Water Community: An Empirical Analysis of Cooperation on Irrigation in South India[1]

by

Pranab Bardhan

University of California at Berkeley

I

A controlled supply of water is crucial for much of the world's agriculture. This is particularly the case in many of the semi-arid and uneven-rainfall areas of South Asia. While there is considerable amount of work on the management of large canal systems and the structure and practices of the irrigation bureaucracy, economists have only recently started paying attention to issues of local community-level cooperation and other institutional arrangements that are key to substantially improving the existing levels of utilization of irrigation potential.

Community institutions can have various functions in different irrigation systems: For example, they aim at pooling efforts and resources in constructing and maintaining field channels at the local outlet level, at regulating water allocation and monitoring violations; in cases of tank irrigation also at desilting, weeding, and stopping encroachments on tank beds; at repairing, maintaining, and controlling water allocation from public and community tubewells; at controlling groundwater overexploitation with privately owned pumps in areas with fragile aquifers, and so on. Water reform in the sense of building or promoting such community institutions of cooperation is at least as important as land reform in rural development.[2]

But the history of local community-level cooperation in water management in South Asia is rather mixed.[3] There are several documented examples of successful local community water management (although usually at a rather low level of organizational form) in different parts of the region, some of them going many hundreds of years back in history and still surviving, but there are also numerous cases of failure of cooperation, leading sometimes to an anarchical scramble for water. It is important to understand the conditions working for and against sustainability of local cooperation in situations of general social and economic interdependence.

The usual game-theoretic models of cooperation among self-interested agents in repeated situations of strategic interdependence provide some useful insights. But, in view of their admissibility of multiplicity of equilibria, many of the comparative-static questions cannot be satisfactorily resolved without recourse to contextual data analysis. Besides, these models are often couched in too restrictive a framework, inadequate in capturing some of the salient issues of real-world cooperation (or lack of it); for a long time we will have to depend on arduous empirical work to give us clues about the building blocks to more satisfactory theoretical models and policy action. Much of the existing empirical literature on these issues are social-anthropological, without a great deal of quantification; among other things, this makes deciphering the effect of a particular factor, controlling for other factors, rather difficult.

This paper concentrates on a quantitative analysis of the (physical, institutional and socio-economic) determinants of cooperation in irrigation communities[4] on the basis of a large survey conducted in the South Indian state of Tamil Nadu. In section II we describe the variables and the data and our expected effects that the independent variables may have on cooperation, and in section III we report the actual results of the statistical analysis.

II

In all data were collected from 48 villages spread over 6 districts in Tamil Nadu, with a selected unit (called 'ayacut') of irrigation system in each village (either a tank or a branch of canal with roughly about 50 hectares size of command area). Half of the irrigation units belonged to canal systems, and the other half to more traditional tank systems. All the canal systems are under the general administration of the government (usually the Public Works Department, PWD). Within tank systems, half belonged to what are called 'isolated or chain tank' systems, and the other half to 'system tanks' (where the tanks were, unlike in the former case, linked to larger irrigation units). Within each system the villages were randomly chosen. Within each village a stratified sample of 10 farmers (stratified by land size classes) were chosen. Most of the analysis in the paper is, however, on the basis of data for the irrigation unit or the 'ayacut' as a whole; in some cases we have derived data from the individual farmers' response. In general on matters of cooperation differences across villages were much more prominent than intra-village differences among the 10 farmers.

First a few words on the description of the general functioning of the water users' organizations. The majority of the organizations surveyed are traditional and informal community organizations that have been in existence for some time (27 of the 48 surveyed are reported either as ‘traditional’ or at least 20 years old). But only 13 of these units have formal associations (and 10 of these have formal associations not at the village or sluice levels but at the more aggregative zonal level). The organization in 12 of the (canal-based) irrigation units surveyed has been set up (relatively recently) and is run directly by the PWD. In another 12 canal-based irrigation units, although PWD is the over-all official agency, it is the traditional village committee that manages irrigation matters at the village level.

There is a great deal of variation among the organizations with respect to appointment of guards as monitors and enforcers, frequency of meeting, mobilization of collective labor, mobilization of funds, method of cost-sharing, and involvement in non-irrigation activities.[5] Most of the users’ organizations meet at least once every one to two years; only 9 reported never meeting at all. The units run directly by the PWD reported meeting at most once a year (and often only every two years), while most others meet once or twice a year during the cropping season. Five of the units surveyed have organizations which reported having regular meetings at least 10 times a year. One function of the water users’ organization in many of the units surveyed is to mobilize community labor for the purpose of maintaining and repairing the field channels. Generally, it appears that community labor is most common in those organizations that are traditional or have existed for over 40 years. While most of these units mobilize community labor both for regular maintenance and for emergency repairs, several units reported mobilizing community labor only in the event of emergency repairs. Community labor does not appear to be used systematically in any of those units where the PWD directly runs the organizations.

