An Institutional Analysis Approach: Findings from the NIIS on Irrigation Performance[1]

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COLLECTIVE ACTION AND THE PRESUMED NEED FOR CENTRAL GOVERNANCE

Current theories of development are predominantly based on the presumption that the obstacles and temptations involved in local collective action problems are so substantial that only national governments have the capacity to surmount them. The temptation to free-ride that underlies collective action problems is viewed as a major deterrent to development. Because each villager would be better off if everyone else contributed to the provision of joint benefits available to all in the village, whether any particular villager contributed or not, it is presumed that villagers will not contribute.

The difficulty of sustaining collective action over the long term, where contributions are obviously costly and benefits are both hard to measure and dispersed over time and space, deepens the pessimism about the likelihood of success of self-organized efforts. The presumed inability of individuals to undertake their own collective action is used as the foundation for a theory of governance that expounds the need for the State. Only the State is viewed as powerful enough to impose and enforce rules on individuals to realize collective benefits. Further, where technical knowledge and economies of scale are involved, it is presumed that this external force should be a large, central government.[3]

National governments in many parts of Asia are perceived as the "owner" of all water (and other natural resources as well) and thus, the only agency that should or could invest in the development of irrigation, and manage the resulting systems through a central bureaucratic structure. This orientation toward the necessity of central authority is intensified by a second presumption that supplying irrigation is largely a technical problem. Together these lead to a belief that "scarce technical expertise is best located in a powerful state bureaucracy where it can be effectively dispensed" (Barker et al., 1984: 26). This persuasion toward professional, central control over the supply of irrigation water is reinforced by the orientation of international aid agencies to work directly with the central ministries of the national government to whom aid funds are extended.[4]

THE PUZZLE OF FARMER-GOVERNED IRRIGATION SYSTEMS IN NEPAL

The existence of a very large number of irrigation systems in Nepal, where farmers have overcome problems of collective action, poses intriguing theoretical puzzles. How have farmers overcome a series of collective action problems to construct, govern, maintain, and manage such a large number of irrigation systems? Even for the systems that have received grants or loans from the national government or from donor agencies, keeping up the maintenance of these systems and regulating their use continues as a day-to-day series of processes requiring substantial and sustained collective action on the part of farmers. Given the remoteness of most of these systems, farmers cannot rely on external agents to enforce rules relating to maintenance responsibilities or allocation of water.

Even more surprising for some development scholars and practitioners are the repeated findings from case studies of farmer-organized irrigation systems in Nepal: agricultural productivity is higher on many farmer-managed systems than is achieved on the larger, professionally-managed government systems that have been constructed in recent years (Pradhan, 1989; Svendsen and Small, 1990; Laitos, et al., 1986; Martin and Yoder, 1983; Shivakoti, 1991, 1992b; Yoder, 1986). The Nepal Irrigation Institutions and Systems (NIIS) database has now been established with information about 127 irrigation systems in Nepal (see E. Ostrom, Benjamin, and Shivakoti, 1992). The initial analysis based on this large number of irrigation systems has also found that farmer-managed irrigation systems (FMIS) perform more effectively in terms of agricultural productivity than agency-managed irrigation systems (AMIS). In Nepal, FMIS achieve a higher average level of agricultural productivity. Of the 127 systems in the NIIS database, we have yield data for 108 systems. The 86 FMIS average 6 metric tons a year per hectare (MT/ha); the 22 AMIS average 5 MT/ha ($p = .06$).

FMIS also tend to achieve higher crop intensities. A crop intensity of 100% means that all land in an irrigation system is put to full use for one season, or partial use over multiple seasons amounting to the same coverage. Similarly, a crop intensity of 200% is full use for two seasons; 300% full use of all land for three seasons. The cropping intensity achieved at the tail end of irrigation systems in the three major agricultural regions of Nepal--the Hills, the River Valleys, and the Terai--are arrayed in Table 1. In all regions, the average tail end cropping intensity achieved on FMIS is greater than on AMIS.

TABLE / **Tailend Cropping Intensity by Type of Governance Arrangement and Terrain**

Terrain	Farmer-Managed Irrigation Systems	Agency-Managed Irrigation Systems	p
Hills (46)	238% (46)	155% (6)	.00
River Valleys (26)	205% (17)	182% (9)	.31
Terai (46)	250% (40)	208% (6)	.06
All Systems (118)	237% (97)	182% (21)	.00

The agricultural yields and crop intensities that farmers obtain depend on whether they can be assured of water during the winter and spring seasons when water becomes progressively more scarce. A higher percentage of FMIS in Nepal are able to get adequate water to *both* the head and the tail of their systems across all three seasons as shown in Table 2. During the spring when water is normally very scarce, about 1 out of 4 FMIS are able to get adequate water to the tail of their systems, while only 1 out of 11 AMIS get adequate water to the tail of their systems. Even in the summer monsoon season, less than

TABLE 2 **Water Adequacy by Type of Governance Arrangement and Season**

Season of Year	FMIS with Adequate Water at the Head	AMIS with Adequate Water at the Head	FMIS with Adequate Water at the Tail	AMIS with Adequate Water at the Tail
Monsoon	97% n = 100	91% n = 23	88% n = 98	43% n = 23
Winter	48% n = 99	43% n = 23	38% n = 98	13% n = 23
Spring	35% n = 98	26% n = 23	24% n = 96	9% n = 23

half of the AMIS get adequate water to the tails while almost 90% of the FMIS get adequate water to the tail of their systems.

Many of the farmer-organized systems in Nepal lack permanent headworks and lining while many government-organized systems have permanent headworks and are at least partially lined. The design and engineering of the farmer-organized systems was undertaken by local farmers or by members of specialized castes who had learned their skill from their forefathers rather than in a schoolroom. The design and engineering of the government-organized systems was undertaken by skilled and trained engineers. Modern engineering works, frequently paid for by international donors, characterize many government systems.

