the watercourse (Merrey and Wolf, 1986: 46).

As discussed in Chapter 2, the effectiveness of operational rules depends on local circumstances. The involvement of cultivators in the formulation and enforcement of operational rules at the watercourse level facilitates adaptation to the specific needs of different appropriation areas within a larger irrigation system. In some of the bureaucratic cases, local appropriators have constituted collective choice entities that adopt and enforce their own operational rules at the watercourse level. Complex, bureaucratic cases with local irriagators' 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 percent of those with local collective choice entities are characterized by a high degree of rule conformance and adequate maintenance than those without (see Table 5.15).

As shown in Table 5.16, local collective choice rules in the bureaucratic cases are very similar to the ones found in community irrigation systems. Most of the local collective choice entities in the bureaucratic cases have general meetings that involve their members in making major collective choices. Specialized officials or monitors are appointed by irrigators in most cases to oversee the implementation of operational rules within their appropriation resources. Executives, most of who have fixed or variable terms of office, are selected by irrigators.

Table 5.16
Collective Choice Rules in Local Collective Choice Entities in Bureaucratic Cases

NAME	GENERAL-MEETINGS	MONITORS	EXECUTIVE-ELECTION	EXECUTIVE-TENURE	EXECUTIVE-PAY
Amphoe Choke Chai *	yes	no	yes	fixed +	-
Area Three *	yes	yes	-	-	-
Kottapalle	yes	yes	yes	fixed	no
Nam Tam Watercourse	-	yes	yes	var. ++	yes
Sananeri	yes	yes	yes	var.	no
Area Four Watercourse	yes	yes	yes	fixed	-
Kaset Samakee	yes	no	yes	fixed	-
El Mujarilin	no	-	no	life +++	yes

Cases with an * are either negative in RULE-CONFORMANCE or MAINTENANCE, or both.
Cases without an * are positive in both RULE-CONFORMANCE and MAINTENANCE.
- Missing in case
+ fixed period of time, may be re-elected
++ variable subject to vote of confidence
+++ life term

Despite these similarities, however, one should avoid making any unqualified analogy between irrigators' organizations in community irrigation systems and those within bureaucratic irrigation systems. Irrigators' organizations in community irrigation systems are self-contained entities while those in bureaucratic systems are units within a larger organizational environment. Irrigators' organizations in bureaucratic irrigation systems will not be successful if irrigators fail to perceive a need for them to organize or if their organizations are unable to maintain a significant degree of autonomy in governing their own affairs.

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. Even with the encouragement of the government agency, the irrigators' organization has not been very successful in attracting members and organizing water allocation and maintenance activities because farmers are able to receive sufficient water from the natural flooding of rivers and therefore are not motivated to operate and maintain the canal networks that belong to the irrigation project.

Kottapalle is an example where farmers have been able to constitute their own collective choice entity and enforce their own rules governing their investments and water allocation. The tasks of this entity are performed with neither support nor interference from the government agencies responsible for the irrigation system. Most government officials are not even aware of the existence of the entity. The real need for cooperation in water allocation and the lack of interference from government officials have enabled individual irrigators in Kottapalle to develop their own collective choice arrangements to govern their appropriation resource.

In other cases, such as Nam Tan Watercourse and El Mujarilin, 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, it is a common practice for him to refer 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 solving conflicts among irrigators.

Relationships with Physical and Community Attributes

Differences in collective choice arrangements help to explain why a higher percent of the bureaucratic cases in the sample have problems in rule conformance and maintenance than the community cases. A puzzle, however, remains as to whether the bureaucratic and community cases differ in their performance only because bureaucratic systems tend to have less favorable physical and community features than community cases. As discussed in Chapter 4, inadequate supplies of water, major social cleavages, and high income variance among irrigators are attributes that tend to be associated with problems in rule-conformance and maintenance. As shown in Table 5.17, the community cases in the sample in general are characterized by more favorable physical and community attributes than the bureaucratic

Table 5.17
Physical and Community Attributes and Collective Choice Arrangements in All Cases

NAME	ADEQUACY	CLEAVAGES	INCOME-VARIANCE	Local Collective Choice Arrangements
COMMUNITY SYSTEMS				
Mauraro *	no	no	-	no
Chhahare Khola *	no	-	-	no
Naya Dhara *	no	no	-	no
Char Hazar *	no	no	-	yes
San Antonio (1) *	no	no	-	yes
San Antonio (2) *	no	no	-	yes
Oaig-Daya *	no	no	low	yes
Silag-Butir	no	no	-	yes
Tanowong (T)	no	no	-	yes
Sabangan Bato	no	no	-	yes
Nayband	no	no	low	no
Calaoaan	yes	no	-	yes
Felderin	yes	no	moderate	no
Kheri	yes	no	moderate	yes
Raj Kulo	yes	no	low	yes
Saebah	yes	no	-	yes
Chiangmai	yes	yes	high	yes
Zanjera Danum Sitio	yes	no	moderate	yes
Tanowong (B)	yes	no	-	yes
Pinagbayanan	yes	no	moderate	yes
Thulo Kulo	yes	no	low	yes
Takkapala	yes	no	-	yes
Deh Salm	yes	yes	moderate	no
Bondar Parhudagar	yes	no	low	yes
Nabagram	yes	no	moderate	yes