About three-quarters (37 in number) of the units surveyed have some formal system of fundraising. Of these 28 units have a system of dues, fines and/or taxes. Such a system is most prevalent in those units which are canal-based. In the tank-based systems, an alternate system of fundraising is possible, the sale of collective resources such as fish and trees. Nineteen of the tank-based units have collective funds which are mobilized this way; 10 of these units supplement the collective fund with a system of dues and/or tax collection. About half of the water users’ organizations report participating in other, usually village-wide, activities, such as conducting the temple festival. This does not appear to be true of any of the organizations which are run by the PWD.

Since issues like cooperation and some of its determinants involve the quality of social and economic relations, much of the data are more qualitative (sometimes with yes-no answers) than quantitative, from which we had to construct variables that therefore take only a limited range of values. The description of the dependent and independent variables, including their mean values with standard deviation and the range of variation, is given in

Table 1. We have used three alternative variables as indicators of cooperation [6] within the community on matters of irrigation: (a) quality of maintenance of distributaries and field channels (we call the variable DISTFDCH); (b) absence of conflict in water allocation in the ayacut in the last five years (we call this variable H20COOP); and (c) extent of violations in water allocation rules (we call the variable VIOLH20). From Table 1 we can see that there is a considerable amount of variations among the villages in the values of these variables.

Let us now describe and comment upon the explanatory variables that we have used. One obvious variable to consider is that relating to the group size: We have used a variable called NUMUSERS, which is the number of households [7] using the particular irrigation source (the number varies between 11 and 279, with a mean of 53). The common presumption in the literature on local commons is that cooperation works better in small groups. The early work of Olson (1965) suggested that collective action is easier to organize in smaller groups. In a game played by rotating irrigators (turntakers and turnwaiters) with self-enforced rules (i.e. without formal guards), Weissing and Ostrom (1990) show in their theoretical model that in the equilibrium an increase in the number of irrigators is associated with an increase in the stealing of water, other things remaining the same.[8] In general, models of repeated games suggest that cooperative strategies are more likely to emerge and be sustained in smaller groups. In small irrigation communities peer monitoring is easier, the ‘common knowledge’ assumption of models of strategic decisions is likely to be more valid, shared norms and patterns of reciprocity are more common, social sanctions may be easier to implement through reputation mechanisms and multiplex relationships, and even hydrologic needs of farmers may be relatively similar. On the other hand, there may be some positive economies of scale in larger groups, particularly in matters of pooling resources, appointing guards, lobbying with officials, and so on.

Another possibly important explanatory variable is heterogeneity, both social and economic. The only variable in our dataset that relates to social homogeneity or heterogeneity is CASTE75, which takes a value of 1 in villages where at least 75% of the sampled farmers are members of the same generic caste group (in most cases a ‘backward’ caste group) in the village. By this crude measure, 69 per cent of the ayacuts in our dataset are socially relatively homogeneous. In terms of economic heterogeneity we have a variable called GINI, which measures the Gini coefficient of inequality of landholding of farmers in the ayacut area. The mean value of GINI in our dataset is 0.41.

Theoretically, the relationship between heterogeneity and successful collective action is rather complex.[9] On the one hand, there is the well-known suggestion of Olson (1965) that in a heterogenous group a dominant member enjoying a large part of the benefits of a collective resource is likely to see to its provision even if he has to pay all of the cost himself (with the small players free-riding on the contribution of the large player). On the other hand, there are cases where the net benefits of coordination of each individual may be structured in such a way that in situations of marked heterogeneity or inequality some individuals (particularly those with better exit options) may not participate, and the resulting outcome may be more inefficient. In addition, the transaction and enforcement costs of cooperative arrangements may be high in situations of intra-village heterogeneity, conflicts, and inequality. Internalization of cooperative norms is more difficult under such circumstances; the degree of confidence or trust that individuals have in the likelihood that others will play their part in a cooperative agreement may be low. In anticipation that the relationship between inequality and cooperation may be non-linear, we have introduced a squared Gini coefficient (called GINISQU) in our set of explanatory variables.[10]

Another kind of factors that affect cooperation in water management is the physical condition of water availability. In conditions of extreme scarcity arrangements of cooperation often break down. When there is some significant access to water, it pays the irrigators to cooperate in maintaining field channels, and in obeying allocation rules. In our dataset the villages with acute water scarcity in general have less cooperation, but (probably for historical reasons) the water-scarce villages are also more likely to have canal-based irrigation; so the effect of water-scarcity is mixed up with that of possible bureaucratic inefficiencies in release of canal water (more on this below). We have defined a variable AVGACCES to indicate the number of months in a year that the farmers in the ayacut have access to water: it varies from 2 to 7 months, with a mean of 3.7 (2.8 for the canal areas).[11] We have also used two other variables relating to physical conditions: one is TOPOGRPH to indicate where the topographical nature of the ayacut precludes equal access to water for all the farmers; and the other is LINED to indicate where the irrigation channel is lined.