How could these relatively primitive irrigation systems organized by farmers perform at the same or higher levels than the systems operated by a central government? How can these systems motivate farmers to devote days of hard work to keeping these systems going when farmers on many government systems refuse to pay irrigation fees--frequently set at a very low level--to help defray the cost of providing them irrigation water? Are there any principles at work that can help explain the higher performance? Are any of these principles usable in contexts outside of Nepal? What happens when external agencies try to improve the performance of these systems? What can be learned to increase the probability of successful future interventions? How can one account for the range of performance of both farmer and government-organized systems? What general lessons can be learned from an in-depth examination of the institutional, community, and physical variables that affect performance? These are some of the key questions that we are addressing in our larger effort. In this paper, we obviously cannot answer all of these questions but we will provide an overview of the general approach we are taking.

As part of our effort, we have developed a measurement model for evaluating the performance of irrigation systems (Lam, 1992). We identify three dimensions of irrigation performance:

1. **physical**: the condition of the physical system itself (e.g., how well maintained are the irrigation canals),
2. **delivery**: the distribution of water to farmers (e.g., how adequate is the water to the head and tail of systems across agricultural seasons), and
3. **productivity**: the agricultural productivity of the system (e.g., what type of crop intensity and yields are achieved).

In our approach, we examine the key physical attributes of a good or a resource system and how these affect incentives facing participants in regard to the patterns of interaction that affect the performance of a system given the type of rules in use and key attributes of the participants themselves.

IRRIGATION SYSTEMS AS COMMON-POOL RESOURCES

Once an irrigation system is constructed, a common-pool resource (CPR) is created. CPRs are natural resources or constructed facilities where solving the problem of excluding beneficiaries is nontrivial and benefits are subtractable (see Gardner, E. Ostrom, and Walker, 1990; E. Ostrom, Gardner, and Walker, 1993).

Exclusion Problems

Once water is flowing in a canal, it is not very costly for a farmer, whose fields are adjacent to the canal, to construct an opening to allow water to flow onto the farmer's land. If *any* farmer can take water from a system--whether or not the farmer contributes to the cost of providing the system (by participating in governing the system and by contributing labor, materials, or irrigation fees)--few incentives exist for any other farmer to contribute. If farmers do not contribute to the provision of the system, then whether the condition of the system deteriorates or not depends on whether a governmental agency (or a donor) assigns public officials to operate and maintain the system, and the incentives of the public officials who are assigned these tasks.

Subtractability

The second key characteristic of all CPRs is that the flow of benefits produced by a CPR is subtractable. The water that a farmer takes out of an irrigation canal is subtracted from the volume of water in the canal and is not available to other farmers except as drainage occurs in a system. Both CPRs and private goods share the characteristic of subtractability. The water used by one farmer is not available for use by others. A wide variety of allocation rules can potentially be adopted to regulate who receives water, when they receive it, and under what conditions. Whatever allocation rules that officials and/or farmers attempt to establish for an irrigation system, temptations always exist to cheat by taking more water than authorized, taking water at a time that is of more value to the individual farmer than following rules, contributing less inputs than required given the water allocated, or in some other ways of not following rules. Rice farmers in particular prefer to keep their rice fields flooded continuously since rice is intolerant to drying and highly tolerant to excess water. Extra water helps to keep weeds under control.

Asymmetry of Interests

Individuals using surface irrigation systems also face strong asymmetries among themselves created by the physical differences at the head end versus the tail end of an irrigation system. Farmers located high in the system have an opportunity to take water with relatively less effort and do not feel the effect of the scarcity their actions produce on those lower in the system. In addition, farmers located high in the system receive fewer benefits from work devoted to repairing canals--even the canal that passes by their own farm. This asymmetry is a result of the cumulative nature of the process of water loss along a stretch of a canal.

Farmers can increase the level of delivery efficiency of a water course by allocating time and resources to the repair and upkeep of their system. Farmers located high in the system, however, do not fully perceive the extent of benefits produced by maintenance activities since the benefits are compounded along the length of the watercourse. A farmer, who is solely responsible for maintaining the canal passing by his farm outlet, could increase the delivery efficiency in his own reach a small amount--say 1%. If all farmers along the reach were to increase the water delivery efficiency of their own reach by the same small amount, however, the sum of all these improvements would be quite substantial.

The importance of asymmetry is the challenge it adds to the problem of providing irrigation systems over time. Not only is there the regular temptation to free ride, but the farmers at the head of the system would have a hard time fully comprehending how much harm they could generate for those lower in the system by not investing adequately in the maintenance of the canal reaches located higher in the system. Solving this problem calls for the design of rather extraordinarily clever rules to insure that sufficient resources are generated to overcome the typical problems of collective action, made even more difficult by the added problems of asymmetry.

THE EFFECT OF ENGINEERING WORKS

In addition to the shared physical attributes, irrigation systems *differ* in regard to many other physical factors. The presence or absence of storage strongly affects how an irrigation system is operated. In Nepal, most systems are run-of-the-river systems so there is no great variation among Nepali systems in regard to storage.[7] There are, on the other hand, substantial differences among Nepali systems in regard to the permanence of headworks, whether canals are lined or not, the terrain in which an irrigation system is located, and the physical layout of the system including the length of canals and the number of branches. These physical attributes of irrigation systems have been considered extremely important by irrigation engineers and donor agencies.

Substantial investments have been made to improve the performance of irrigation systems by constructing permanent headworks and lining canals. The expectation has been that the investment in improving physical infrastructure would both improve the operation of the systems and substantially reduce the quantity of resources needed each year to maintain the irrigation systems over time. In most instances where external agencies have invested in modern engineering works, however, farmers who had been operating these systems for long periods of time were not consulted about the improvements they were being given. Educated engineers presumed that uneducated farmers did not know enough about hydrology and engineering to be consulted in this process. Consequently, external engineers did not learn from local farmers many of the local details about soil conditions, water velocity, and shifts in the water course of the source, that are important to make physical improvement operate much better than the traditional systems they replace. Nor have irrigation engineers paid much attention to the distribution of water rights that had existed prior to the construction of new systems.