Cases with an * are either negative in RULE-CONFORMANCE or MAINTENANCE, or both.
Cases without an * are positive in both RULE-CONFORMANCE and MAINTENANCE.
- Missing in case

to be continued...

Table 5.17 (continued)
Physical and Community Attributes and Collective Choice Arrangements in All Cases

Name	ADEQUACY	CLEAVAGES	INCOME-VARIANCE	Local Collective Choice Arrangements
COMMUNITY SYSTEMS				
Na Pae	yes	no	low	yes
Agcuyo	yes	no	-	no
Cadchog	yes	no	-	yes
Silean Banua	yes	no	-	yes
BUREAUCRATIC SYSTEMS				
Gondalpur Watercourse *	no	yes	high	no
Area One Watercourse *	no	-	high	no
Area Two Watercourse *	no	yes	high	no
Dakh Branch Watercourse *	no	yes	high	no
Dhabi Minor Watercoures *	no	yes	high	no
Punjab Watercourse *	no	yes	moderate	no
Amphoe Choke Chai *	no	no	-	yes
Area Three Watercourse *	no	no	moderate	yes
Kottapalle	no	no	moderate	yes
Nam Tan Watercourse	no	no	low	yes
Sananeri	no	no	moderate	yes
Area Four Watercourse	no	no	low	yes
Kaset Samakee	yes	no	-	yes
El Mujarilin	yes	no	moderate	yes
OTHER SYSTEMS				
Hanan Sayoc *	no	no	-	no
Lurin Sayoc (1) *	no	no	-	no
Lurin Sayoc (2) *	no	no	-	no
Diaz Ordaz Tramo	yes	-	low	yes

Cases with an * are either negative in RULE-CONFORMANCE or MAINTENANCE, or both.
Cases without an * are positive in both RULE-CONFORMANE and MAINTENANCE.
- Missing in case

cases. A majority of the community cases are characterized by an adequate supply of water, no major social cleavages, and low to moderate income variance. Twelve out of 14 of the bureaucratic cases, on the other hand, are characterized by an inadequate supply of water. Many of them are also characterized by major social cleavages and high income variance. Within the 14 bureaucratic cases, any one of the three attributes -- major social cleavages, high income variance, or the absence of local collective choice arrangements -- is a sufficient condition for problems in rule-conformance and maintenance.

Because of the limited size of the sample, it is not possible to determine whether institutional attributes or physical and community attributes are more important factors for explaining why a higher percent of the bureaucratic cases have problems in rule conformance and maintenance than the community cases. One cannot begin to separate spurious effects from the actual effects of each of these attributes until a larger set of cases is available.

Despite this limitation, several observations can be made about the configurations of attributes and outcomes shown in Table 5.17. First, no single community case in the sample is characterized by an inadequate supply of water, major social cleavages, and high income variance simultaneously. One possible explanation for this is that farmers in such a situation would face so many obstacles for collective action that they would not have developed and sustained an irrigation system on their own in the first place. Farmers are capable of constructing and governing their own community irrigation systems mostly in situations where neither major physical nor community obstacles exist.

Second, unlike community irrigation systems, many bureaucratic irrigation systems are found in physical and social environments that are unfavorable to cooperation among farmers. One possible reason for this is that bureaucratic agencies are involved mostly in situations where farmers fail to develop their own community irrigation systems in the first place. Another possible explanation is that many bureaucratic irrigation systems are designed to deliver water to as many farmers as possible in order to justify their construction and maintenance costs. Furthermore, some bureaucratic irrigation systems in countries like India and Pakistan were developed as parts of large-scale settlement projects. In such settlement projects, individuals with divergent economic, social, and cultural backgrounds are brought together to share an irrigation system (see Merrey and Wolf, 1986). Bureaucratic agencies in these situations are more likely to face serious governance problems than irrigators' organizations in community irrigation systems.

Third, although bureaucratic agencies are capable of constructing appropriation resources in areas characterized by unfavorable physical and community features, they may not be sufficient to ensure effective operation and maintenance of the appropriation resources. Six of the bureaucratic cases in the sample are characterized by two or three of the unfavorable physical and community features. All six cases are characterized by both a low degree of rule conformance and poor maintenance. Irrigators in these cases face a difficult situation: while the bureaucratic agencies are not effective enough in enforcing rules and maintaining the appropriation resources, irrigators are unable to develop local collective choice arrangements to govern their own activities. Their situation can hardly be improved unless the governing capabilities of the bureaucratic agencies are improved considerably or special initiatives are undertaken to help irrigators develop their own local collective choice arrangements.