For government involvement we have used two alternate variables, CANAL (to mark half the villages where it is a government administered canal system), and the other is PWDDECID, i.e. where PWD makes all the decisions about water allocation and distribution. In the canal area villages there is not merely less water availability, water is also more inequitably distributed: in 19 out of 24 canal area villages in our dataset (as opposed to 2 out of the 24 villages served by the tank systems) there is evidence of such inequity of water supply or access. In general, the water release cycles may be more unreliable from the farmers' point of view when they are administered by PWD officials. Of course, there is potentially a major problem of endogeneity here: does the PWD get involved when irrigators' cooperation has failed?[12] After some background checking we have found that the villages where PWD takes all the decisions are all located in Coimbatore district and are precisely those where due to primarily physical reasons of long-term water scarcity a large-scale system of inter-river basin water transfer scheme had been undertaken by the government (called PAP -- Parambikulam Aliyar Project). We therefore think the problem of endogeneity may not be that serious here.

A few variables relate to the locational context of the ayacut in question. The variable TAILEND refers to the cases where the village is situated at the tailend of the irrigation system, which, other things remaining the same, may unite the farmers of the village in their struggle to get more water away from the more favorably located villages. In our dataset 75 per cent of the villages are at the tail end of their respective system. In general only 44 per cent of villages report that there is no conflict with other villages over water. As an alternative to TAILEND, we have also used a variable PRIORAPP to indicate those villages where no water conflict is reported with other villages.

The locational context is also important in the matter of the exit options open to the villagers in conforming to cooperative arrangements. We have used LINKAGE as a variable to be a proxy for the connection of the village to urban areas or transport and communication modes (like bus and telephone). We also have a variable MARKET as a measure of the extent to which the farmers are oriented to selling their produce in the outside market. (Since how much a farmer sells his produce may be determined by his other characteristics, i.e. it may be endogenous, we have used a predicted value of the MARKET variable in the regressions for determinants of cooperation). A somewhat different kind of exit-option variable may be indicated by how much access an ayacut member has to water sources outside the ayacut.[13] The variable OTHIRRIG is the estimated fraction of the total irrigated land (of the sampled farmers in the ayacut) that is outside the ayacut. For all of these exit option-like variables our prior is to expect a negative effect on cooperation.[14]

History of cooperation in a village may matter, as cooperation may be self-reinforcing, or, 'habit-forming', as Seabright (1997) explains in a theoretical model. We have a variable TRADLORG to indicate villages where the water users' organization has been there for 20 years or more. These villages are characterized by more use of community labor in maintenance works and emergencies, are more likely to hire guards (called "neerani" in much of this area) for monitoring and enforcement (indicated generally by the variable GUARD), and to use cost-sharing proportional to land holding (indicated generally by variable SHRPROP). Since the use of guards and a cost-sharing regime may be endogenous, we have used in the cooperation regressions predicted values of these variables, PGUARD and PSHRPROP. We have also asked questions about the farmers' perception about the process of rule crafting. For example, in villages where at least 4 out of 10 sampled farmers believe that the water rules were crafted by the elite, we indicate that by our variable ELITERUL.

(We also had a variable, FAIR, for villages where the rules are generally perceived as fair, but we dropped this variable as it almost coincides with cases of cooperative behavior).