Further, unless an agency allocates substantial personnel to the operation and maintenance of an irrigation system, it is the farmers who must make these systems work after the engineers have reconstructed them. Even when a government agency reconstructs a system that had been built and operated by farmers and takes on the further task of Operation and Maintenance (O&M) of the rebuilt system, it is the farmers who must bear all the risk of growing crops dependent on a supply of water over which they now have no control. Until recently, very little emphasis has been placed on the incentives that farmers or officials (of either a national irrigation bureau or a farmer-organized system) would face after a new irrigation system was constructed or an existing system was improved in terms of physical operation. The presumption has been that making a physical system easier to operate and maintain would *automatically* enable the farmers to produce agricultural products more effectively.

PHYSICAL ATTRIBUTES OF IRRIGATION SYSTEMS AND PERFORMANCE

Headworks

Let us first explore the relationship between the presence or absence of permanent headworks on the three dimensions of performance listed above and developed in Lam (1992). Each of the dimensions is measured by a standardized factor score that depends upon multiple under-

TABLE 3 **The Relationship of Type of Headworks with Dimensions of Performance**

	N	Systems Without Permanent Headworks	Systems With Permanent Headworks	F	P
Physical Condition	(88)	3.7	3.1	18.0	.00
Delivery	(88)	3.8	3.0	19.8	.00
Productivity	(88)	4.4	3.6	18.1	.00

lying variables. There is complete information on all three dimensions of performance in the NIIS database for 88 irrigation systems (30 of which have permanent headworks). The relationship between the presence of permanent headworks and the three measures of performance is shown in Table 3.

These startling results indicate that in regard to the systems for which we have full data, those with permanent headworks perform at a significantly lower level on all three dimensions of system performance. The condition of the canals is not as good, the adequacy of water delivery to farmers is lower, and agricultural yields are lower. Part of the reason for the negative impact of permanent headworks in Nepal may be associated with the problem of aligning a permanent headworks so that it captures water efficiently as river sources shift dramatically from one year to another. Rivers do shift their courses dramatically in the rugged geography of Nepal and it is not unusual to see a permanent headworks that is well aligned to an old river course but very poorly aligned to the current canal of the river.

Permanent Headworks and Labor Inputs

The relationship between the presence of permanent headworks and levels of performance is in the opposite direction than expected by donors and external agencies who have financed most of the permanent headworks constructed in Nepal. On the other hand, the labor mobilized to undertake routine maintenance is much lower on systems with permanent headworks as expected by many irrigation specialists. As shown in Table 4, the average number of days devoted to routine maintenance (unstandardized and standardized by the number of hectares in the service area of an irrigation system and by the number of households being served) is less on systems with headworks than on systems without headworks. This relationship is statis-

TABLE 4 **The Relationship of Type of Headworks with Labor Mobilization**

Average Number of Days:	N	Systems Without Permanent Headworks	Systems With Permanent Headworks	F	P
Devoted to routine maintenance	(107)	1542	948	.7	.40
Per hectare devoted to routine maintenance	(107)	11.5	5.6	4.0	.05
Per household devoted to routine maintenance	(102)	6.6	3.9	2.3	.13

tically significant at the .05 level only for the measure of labor days per hectare.

Reducing the amount of labor resources that farmers allocate to keeping their irrigation system in running order has been interpreted by those making such investments as an unambiguous benefit resulting from the investment in physical capital. These investments are justified in terms of the expected improvements in the performance of systems with better capital structures as well as the savings in yearly maintenance costs that will result. The presumption that the construction of permanent headworks will be associated with a lower amount of labor devoted to maintenance seems to be valid in the Nepal context, but not the expected enhanced performance.

Neither increasing nor decreasing the amount of labor mobilized for routine maintenance should be considered entirely a benefit or a cost. On the one hand, the labor devoted to cleaning canals takes time that could be devoted to other activities (including leisure). The work is onerous and, at times, dangerous. Freeing farmers of heavy work appears to be a benefit. On the other hand, systems where substantial labor is needed from all farmers may be ones in which the mutual interdependence of farmers on each other is made patently obvious to all, particularly to those located at the head end of a system.

Devoting one's labor to the construction and later the maintenance of an irrigation system has been an essential aspect of the creation and recreation of *de facto* property rights for those who do not have extensive assets. Investing one's labor "creates a social contract by which each irrigator both claims a portion of the water available to the system and agrees to acknowledge the claims of others" (Ambler, 1990: 37). Building irrigation works that reduce labor inputs may have a concomitant result of reducing the water rights of those who are least well off--the poor farmers, particularly those located at the tail end of a system.

The asymmetries that exist between head enders and tail enders on irrigation systems can be extreme and can generate substantial conflict and lack of cooperation among farmers. If the strategic physical advantage that head enders derive from their location on a canal is not offset by an active operation and management system (organized and enforced locally either by the farmers themselves or by an agency), head enders may simply take far more than their share of water thus reducing the quantity and reliability of water available to tail enders.

As a result, where tail enders are obviously needed by head enders for the labor they contribute to the maintenance of the system, substantially reducing the amount of labor that farmers contribute to maintenance through an externally funded and constructed permanent headworks, may disrupt the internal relationships among farmers and destroy the organization that had made the earlier more primitive structure work.

Lining and Performance

Lining the canals of an irrigation system, like the construction of permanent headworks, is considered by many irrigation specialists to be an essential aspect of any modern well-functioning irrigation system. An unlined canal may allow a substantial amount of water to seep into the ground before it reaches the roots of the crops planted by farmers. In Table 5 we examine how combinations of lining and permanent headworks are related to levels of labor mobilization and irrigation performance.