Summary

Institutional arrangements in an irrigation system can be analyzed by reference to two levels -- operational and collective choice levels. Operational rules prescribe what must, may, or may not be done in relation to everyday operating activities in an irrigation system. In order to be effective for coordinating irrigators' activities, operational rules have to be compatible with the special circumstances of each irrigation system and appropriation resource. No single set of operational rules is good for all irrigation systems. A boundary requirement that includes more irrigators than the irrigation system can support will induce conflict among appropriators and make cooperation among them difficult. Allocation rules within an irrigation system have to be adjusted in the light of changes in water supplies. Labor inputs from appropriators can be mobilized on different bases depending on the amount of labor needed to maintain a system. The effectiveness of a penalty rule depends on whether it is compatible with other institutional and community attributes.

Counter-intentional consequences may arise if a uniform set of rules is imposed on a large area without considering local variations. One example discussed concerns the use of land as the sole boundary requirement in many bureaucratic irrigation systems. Although the official policy in these systems is to ensure that everyone who needs water gets it, the actual outcome is that many farmers are unable to get the amount of water they are promised.

A greater diversity of operational rules is found among the community cases than the bureaucratic cases in the sample. In most irrigators' organizations, irrigators are regularly involved in making major collective decisions for their own appropriation resources. In most bureaucratic systems, major decisions for an appropriation resource are made by officials who reside far away from the appropriation resource and have little identification with the irrigators. Irrigators' organizations are therefore more likely to develop rules that suit their specific circumstances than government agencies. Collective choice rules adopted by most irrigators' organizations are also more conducive to rule enforcement and holding officials accountable than those adopted in government agencies.

Differences in collective choice arrangements help to explain why a higher percent of the community cases are characterized by high degrees of rule conformance and good maintenance than the bureaucratic cases. The differences also help to explain why, among the bureaucratic cases, those with irrigators' organizations at the watercourse level are more likely to be characterized by a high degree of rule conformance and good maintenance.

Besides collective choice arrangements, physical and community attributes also help to explain why the community cases are likely to have better performance than the bureaucratic cases. Community irrigation systems are likely to be developed and sustained in situations where there is a reasonable supply of water, no major social cleavages, and low to moderate income variance among irrigators. A majority of the bureaucratic cases, on the other hand, are characterized by inadequate supplies of water. Many of them are also characterized by major social cleavages and high income variance. In comparison with irrigators' organizations in community irrigation systems, government agencies in bureaucratic irrigation systems are more likely to face serious collective action problems.

Notes

1. The constitutional choice level that pertains to choices on collective choice rules also has profound effects on any long-term cooperative efforts among humans (see V. Ostrom, 1987). Unfortunately, I am unable to address problems related to constitutional choice rules because they are rarely discussed in the case studies.

2. Of the four cases listed under "OTHER SYSTEMS" in Table 5.1, Lurin Sayoc (1) is governed by barrio-wide rural political officials. The other three are governed by municipal governments.

3. Personal communication.

4. Where there is an abundant supply of water, however, allocation rules may not be necessary. One example is an irrigation system in the Philippines, Nazareno-Gamutan, where water is so abundant that appropriators can have a continuous supply of water and no allocation rule is needed (see Ongkingco, 1973).

5. Letting officials keep the fines they levy is a way to motivate them to monitor and impose sanctions on rule-breakers. The arrangement may also have a perverse effect of encouraging officials to impose fines on irrigators indiscriminately. This perverse effect, however, is counter-balanced by other arrangements such as elections and general meetings that hold officials accountable to irrigators.

CHAPTER 6

CONCLUSIONS

This study began by describing some typical collective action situations faced by participants in irrigation systems. Drawing upon concepts in institutional analysis and transaction cost economics, I developed a theoretical framework for examining how institutional arrangements, in conjunction with various physical and community attributes, affect the structures of incentives facing participants in different collective action situations in irrigation systems. It was argued that participants react differently according to the structure of incentives inherent in the situations they face. Strategic interactions among participants produce different outcomes. Information from 47 case studies was used to examine arguments derived from the theoretical framework.

In this concluding chapter, I first review how information about institutional arrangements in the case studies were deciphered and used for comparison. Second, I highlight the factors that potentially affect the structures of incentives facing participants and their choice of strategies in irrigation systems. Third, I examine the practical implications of this study. In the final section, I discuss some directions for future research.

Comparing Institutional Arrangements

Institutional arrangements are frequently described using specific words that are not comparable from case to case. If one has to rely entirely on these descriptions, it would be impossible to undertake a systematic analysis of the wide diversity of institutional arrangements found in the cases. In this study, institutional arrangements are conceptualized as rules that refer to prescriptions used by a set of individuals to structure interdependent relationships. By searching for the underlying generic structure of rules, rather than the surface manifestations, I was able to identify similarities and differences underlying specific institutional arrangements found in various irrigation systems. This research strategy enabled me to translate information about institutional arrangements contained in the case studies into the form used for comparison.

Two levels of rules -- operational and collective choice rules -- were examined in this study.[1] Operational rules stipulate who can participate in which situations, what the participants may, must, or must not do, and how they will be rewarded and punished. Another set of rules -- collective choice rules -- stipulates the conditions for adopting, enforcing, and modifying operational rules. While participants are subject to the two sets of rules simultaneously, these rules are nested in a hierarchy. Operational rules can be changed or enforced only within the conditions stipulated by collective choice rules. It is usually the case that operational rules can be changed at low cost and more rapidly than collective choice rules. The relative stability of collective choice rules creates continuity for a long-term cooperative arrangement.[2] It is important to make a clear distinction between the two levels of rules when analyzing effects of institutional arrangements and their changes. By examining rule configurations at each level and how they are related, one can identify the essential similarities and differences of institutional arrangements across irrigation systems.

The generic forms of four major operational rules in irrigation systems -- boundary, allocation, input, and penalty rules -- were developed and analyzed in this study. Relationships between several forms of operational rules and outcomes were identified by representing rules in these generic forms. By distinguishing the basic boundary requirements used in irrigation systems, for instance, it was found that a higher percent of the cases using land as the sole boundary requirement have problems in water supply, rule conformance, and maintenance than the cases using other types or combinations of boundary requirements. By using the generic forms to identify operational rules, one will be able to further examine the validity of these relationships when a larger sample of cases is made available in the future. With a larger sample of cases, one may also be able to discover other counter-intuitive relationships between operational rules and outcomes.

Different collective choice entities could be constituted to exercise collective choice prerogatives on behalf of irrigators and related individuals or entities. An irrigation system can be classified by reference to the kinds of collective choice entities that are involved in governing various parts of the system. A bureaucratic irrigation system, in this study, refers to a system whose production resource is governed by a national or regional government agency or enterprise. In some bureaucratic irrigation systems, the distribution and appropriation resources are governed by the same agencies or enterprises. In other bureaucratic systems, separate collective choice entities such as irrigators' organizations or communal enterprises may be responsible for governing activities in the distribution or appropriation resources. A community irrigation system refers to a system whose production resource is governed by an irrigators' organization or a communal enterprise. The distribution and appropriation resources in almost all community irrigation systems are also governed by irrigators' organizations or communal enterprises.

It was found that within the sample of cases, different types of collective choice rules are used in the bureaucratic agencies than irrigators' or communal organizations. The differences in collective choice rules in turn affect what operational rules a collective choice entity adopts and how the collective choice entity enforces them. Bureaucratic irrigation systems are also more likely to be situated in physical and social environments that are less favorable to cooperation among farmers than community irrigation systems. These relationships are further summarized in the next section.

Physical and Community Attributes and Choice of Institutional Arrangements

Institutional arrangements in an irrigation system can be conceptualized as implicit or explicit contractual relationships established by participants to stipulate the constraints for a continuing association. Potential conflicts, however, may arise when individuals, who are characterized by bounded rationality and opportunism, enter into a contractual relationship. The viability of any contractual relationship depends on whether appropriate institutional arrangements are in place to economize on bounded rationality and limit opportunistic behavior of the participants.

In transaction costs economics, asset specificity is the most important factor for explaining the choice of institutional arrangements. It is argued that transactions that involve durable and transaction-specific assets experience "lock in" effects that lead participants to prefer unified ownership (vertical integration) over autonomous trading in the open market (Williamson, 1985; Klein, Crawford, and Alchian, 1978). The involvement of highly transaction-specific assets such as dams, canals, and farmland in an irrigation system also motivates irrigators to develop institutional arrangements that can reduce the level of free-riding that might otherwise occur. Asset specificity, however, is not the only source of collective action problems in irrigation systems.

Physical and Community Attributes

The level of water supply affects individuals' incentives to coordinate with one another in water allocation and maintenance. As the quantity of water available decreases, the temptation to free-ride in water acquisition increases. In a situation of water shortage, extra efforts in monitoring and sanctioning are needed to enforce discipline in water allocation. These extra coordination costs may inhibit collective action in some irrigation systems. Within the sample of cases, a higher percent of the cases with inadequate supplies of water have problems in rule conformance and maintenance than those with adequate supplies of water.