The first entry in each cell in Table 5 is the average value for this type of system. The second entry within square brackets is the standard deviation. While the number of cases for some combinations of headworks and lining are relatively low and the standard deviations for most of the labor and performance measures are relatively high, the table provides some interesting information not previously available. Irrigation systems that have both permanent headworks and are fully lined mobilize the least amount of labor but are also at the lower end of the measure of agricultural productivity. Partially lined systems mobilize an intermediate amount of labor--how much depending on whether the systems also have permanent headworks--and perform at an intermediate level. Systems with the highest agricultural productivity are those that lack permanent headworks or even partial lining and face the highest need for labor mobilization for routine maintenance.

To better analyze how physical attributes of irrigation systems, such as headworks and lining, interact with various institutional variables which in turn affect system performance, we have simplified the classification used in Table 5 and classified systems into three groups of physical environment: Group 1--systems without any lining or permanent headworks; Group 2--systems with partial lining but without permanent headworks; and Group 3--systems with permanent headworks. Most of the Nepali irrigation systems in the database with permanent headworks are partially lined, but six systems in Group 2 have full lining and three of these systems have no lining at all.

We have data about physical attributes for 125 systems. In Table 6, we have arrayed these three groupings of systems by whether they are self-governed by the farmers or agency-governed. All of the Group 1 systems in the NIIS database--without permanent headworks and without lining--are farmer-governed systems. Almost 9 out of 10 of the Group 2 systems are FMIS. Of the 23 AMIS in the NIIS database, 18 are in Group 3 and have permanent headworks. Of the 102 farmer-governed systems in the database, 28 are in the third group.

TABLE 5 **Effect of Headworks and Lining on Labor Mobilization and Irrigation Performance**

Type	Total Labor Days	Labor Days per Hectare	Labor Days per Household	Physical Condition	Agricultural Productivity
Fully lined systems with permanent headworks	218 [323] N = 5	1.38 [1.45] N = 5	.85 [1.03] N = 4	3.65 [.54] N = 5	3.57 [.25] N = 5
Partially lined systems with permanent headworks	925 [1636] N = 27	5.01 [7.4] N = 27	3.0 [5.7] N = 26	3.00 [.61] N = 22	3.54 [.92] N = 22
Partially lined systems without permanent headworks	859 [1735] N = 39	10.9 [16.9] N = 39	4.9 [7.0] N = 37	3.83 [.77] N = 33	4.34 [.95] N = 33
Unlined systems with permanent headworks	619 [494] N = 2	7.6 [4.4] N = 2	6.7 [1.8] N = 2	3.39 [.08] N = 2	4.09 [.68] N = 2
Unlined systems without permanent headworks	2375 [5692] N = 32	12.3 [17.0] N = 32	8.5 [10.7] N = 31	3.61 [.50] N = 25	4.57 [.91] N = 25

Note: Numbers in square brackets are Standard Deviation.

TABLE 6 Proportion of FMIS and AMIS with Different Physical Attributes

Group	Agency-Governed Irrigation Systems		Farmer-Governed Irrigation Systems		N	
Group 1: Systems Without Lining and Without Permanent Headworks	(0)	0%	(38)	100%	(38) 30%	100%
Group 2: Systems With Partial Lining and Without Permanent Headworks	(5)	12%	(36)	88%	(41) 33%	100%
Group 3: Systems With Permanent Headworks	(18)	39%	(28)	61%	(46) 37%	100%
N	(23)	18%	(102)	82%	(125) 100%	100%

Given the small number of systems in each of these three groups, we must dichotomize the measure of agricultural productivity at the mean so as to create a variable with two values: "above average productivity" and "below average productivity." We have data about productivity for 88 systems, arrayed by the three physical types of irrigation systems in Table 7. The distribution of above and below average agricultural performance for irrigation systems with permanent headworks (Group 3) is strongly skewed toward below average performance. This is unfortunate both for the farmers on these systems and for the purposes of analysis. When there are only 5 systems out of 30 whose agricultural performance is above average, it is hard for *any* variable to affect the basic relationship between permanent headworks and below average performance.[5]

TABLE 7 Relationship Between Physical Type and Dichotomized Productivity Measure

Group	Systems Lower Than Mean Agricultural Productivity		Systems Higher Than Mean Agricultural Productivity		N
Group 1: Systems Without Lining & Without Permanent Headworks	(9)	35%	(17)	65%	(26)
Group 2: Systems With Partial Lining & Without Permanent Headworks	(15)	47%	(17)	53%	(32)
Group 3: Systems With Permanent Headworks	(25)	83%	(5)	17%	(30)
N	(49)		(39)		(88)

GOVERNANCE, PHYSICAL ATTRIBUTES, AND PERFORMANCE

The way an irrigation system is governed in Nepal is also strongly related to performance. Agricultural productivity is higher on farmer-governed systems than on agency systems regardless of the presence or absence of permanent headworks (see Table 8). In Table 9, we array the relationships between governance arrangement (farmer-managed versus agency-managed) and the three dimensions of performance measures for each of the three types of physical environment. Except for Group 1 which does not have any AMIS, and hence comparison is im-

TABLE 8 Relationship Between Governance Arrangement of Irrigation System, Permanent Headworks and Agricultural Productivity

System Type	Agency Systems	Farmer Systems
Systems Without Permanent Headworks	3.7	4.5
Systems With Permanent Headworks	3.3	3.8
All Systems	3.4	4.4
(N)	(19)	(69)

Combined effect of Headworks and Governance Arrangement: $F = 13.1$, $p = 0.00$
Effect of Headworks: $F = 7.9$, $p = 0.01$
Effect of Governance Arrangement: $F = 6.8$, $p = 0.01$

TABLE 9 Relationship of Governance Arrangement, Physical Type, and System Performance

Group	Physical Condition FMIS	Physical Condition AMIS	Delivery FMIS	Delivery AMIS	Agricultural Productivity FMIS	Agricultural Productivity AMIS
Group 1: Systems Without Lining & Without Permanent Headworks	3.65 [.53] N = 26	. . N = 0	3.60 [.65] N = 26	. . N = 0	4.60 [.91] N = 26	. . N = 0
Group 2: Systems With Partial Lining & Without Permanent Headworks	4.00 [.61] N = 27	2.72 [.60] N = 5	4.11 [.69] N = 27	2.56 [.69] N = 5	4.43 [.74] N = 27	3.66 [1.68] N = 5
Group 3: Systems With Permanent Headworks	3.43 [.51] N = 16	2.76 [.52] N = 14	3.35 [.47] N = 16	2.68 [.51] N = 14	3.83 [.57] N = 16	3.30 [.96] N = 14

possible, FMIS perform much better in terms of better physical condition, more effective water delivery, and higher levels of productivity in both Group 2 and Group 3. The differences in performance are all statistically significant at the .10 level.