Social and cultural divisions can inhibit coordination among irrigators. The costs of organizing collective action will be higher in communities that are divided by ethnic, caste, clan or other social and cultural differences. In some situations, the divisions may be great enough to prevent any form of long-term cooperation among irrigators. In other situations, conflicts among different groups can be mitigated by organizing collective action within social groups instead of across groups. This strategy however has its limitations, especially in situations that require cooperation involving large numbers of irrigators.

The distribution of wealth among irrigators affects their incentives to cooperate with one another in water allocation and maintenance. A high level of variance among the incomes of irrigators may create obstacles for collective action in some situations. Farmers with disproportionate wealth and influence may be reluctant to cooperate with poorer farmers; or if they do, they may demand more privileges and benefits. Within the sample of cases, a higher percent of the cases where the variance in incomes is low are characterized by rule conformance and good maintenance than those where the variance in incomes is large.

Irrigators' degree of dependency on an appropriation resource may either increase or decrease their incentives for cooperation in water allocation and maintenance, depending on other contextual variables. One of the cases in the sample, for example, shows that if irrigators have enough water for cultivation from an alternative source without much extra effort, they have little incentive to participate in water allocation and maintenance activities within the original irrigation system. In another case irrigators have access to an alternative source of water, well water, by paying a price. Irrigators in this case are still motivated to preserve the original surface irrigation system because it remains a major source of water for them. The availability of the well water as an alternative also helps to ease tension among irrigators when the level of water supply in the surface system decreases.

Locational differences among irrigators affect collective action in many irrigation systems. Depending on how plots are distributed along the main canal in an appropriation resource, irrigators face different incentives in relation to cooperation in water allocation and maintenance. In most canal irrigation systems, plots that are located in the head portion of a canal usually have a more direct and secure access to water than those located in the tail portion. Individuals who only cultivate plots in the head portion may have less incentive to participate in water allocation and maintenance activities than those who cultivate plots in the tail portion. Irrigators will be more willing to cooperate with one another if most of them cultivate plots in both the head and tail portions of a watercourse. In such a situation, most irrigators will have incentive to help move water from the headend to the tailend of the watercourse. In one of the cases in the sample, irrigators have even developed rules that require each member of the irrigation association to cultivate land along the tail, middle, and end portions of the main canal.

In some circumstances, it is more economical to build a large irrigation system that serves a large amount of farmland in order to take advantage of a major source of water. For a large-scale irrigation system, multiple levels of organizations are needed to coordinate activities within the system. Within the sample of cases, the size of the irrigated area and number of irrigators are not significantly related to the degree of rule conformance and maintenance in the appropriation resource. It appears that institutional arrangements, if properly constituted, can reduce coordination costs and facilitate collective action in large irrigation systems.

Operational Rules

While operational rules facilitate coordination among participants, no single set of operational rules is suitable for all circumstances. In order to be effective, operational rules have to be compatible with their physical and community environments. Variety, instead of uniformity, is to be expected when irrigators in diverse physical and community environments develop operational rules to solve their problems.

A boundary rule will facilitate cooperation among irrigators if it can limit the number of appropriators to a point where the demand for water does not far exceed the capacity of the irrigation system. All bureaucratic cases in the sample adopt land as the sole boundary requirement. Although the formal policy in many of these bureaucratic systems is to deliver water to as many farmers and as much land as possible, more irrigators are often included than can be supported by the sources of water. Irrigators in many of these systems face water scarcity and various water allocation and maintenance problems.

Besides the ownership or leasing of land, the other commonly used boundary requirement is the ownership or leasing of water shares that can be transferred independently of land. The system of independently transferable water shares tends to encourage efficient uses of water. If farmers are free to exchange water shares with one another and there is a relatively equal distribution of wealth among farmers, water tends to go to those who can use it in the most productive way.

To organize water allocation activities in an appropriation resource requires detailed knowledge about local circumstances. Even within one appropriation area, allocation rules may have to be adjusted several times a year to match changes in the level of water supply. In some situations, community features affect the choice of allocation rules. In an appropriation resource with major social or cultural cleavages among irrigators, for example, conflicts can be reduced by arranging water turn schedules along lines that divide major social or cultural groups in the community.

Depending on the amount of labor needed to undertake regular and emergency maintenance, labor contributions from irrigators may be mobilized according to different bases. In general, communal labor is likely to be effective if the labor contributions required of an irrigator is roughly proportional to the benefits obtained from the irrigation system, e.g., proportional to the share of water from the system or to the amount of land cultivated. On the other hand, for systems that require only a few days of work from each appropriator every year, the potential benefits of proportional rules can easily be offset by the costs of keeping records and enforcing the proportional rules. In such systems, input rules that require equal contribution from each irrigator can be effective for maintenance. Equal contribution rules may also be an effective means of mobilizing labor for emergency repair. By using equal contribution rules, emergency labor can be mobilized rapidly to deal with situations where speedy repair is necessary for ensuring that the supply of water is not interrupted.

The effectiveness of a penalty rule depends on various contextual attributes of an irrigation system. Incarceration, for example, is not commonly used as a penalty in irrigation matters because its enforcement often requires recourse to formal courts and law enforcement agencies that are not readily available in most irrigation systems. Fines are used in most of the cases in the sample. While fines are often used as a penalty for breaking rules, they are also used as a substitute for labor inputs in many cases. The fine imposed for missing one day's labor is frequently the cost of hiring a replacement worker. Allowing irrigators to bail out from physical work by paying for their replacement gives them more flexibility in planning their own activities, without undermining their cooperative arrangements. Community shunning is also an important means of punishing rule-breakers. In irrigation systems where irrigators have a high level of consensus about the legitimacy and usefulness of the operational rules, community shunning alone can be a sufficient penalty for detering rule violations.

Collective Choice Arrangements

Operational rules are not self-generating nor self-enforcing. Individuals in coordination with one another formulate and enforce operational rules. In irrigation systems where the physical environment is stable and only a small group of irrigators is involved, irrigators may be able to develop and enforce operational rules without any explicit collective choice rules. Irrigators in such irrigation systems, however, may fail to adjust their operational rules or undertake collective initiatives when major challenges arise. In most other irrigation systems, explicit collective choice rules have to be established to stipulate the conditions for rule formulation, adoption, and enforcement. The form of collective choice arrangement used in an irrigation system affects whether effective operational rules can be adopted and how well the operational rules are enforced.

Within the sample of cases, collective choice arrangements have systematic relationships with the kinds of operational rules adopted and outcomes in an appropriation resource. A greater diversity of operational rules was found among the community systems than the bureaucratic systems in the sample. All the bureaucratic cases in the sample, for example, adopt land as the sole boundary requirements while a great diversity of boundary requirements exists among the community cases. While "fixed time slots" are used as the water distribution procedure in most of the bureaucratic cases, a more diverse set of water distribution procedures exists among the community cases. A higher percent of the community cases are characterized by high degrees of rule conformance and good maintenance than the bureaucratic cases. Among the bureaucratic cases, those with irrigators' organizations at the watercourse level are more likely to be characterized by a high degree of rule conformance and good maintenance than those without.

These relationships can be explained in part by the differences in collective choice rules between government agencies and irrigators' or communal organizations. Collective choice rules used in most bureaucratic agencies in the sample of cases are not conducive to effective rule formulation, rule enforcement, or holding officials accountable to irrigators. Most of these bureaucratic agencies, for example, obtain financial resources from either provincial or national governments and not from the farmers they are supposed to serve. Officials in these agencies, being full-time employees of government agencies, report only to authorities within their agencies or supervising their agencies. Few of these officials are strongly motivated to serve the irrigators who can have little effect on the officials' careers inside the bureaucratic hierarchy. These officials tend to adopt uniform sets of rules for different appropriation resources without considering their specific circumstances.

In most of the communal organizations in the sample, irrigators are regularly involved in making collective choices for the irrigation systems. Officials in these organizations are mostly irrigators themselves. They are selected by irrigators and report to irrigators regularly. These collective choice arrangements facilitate the adoption and modification of rules in response to changing circumstances. They also help to enforce rule compliance and hold officials accountable to irrigators. These collective choice arrangements help explain why a greater diversity of operational rules are adopted in the community cases and why a higher percent of the community cases have better performance than the bureaucratic cases. They also help explain why, among the bureaucratic cases, those with irrigators' organizations at the watercourse level are more likely to perform better than those without.

Physical and community attributes also help explain why a higher percent of the community cases have better performance than the bureaucratic cases. Within the sample of cases, community systems in general are characterized by more favorable physical and community attributes than bureaucratic systems. A majority of the community systems are characterized by an adequate supply of water, no major social cleavages, and low to moderate income variance. A majority of the bureaucratic systems, on the other hand, are characterized by inadequate supplies of water. Many of them are also characterized by major social cleavages and high income variance. In comparison with irrigators' organizations in community irrigation systems, government agencies in bureaucratic irrigation systems are more likely to face serious collective action problems.

There are several possible explanations why a higher percent of the bureaucratic irrigation systems are characterized by unfavorable physical and community attributes than community systems. First, many bureaucratic irrigation systems are designed to deliver water to as many farmers as possible in order to justify their construction and maintenance costs. Second, government agencies construct and govern irrigation systems mostly in locations where farmers fail to develop their own community irrigation systems in the first place. Third, some bureaucratic irrigation systems are constructed and governed as a part of a larger settlement project. In such a project, individuals with diverse economic and social backgrounds are brought together in one location. Their economic and social differences can be major obstacles for their cooperation in irrigation matters.