To further explore the effect of institutional arrangements on system performance, we examine seven key institutional variables that might affect farmers' capability to organize themselves for various collective actions required for effective irrigation management.

Monitoring and Sanctioning

Among the types of rules that we have previously found to be important both in natural and field settings are those related to monitoring and to sanctioning. Monitoring includes a wide diversity of activities including the seemingly unimportant procedure followed in some irrigation systems of keeping an attendance log at the beginning of every day which is designated as a day on which labor is to be devoted to maintaining canals. We have argued that if conformance to rules is not monitored, then the likelihood that individuals will continue to follow rules where there are strong temptations to avoid following them is reduced. Similarly, we assume that some level of sanctioning is necessary to back up monitoring. But in our previous work, we were surprised to find that the initial punishments used in many self-organized systems were frequently very low. Only after repeated rule infractions did the sanctions become somewhat larger. Thus, the first two questions to be explored are the effects of monitoring and sanctioning activities in these three physical environments.

We will examine two types of monitoring arrangements used frequently on irrigation systems. The first is whether records are kept of attendance on the days of required labor for routine maintenance. The second is whether records are kept about water allocations. The pattern that we observe in Table 10 is quite similar to that in the next two tables. Group 1 systems--systems without lining and without permanent headworks (all of which are also farmer-organized systems)--were more likely to have both types of monitoring rules than the other two types of systems, and the effect of their presence is stronger. Only 3 of the 26 in Group 1 systems did not maintain a record of attendance on labor days. All three of these systems were below average in their agricultural performance. Of the 23 systems with a recording rule, 17 (74%) had above average agricultural performance. Similarly, only six Group 1 systems did not maintain a record of water allocations and four out of that six (67%) were below average on productivity while 15 out of the 19 Group 1 systems (79%) that did record water allocations were above mean in regard to agricultural performance. Group 2 and Group 3 systems were less likely to have these two monitoring rules and their presence either made little difference, or in the case of recording labor contributions on Group 3 systems, came close to having the opposite effect.

In Table 11, we examine three variables related to sanctioning: whether the right to withdraw water could be forfeited in some instances of rule infractions, whether sanctions varied from small to large in their effect, and whether penalties were well enforced. A rule that threatened the loss of the right to withdraw water--usually on a temporary basis--when adopted, was effective in systems of two of the three types of physical environments. Group 1 systems were most likely to adopt this rule and 16 out of the 21 systems (76%) that did adopt it were above average in performance. Further, four of the five Group 1 systems (80%) that did not adopt this rule were among those who performed below average. For both Group 1 and Group 2 systems, 70% or more of the systems that adopted this rule were among the above average systems in agricultural productivity. For Group 3 systems, all 13 of systems that did not use this rule were below average in their pro-

TABLE 10 **Relationship Between Physical System, Monitoring Rules and Agricultural Productivity**

Group	Agricultural Productivity	Record Attendance for Routine Maintenance: No	Record Attendance for Routine Maintenance: Yes	Record Water Rights: No	Record Water Rights: Yes
Group 1: Systems Without Lining & Without Permanent Headworks		(3)	(23)	(6)	(19)
	Below Mean	(3) 100%	(6) 26%	(4) 67%	(4) 21%
	Above Mean	(0) 0%	(17) 74%	(2) 33%	(15) 79%
		p = .01		p = .04	
Group 2: Systems With Partial Lining & Without Permanent Headworks		(6)	(25)	(21)	(9)
	Below Mean	(2) 33%	(12) 48%	(10) 45%	(3) 38%
	Above Mean	(4) 67%	(13) 52%	(12) 55%	(5) 62%
		p = .52		p = .70	
Group 3: Systems With Permanent Headworks		(8)	(22)	(11)	(17)
	Below Mean	(5) 62%	(20) 91%	(10) 91%	(13) 76%
	Above Mean	(3) 38%	(2) 9%	(1) 9%	(4) 24%
		p = .07		p = .33	

ductivity and all five of the above average systems did use the rule.

In regard to sanctions varying from very small to substantial in their effect, both Group 1 and Group 2 systems adopted such rules in about the same proportion but the effect was significantly positive in Group 1 systems and had only a neutral effect in Group 2. Having well-enforced penalties was again more likely in Group 1 systems than in the other types of systems and had a more positive effect in Group 1 systems. Fifteen out of 19 Group 1 systems (79%) that had variable sanctions were among the above average systems and five out of the seven systems (71%) that did not have variable sanctions were among the below average systems.

Trust and Rule Following

A further inquiry into the level of trust and rule following found in these three groups also shows a substantial difference between them (see Table 12). Group 1 systems were most likely to exhibit higher levels of trust and to follow rules at a higher rate than the systems in other groups. Further, the association between levels of trust and rule following with agricultural productivity was higher in these systems than it was in the other two types of irrigation systems. Of the 17

TABLE 11 **Relationship between Physical System, Sanctioning Rules, and Agricultural Productivity**

Group	Agricultural Productivity	Water Withdrawals May be Forfeited for Rule Infraction		Sanctions Vary from Very Small to Substantial		Penalties Well Enforced	
		No	Yes	No	Yes	No	Yes
Group 1: Systems Without Lining & Without Permanent Headworks		(5)	(21)	(11)	(13)	(7)	(19)
	Below Mean	(4) 80%	(5) 24%	(5) 45%	(2) 15%	(5) 71%	(4) 21%
	Above Mean	(1) 20%	(16) 76%	(6) 55%	(11) 85%	(2) 29%	(15) 79%
		p = .02		p = .1		p = .02	
Group 2: Systems With Partial Lining & Without Permanent Headworks		(20)	(9)	(10)	(12)	(17)	(14)
	Below Mean	(10) 50%	(2) 22%	(4) 40%	(4) 33%	(7) 41%	(7) 50%
	Above Mean	(10) 50%	(7) 78%	(6) 60%	(8) 67%	(10) 59%	(7) 50%
		p = .16		p = .75		p = .62	
Group 3: Systems With Permanent Headworks		(13)	(13)	(15)	(12)	(12)	(16)
	Below Mean	(13) 100%	(8) 62%	(13) 87%	(9) 75%	(11) 92%	(13) 81%
	Above Mean	(3) 0%	(0) 38%	(5) 13%	(2) 25%	(1) 8%	(3) 19%
		p = .01		p = .4		p = .44	

Group 1 systems that exhibited high levels of trust, 15 (nearly 90%) had above average performance. Similarly, of the 9 Group 1 systems that exhibited low to moderate levels of trust, seven (78%) were below average in agricultural productivity. Only in Group 1 were more than half of the systems characterized by very high levels of rule conformance. In Groups 2 and 3, about half of the systems were not characterized by high levels of rule conformance.

Index of Institutional Development

To get a somewhat more comprehensive view of the relationship between types of rules, trust, and rule-following, on the one hand, with agricultural productivity on the other hand, we have constructed an index of institutional development by assigning a 1 to the presence of, or a 0 to the absence of any of the seven institutional variables that we have discussed. These are dis-

TABLE 12 **Relationship between Physical System, Participant Interactions, and Agricultural Productivity**

Group	Agricultural Productivity	Levels of Trust: Low to Moderate	Levels of Trust: High	Extent of Rule Following: Low to Moderate	Extent of Rule Following: High
Group 1:		(9)	(17)	(10)	(16)
Systems Without	Below	(7)	(2)	(6)	(3)
Lining &	Mean	78%	12%	60%	19%
Without					
Permanent	Above	(2)	(15)	(4)	(13)
Headworks	Mean	22%	88%	40%	81%
		p = .00		p = .03	
Group 2:		(13)	(18)	(18)	(14)
Systems With	Below	(8)	(6)	(10)	(5)
Partial Lining &	Mean	62%	33%	59%	33%
Without					
Permanent					
Headworks	Above	(5)	(12)	(8)	(9)
	Mean	38%	67%	41%	67%
		p = .12		p = .15	
Group 3:		(14)	(15)	(15)	(14)
Systems With					
Permanent	Below	(12)	(12)	(13)	(11)
Headworks	Mean	86%	80%	86%	79%
	Above	(2)	(3)	(2)	(3)
	Mean	14%	20%	13%	21%
		p = .68		p = .56	

played in Tables 10 through 12. A system that has a score of 7 for this index would have been coded as: 1) recording attendance related to routine maintenance, 2) recording water rights, 3) potentially denying water to farmers who broke rules, 4) using graduated punishments for rule infractions, 5) enforcing penalties well, 6) having high levels of trust, and 7) having high levels of rule conformance. The distribution of systems on this index is shown in Table 13.

In Table 14, we examine the relationship between the index of institutional development and agricultural productivity within each of the three groups of irrigation systems discussed above.[6] All of the Group 1 systems that scored less than 4 on the index of institutional development had below average agricultural productivity, while 89% of the Group 1 systems that scored at least a 4 were above average. If this pattern consistently held for all three groups, one could conclude that the likelihood of an irrigation system achieving above average performance is greatly enhanced when the system has adopted at least four of the rules and rule following behavior described above. On the other hand, having such rules is no guarantee of above average performance given the many other factors, such as soil, water availability, slope, availability of sun, etc., which also influence agricultural productivity.

TABLE 13 **Distribution of Systems on the Index of Institutional Development**

Index of InstitutionalInstitutional Development	Systems where information on Index of Institutional Development is available	Systems where information on Index of Institutional Development and Productivity Data is available
0	3	3
1	2	2
2	11	10
3	10	10
4	9	6
5	12	9
6	19	16
7	15	13
Total	88	69

TABLE 14 **The Relationship Between the Index of Institutional Development and Agricultural Productivity**

Group	Agricultural Productivity	Index of Institutional Development: Scored less than 4		Scored at least 4	
Group 1: Systems Without Lining & Without Permanent Headworks	Below Mean	(5)	100%	(2)	11%
	Above Mean	(0)	0%	(17)	89%
			p = .00		
Group 2: Systems With Partial Lining & Without Permanent Headworks	Below Mean	(5)	50%	(3)	25%
	Above Mean	(5)	50%	(9)	75%
			p = .23		
Group 3: Systems With Permanent Headworks	Below Mean	(8)	89%	(10)	77%
	Above Mean	(1)	11%	(3)	23%
			p = .47		

Several of the Group 2 systems have missing data for one or more of the several variables used in computing the index of institutional development. For those systems where we have complete data, 9 of the 12 systems that scored at least a 4 on the index of institutional development, had above average agricultural productivity while 5 of the 10 Group 2 systems that had a score of less than 4 were below average. For Group 3 systems, 3 of the 13 systems that scored at least a 4 on the index had above average agricultural productivity, while only one of nine that had a score of less than 4 were above average.

The pattern of relationships is quite clear for Group 1 systems. For Group 3 systems, it would appear that the type of permanent headworks built on many of the Nepali irrigation systems do not improve performance even on some of the well-established systems that have many rules in place. But, an even greater puzzle exists in regard to Group 2 systems where above average agricultural performance is achieved on 50% of the systems that do not have fully articulated rules and levels of trust and rule following.