Practical Implications

The above discussions highlighted the factors that may affect the structures of incentives facing participants and the choice and performance of institutional arrangements in irrigation systems. Several practical implications can be drawn from these discussions.

First, rules have to be compatible with their physical and community environments to be effective; policy goals that fail to recognize these constraints may produce counter-intentional results. An example discussed in this study concerns many bureaucratic irrigation systems that are designed to deliver water to as many farmers and as much land as possible. If irrigators are entitled to withdraw more water than an irrigation system can support, serious collective action problems may arise which can undermine the long-term viability of the system. In irrigation systems that are characterized by a high degree of water scarcity, farmers who only cultivate land in the tailend portion of a canal or watercourse are usually in a disadvantaged position in comparison with those who cultivate land in the headend portion. In many cases, tailenders also happen to be from the poorer stratum of the society. Inequity is sustained in these irrigation systems where the official policy is to spread water to as many farmers as possible.

Second, cultivators who are affected by certain rules should be able to participate in modifying and enforcing these rules. Some of the community cases in the sample demonstrate that cultivators are capable of developing their own collective choice arrangements for formulating, altering, and enforcing operational rules for their own appropriation resources. In complex, bureaucratic irrigation systems, irrigators' involvement in the collective choice process at the watercourse level can also help in formulating and enforcing operational rules that are compatible with their own physical and community environments.

Third, although irrigators have the potential to govern their appropriation resource, one can not assume that irrigators in every appropriation resource have already developed organizing capabilities to handle every kind of collective action problem. In some cases, institutional arrangements developed by irrigators are tailored to deal with a very specific range of activities. Even though a set of institutional arrangements may enable irrigators in an appropriation resource to solve their day-to-day operation and maintenance problems, there is no guarantee that the arrangements can help irrigators to solve other types of problems created under alternative circumstances. I discussed earlier in this study a number of community irrigation systems where appropriators have been able to develop and sustain operational rules that coordinate their water allocation and maintenance activities without any explicit collective choice arrangements. These irrigation systems can remain viable because they serve small numbers of irrigators or small irrigated areas and the water allocation and maintenance tasks in the system are simple and straightforward. Irrigators in these systems, however, may face serious coordination problems when unexpected challenges arise.

Potential danger exists when an external authority attempts to provide assistance to a community irrigation system. The physical and community attributes of an appropriation resource may be changed as a result of government intervention. With a new configuration of physical and community attributes, the nature of collective action problems in the resource may be changed and new operational and collective choice rules may be needed to deal with these problems. A development or government agency, for example, may attempt to help irrigators by rebuilding the headwork of their irrigation system or extending its distributory canals to reach more farmland. As a result of these changes, irrigators may be faced with new collective action problems. After new physical devices are installed, for example, new cooperative arrangements may be needed to operate and maintain the devices. After the distributory canals are extended, additional farmland will be involved and new water allocation and maintenance arrangements may be needed. Institutional arrangements that have been successful in the past may not be sufficient to organize irrigators to undertake these new collective tasks.

Fourth, it follows that before a government agency develops plans to involve irrigators in governing a bureaucratic irrigation system or to provide assistance to a community irrigation system, it is important to investigate whether irrigators have already developed sufficient governing ability among themselves. It is unrealistic to assume that irrigators would automatically develop effective institutional arrangements to govern their water allocation and maintenance activities once water begins to flow into a new watercourse in a bureaucratic irrigation system or once new facilities are installed in a community irrigation system.

Fifth, government or development agencies can play a part in helping irrigators to develop their capabilities for governing their appropriation resources. This can be done not by imposing a single blueprint on irrigators, but by facilitating interactions among irrigators themselves. There is no single blueprint as to how irrigators in an appropriation resource can be organized. Although successful irrigators' or communal organizations generally share some similar kinds of collective choice rules, the specifics of these rules differ from case to case. Leaders in most of these organizations, for example, are selected by irrigators and held accountable to irrigators. The specific arrangements by which these leaders are selected and compensated differ from system to system. While cultivators in most of these organizations have to participate in general meetings that make major collective decisions for the organizations, the specific formats of these meetings vary from case to case.

There are reports in the literature about how government officials acted as catalysts for helping irrigators develop their own collective choice arrangements and achieved rather impressive results. One example is an irrigation development project undertaken in Gal Oya, Sri Lanka (Uphoff, 1985, E. Ostrom, forthcoming). Organizers of the project explicitly rejected the idea of devising a single model of "farmer organization" for all 19,000 irrigators of the project. Instead, institutional organizers (IOs), mostly college graduates, were assigned to different appropriation areas in the project. Each IO had to live in the area and become familiar with the irrigators and the problems they faced. Instead of imposing a predefined organizational format on them, the IO tried to help irrigators organize special working committees to deal with specific problems they faced. After irrigators had experienced various working relationships with one another, the IO moved toward establishing an organization among irrigators and selecting leaders to represent the organization. This bottom-up method of organizing was successful in helping irrigators to develop their collective choice arrangements.