We have tried to understand what might explain the substantial differences in the effect of rules on performance among the three different types of irrigation systems varying in the extent of modern engineering works. In asking ourselves which systems were classified within each of the three groups, we noted that 15 of the Group 2 systems were located in Sindhupalchowk and were part of an innovative Water and Energy Commission Secretariat (WECS) intervention. This is discussed in some depth in Shivakoti (1992a) and Lam and Shivakoti (1992).

This intervention was designed by colleagues associated with the International Irrigation Management Institute (IIMI) in Nepal who have had substantial experience with a wide diversity of farmer organized irrigation systems in Nepal and who recognized that many of the poorly operating, farmer systems lacked effective rules. After an initial survey and assessment of their capacity for physical improvement, 19 systems were selected for external assistance. Each of the systems selected for help was not as productive as it could be due to needs for improved engineering works and improved institutional arrangements (WECS/IIMI, 1990). Farmers in each of the systems had to agree to provide a substantial amount of the labor needed to improve their physical works, and to participate in a peer training program. In this training program, the farmers from the selected systems were taken to visit two irrigation systems where the farmers had organized themselves effectively and were highly productive. The visiting farmers watched an annual meeting, held a seminar with the farmers of the successful systems, and examined the systems' physical works and maintenance schedules.

Funds provided by the Ford Foundation were used to support the training effort, and to invest in the design of improved works such as lining in key segments, and providing PCB pipes to serve as better aqueducts to replace malfunctioning wooden logs. Canal alignments were shifted in some systems so that a larger area could be served or that water was more reliable. The farmers receiving this assistance were fully involved in the design of these improvements and had to agree to the designs before any of the funds could be used to purchase materials. The farmers did most of the labor; they also learned exactly how the improved systems were laid out and how best to maintain that system. The intervention intended to encourage farmers to design their own rules to address the particular problems they faced. Thus, a process of rule development was initiated. The Sindhupalchowk systems, however, were not rushed into the task of devising all the rules they would eventually need.[7]

The data we report in Tables 10 through 14 include information that was obtained in December 1991 from 15 of the 19 systems included in this WECS/IIMI project. All of these projects had reconstructed aspects of their physical works within the previous two years. Many were experimenting with different rules but none of them had sufficient time to develop their own rule systems fully. Elinor Ostrom visited one of these systems in March of 1990. By that time, the farmers had written their own constitution and had devised an ingenious system for monitoring the physical condition of a newly reconstructed, 3000 meter-long canal. They had not yet finished the task of defining exactly who would be included as future members (there were 85 farmers who had signed their *Bidhan* but they hoped to include 15 to 20 additional farmers if they would agree to participate in the maintenance of the system). Thus, many of the rules that farmer systems in Group 1 had already developed were not yet developed in Sindhupalchowk, even though many of the farmers in these systems recognized that they should be developing appropriate rules of this sort as part of their general effort to improve the performance of their systems.

As shown in Table 15, of the 17 Group 2 systems that achieved above average agricultural productivity, 10 were part of the WECS/IIMI experiment--a considerable credit to the success of this intervention. We do not have complete information on all seven variables included in the index for three of these ten systems. Of the other seven systems, for which we have information, only two had scores of 4 or more on the index. On the other hand, there were seven other Group 2 systems, which are not part of the WECS/IIMI experiment, that achieved higher than mean agricultural productivity. All seven of these systems scored 4 or above on the index (4 = 1, 5 = 3, 6 = 1, 7 = 2). Consequently, above mean agricultural productivity is associated with more fully developed institutions except in those situations where recent improvements in the physical works have been undertaken and/or insufficient time has elapsed for farmers to design a more fully articulated set of rules and behavioral patterns. We would be willing to predict that in five to ten years those Group 2 systems that are currently producing above average agricultural productivity without a fully articulated institutional structure, will not continue to produce above average agricultural yields. We are hopeful that the WECS/IIMI systems can be evaluated every two years for some time so that it will be possible to trace the evolution and performance of these systems over time.

IS THERE A TRADE OFF BETWEEN WELL CRAFTED RULES AND WELL CRAFTED TECHNOLOGY?

Much of the thinking about how to improve irrigation performance has focused on improving engineering works and ignored the importance of institutions. One of the strong findings from this study is that when major capital investments are made in engineering works that are not well crafted for their environment, not only do they fail, but they may detract from the capability of farmers to devise effective rules to enhance performance. Only 5 of the 30 systems, for which data is available about both the type of headworks and performance, are able to achieve above average agricultural productivity. We do not wish to argue that constructing permanent headworks is a strong determinant of below average performance even though a casual inspection of the above data might lead to an initial impression that this is the lesson to be learned. We see the lesson as being different.

Many of the permanent headworks that have been constructed in Nepal were constructed by external agencies without: 1) consultation with the farmers about the design of the headworks and 2) requiring the farmers to pay irrigation fees to pay off the capital investment. This has led to several consequences. First, many of these headworks simply do not operate very well in an environment of shifting water courses and level of water in the watercourse. Consequently, some of the mal-designed irrigation works have simply reduced performance. Second, little at-

TABLE 15 **Score of the Index of Institutional Development**

Group	Agricultural Productivity	Irrigation System	Index of Institutional Development
Group 1:	Below Mean	Tedhi/Gurgi	-
		Thambesi	-
Systems Without Lining & Without Permanent Headworks		Hudiko Mulko Kulo	0
		Char Say Phant	2
		Chunatal	2
		Chaurasi	3
		Khairghari	3
		Char Hazar	6
		Gairagaon	7
	Above Mean	Auraha	4
		Laxmipur	4
		Kusuna-Gathauli	5
		Kanchi Kulo	5
		Tulsi	6
		Kathar	6
		Janakpur	6
		Pangduri	6
		Badgaon	6
		Chainpur (Bhutiya) Kulo	6
		Surtana	6
		Jeevanpur	7
		Kapiya	7
		Mudabar	7
		Rapti Pratapur (was Lothar)	7
		Chherlung Thulo Kulo	7
		Kharkgutte (Upper)	7
Group 2:	Below Mean	Mana Besi Phant	-
		Dovan Swar Ko Kulo (Dobhan Swar Kulo)*	-
Systems With Partial Lining & Without Permanent Headworks		Torbang	-
		Magar Kulo*	-
		Chhahare Khola Ko Kulo*	-
		Masina Sat Tale	-
		Naya Dhara Khola Ko Kulo*	-
		Goberdiha	1
		Bhalutar	2
		Chhepetar Ko Kulo	3
		Sajhatar	3

Continued...