Sixth, although government agencies can play an active role in settling disputes among different irrigators' groups and providing legal arrangements that help irrigators to organize and enforce their own contractual arrangements, a local organization will be more effective if it has considerable autonomy to decide on matters that fall within its jurisdiction. In El Mujarilin in Iraq, for example, it is a common practice for irrigation officials to refer conflicts between irrigators back to the local tribe for settlement if the disputes do not involve any clear violation of civil code. This practice allows the traditional tribal organization to remain a viable instrument for solving disputes among its members.

In conclusion, to organize collective action in irrigation systems requires the utilization of "knowledge of the particular circumstances of time and place" (Hayek, 1948). This knowledge is not available to anyone in totality. Collective action problems in irrigation systems have to be solved by recourse to institutional arrangements that enable individuals or groups of individuals to apply their particular knowledge to solve their problems. Even within one irrigation system, multiple decision-making centers can be established to deal with problems of different scopes.

A wide range of constraints and possibilities exists in irrigation systems. Under appropriate circumstances, cultivators are capable of overcoming constraints and sustaining mutually-productive relationships among themselves by developing institutional arrangements that can economize on bounded rationality and limit opportunistic behavior.

Directions for Future Research

In this study, I have utilized a theoretical framework that helps to identify how various physical, community, and institutional variables affect patterns of outcomes in irrigation systems. Arguments derived from the framework have been examined by reference to information contained in 47 cases. Because of the large number of variables and small number of cases available, I could only examine the effects of one variable at a time in most of the analyses. In some instances, it was difficult to separate spurious effects from the actual effects of each of these variables. This limitation was partially compensated by listing crucial contextual variables side by side for each case (as in Tables 4.9 and 5.17). By examining the configurations of these variables, I made some observations as to how these variables are associated with one another and how different configurations of variables are related to various outcomes in the sample of cases. Several possible directions for future research can be identified in light of the present study.

More sophisticated and reliable analyses can be done if the sample is increased to, say, over one hundred cases. First, by using appropriate statistical techniques, one can examine how one variable affects outcomes in an irrigation system while controlling for the effects of other variables. Second, with a larger sample size, one can also use finer scales for the variables than were used in the present study. Most variables in the original coding forms consist of four or five values. In the present study, because of the limited number of cases available, the number of values for most variables was reduced to two. If a larger sample is available, the values as they are used in the coding forms can be retained for analysis. By using a finer scale, one may be able to identify patterns that may not be discernible when a dichotomous scale is used. Third, only 14 out of the 47 cases in the sample are bureaucratic cases. Increasing the number of bureaucratic cases in the sample can compensate for the imbalance in numbers between community cases and bureaucratic cases so that more reliable comparison can be made between the two types of systems.

Collecting and analyzing cases within one country or a particular region of a country is also a way to reduce the problem of spurious effects. By analyzing a set of cases that is situated in similar political, physical, and cultural environments, it will be easier to isolate the effects of institutional arrangements on outcomes. Substantial numbers of cases have been written on irrigation systems in countries such as Nepal, the Philippines, Pakistan, and India (see

Martin, 1989). One may apply the theoretical framework and method developed in this study to examine cases within each of these countries. Information about the general historical, political, and cultural background of each country will help to interpret the patterns of relationships identified in the cases.

Examining changes within one irrigation system is yet another way to reduce the problem of spurious effects. Institutional arrangements of an irrigation system may be changed from time to time while the physical and community attributes of the system remain the same. In Nepal, for instance, many irrigation systems that were once governed by irrigators are now governed by bureaucratic agencies (see Fowler, ed., 1986). By studying how the same irrigation system performs under different institutional arrangements, one can isolate the effects of institutional attributes from other physical and community attributes.

The relationships and puzzles identified in this study can help to guide future field research by suggesting what kinds of control variables to look for when selecting research sites. One puzzle discussed in this study was whether unfavorable physical and community attributes, instead of institutional arrangements, are the major causes of problems in many bureaucratic irrigation systems.
There are two complimentary ways to separate the respective effects of these two sets of variables. One is to select research sites that share similar institutional features, but differ in crucial physical and community features. The other is to select sites that are similar in crucial physical and community features, but differ in institutional features. New research guided by this kind of consideration facilitates knowledge accumulation.

Notes

1. As noted earlier in this study, there is another level of rules -- constitutional choice rules -- that is also a crucial factor affecting the governance of an irrigation system. Due to the lack of relevant information in the cases, this study has not been able to discuss this level of rules.

2. The collective choice rules, in turn, can be changed within terms specified by constitutional choice rules.

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Publications

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