		Soti Bagar Ko Kulo*	3
		Sisabas Parsauni	5
		Barhakol	6
		Satra Say Phant	6
	Above Mean	Besi Kulo*	-
		Subedar Ko Kulo*	-
		Dhap Kulo*	-
		Ghatta Muhan Ko Kulo (Tarali Ko Kulo)*	0
		Baghmara Ko Kulo (Baghmara Kulo)*	2
		Majha Ko Kulo (b) (Majha Kulo)*	2
		Tallo Chapleti Kulo*	3
		Siran Ko Kulo (a) (Siran Kulo)*	3
		Chap Bot Ko Kulo (Beltari Fant Ko Kulo)*	4
		Rapti Nawalpur Farm	4
		Gadkhar	5
		Yampa Phant	5
		Thuli Besi	5
		Argali Raj Kulo	6
		Bhang Bari (was Kota Tar)	7
		Pithuwa	7
		Majha Ko Kulo (d)*	7
Group 3: Mean Systems With Permanent Headworks	Below	Bhairawa Lumbini Ground Water Project	-
		Parwanipur	-
		Dhanauri (Kumalgari)	-
		Seti	-
		Labdu-Dhikure-Sera	-
		Phewa	-
		Bhorletar	-
		Hande Tar	0
		Lahachowk	1
		Hyangja	2
		Sange Patyani	2
		Ramghatar	2
		Champi Kulo (Dimalko Kulo)	2
		Lamage Phant	3
		Kodku	3
		Belgari	4
		Ghachchowk	5
		Supaila Community	5

Continued...

	Rangdi Khola	6
	Serabagua Bandh-Tharpu, G.B.C. Chhang	6
	Bhanu Bhairah	6
	Bhitoria	6
	Malebagar	6
	Chiregad	7
	Bulbule	7
Above Mean	Begnas	-
	Panch Kanya	2
	Thulo Chaur	4
	Naya Simalghari Sathi-Bighe	5
	Logain	7

Key: - = Missing
* = Systems in Sindhupalchowk

tention has been paid to the temptations that farmers might face to ignore one another's interests, and how technology and institutions might enhance or detract from the capacity of farmers to seek better distribution patterns of their water. In a system where expensive headworks have been constructed by outsiders in which farmers have little need to mobilize labor to construct and repair temporary headworks, tail end farmers often lack bargaining power with head enders. Consequently, head enders may ignore the interests of tail enders and divert water at the head end that could be more productively used at the tail end of the system. Tail end farmers on such systems would potentially be better off if, for example, they had to pay an irrigation fee to an agency that directly benefitted from receiving the fee. Under such circumstances, tail end farmers could refuse to pay the fee unless they received adequate water.

At the other end of the spectrum are the systems that have had no major technological interventions--those without permanent headworks and without any lining. These are the systems where farmers have to be extremely well-organized and disciplined if they are going to succeed. A higher proportion of these systems do, in fact, succeed more frequently than either of the two other groups. Their success is strongly affected by the configuration of rules they adopt. Consequently, it is in these systems that farmers have excelled at crafting strong and effective institutional arrangements, and have developed considerable skill in using these rules to make their systems productive.

The Group 2 set of irrigation systems has developed some forms of partial lining. While lining is certainly not a panacea, if key sections of a canal are lined well, it is possible for the system to work more effectively with lower inputs of labor, materials, and financial resources for maintenance. Thus, a well designed, partially lined irrigation system may get water to the tail end through physical means and not need the full panoply of rules that a system without any lining must utilize.

Notes

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[3] How the assumptions of free riding, economies of scale, and the need for scientific and technological knowledge are used as a foundation for centralized governmental solutions is thoroughly discussed in E. Ostrom, Schroeder, and Wynne, 1993.

[4] Not all development theorists hold to these views however. Walter Coward, Norman Uphoff, and others have consistently argued that farmers were far more capable than given credit, and extolled the virtues of participation and self-governance as a serious development strategy (see, for example, Coward, 1980; Uphoff, 1982; Sengupta, 1991).

[5] We have created an index of physical condition that is neutral in regard to agricultural performance, but it is composed of five items. It is consequently quite difficult to interpret. Similar tables to those presented below looking at individual rules using the index of physical condition rather than the three types of physical systems described in this paper are available from the authors.

[6] Table 14 only includes systems that we have complete information on productivity and the seven institutional variables comprising the Index of Institutional Developement. For information on the systems, see Table 15.

[7] The time it takes to experiment with the specific rules that will work effectively on a particular system is frequently not recognized. Giri and Aryal (1989: 33) provide an interesting description of the time it has taken for the farmers in the Gadhkar Irrigation System (a jointly managed systems where the farmers were given the task of allocating water on the system) to develop only one of the rules they use-the rule allocating water as between the two major branches of the system. As they state:

> Rotation has been in effect in Gadkhar since the very beginning of water delivery, however, with limited successes. After experimenting with a number of water distribution rules, the Gadkhar Committees' persistence in finding a rotation pattern that allows water to be distributed equitably finally bore fruits when they decided on the present 96 and 120 hours rotation for a group of two canals on the basis of the aggregate command area and to each farm unit in the command area. The provision of pani pales providing services for making each and every plot of land within the command starting from the tail and penalizing landowners if their farms were found wet when they were not supposed to be has been a remarkable innovation.

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