III

The regression results are in Tables 2 (A, B, and C), Table 3 (A and B), and Table 4 (A and B). (For some of the independent variables the predicted values are estimated on the basis of first-stage regressions in Table 5). We are primarily concerned with the signs of the regression coefficients.[15] Let us start with DISTFDCH, the index of quality of maintenance of distributaries and field channels, as the dependent variable. This index is uniformly lower in ayacuts with higher inequality in landholding: the coefficient for GINI is negative in all of the three alternative cases in Table 2 and highly significant in two of the three cases. (It is interesting to note that a similar negative coefficient for GINI of land distribution has been observed by Dayton-Johnson (1998) for farmer-managed irrigation systems in Mexico, and a negative coefficient for 'variations of income among appropriators' in irrigation systems in Nepal by Lam (1998)). The coefficient is also lower, and significantly so, with ELITERUL, i.e. for villages where rules are perceived to be crafted by the village elite.[16]

As our discussion in the preceding section suggests, the effect of number of users of the irrigation system can be ambiguous.[17] In the ordered logit estimates the coefficient for NUMUSERS is negative but not very significant in one case, and significant at 10% level in another; in another case when we take the number of users per acre of the ayacut area as an alternative, the coefficient is positive but not very significant.[18]

AVGACCES, the number of months in a year there is access to irrigation, is positively and significantly related to DISTFDCH in all three cases. The interpretation is that when there is access to an irrigation system over a longer period in the year the return to investing effort in maintenance of field channels is higher (and may outweigh the increased maintenance costs that may follow from higher use).[19] The negative coefficient of LINED at first seems surprising[20], but probably means that when the channels are lined they are more likely to be found occasionally in a 'broken condition', compared to channels which are not lined at all. (In fact, of the 15 units that are not lined at all, only 2 report the field channels being in bad condition).[21] An alternative explanation, suggested to us by Dayton-Johnson on the basis of his observation in Mexico, is that some poor villages are unable to properly take care of the modern water control structures that tend to accompany lined canals, either because they could not get replacement parts, or because they did not know how to repair them, or both.

Contrary to the general impression about the negative effect of government involvement, the coefficient for PWDDECID is positive and significant in all three cases. It is possible that when PWD is actively involved in water allocation and in maintenance works above the outlet, returns to farmers' collective maintenance effort on channels below the outlet are higher. Looking more closely at the detailed data we find the picture a little more complex: of the 12 units where PWD is actively involved, in half of them the field channels are well maintained,[22] and in the other half of the units they are badly maintained. It is interesting to observe that in the latter half the farmers have more private sources of water (pumps and open wells) than in the former half (and the GINI coefficient of land distribution in the ayacut is considerably higher, i.e., as expected, inequality of land holding goes with more access to pumps and open wells).

The coefficient for TAILEND is positive but not significant. But the coefficient for PRIORAPP is negative, and in one case highly significant. This suggests that water conflicts with other villages may be helping the farmers of the ayacut unite in cooperative maintenance effort.

The variable for urban connections, LINKAGE, has a highly significant negative coefficient in all the three alternate cases in Table 2. This is consistent with our prior about the adverse effect of exit options on cooperative behavior discussed in the preceding section. The variable OTHIRRIG, indicating access to alternative sources of irrigation outside the ayacut for the farmers, has an appropriately negative sign, but it is not significant.

The quality of maintenance is understandably highly positively correlated with the existence of a guard, whose enforcement of water distribution rules increases the benefits of field channel maintenance.[23] Since the appointment of a guard is itself dependent on some of the factors that enter into the determination of cooperative behavior, we use here only the predicted value, PGUARD, in this second-stage regression.[24] In the first-stage logit analysis for GUARD, reported in Table 5, we use as instruments the variables CANAL and TRADLORG. In canal areas there is much less use of a guard, whereas in ayacuts with a traditional organization appointing a guard is quite common. We presume this is determined more by historical-conventional factors. In fact in areas where the government takes the decisions the enforcement of rules is usually by government officials or police, not by guards.[25] The only other variable that is significant (at the 10% level) in the first stage regression for GUARD is LINKAGE: it seems that better urban-linked villages use more guards. But Table 2 suggests that, *controlling* for the positive effect on PGUARD, LINKAGE has a significant negative effect on maintenance of field channels.

In Table 2 we also see the positive (but not always significant) effect of the proportional cost-sharing rule on maintenance: cost-sharing proportional to landholding may be perceived as more fair than, for example, cases where all farmers have to bear the same cost even though the larger farmers get more of the benefit, or where there is no rule.[26] Since SHRPROP rule may itself be dependent on factors that enter into the determination of cooperative behavior, we use in Table 2 only the predicted value, PSHRPROP. The first-stage logit analysis for SHRPROP is reported in Table 5. SHRPROP is positively and significantly related to the number of ayacut members, inequality of landholding among them, canal areas, ayacuts where the irrigation organization is old, and where formal water rights is more prevalent.[27] Since GINI has a positive effect on SHRPROP (possibly indicating social pressure for a redistributive adjustment of the cost-sharing rule to take account of wealth disparities) and PSHRPROP has a somewhat significant positive effect on DISTFDCH, we can say that the effect of inequality of land distribution on the quality of maintenance on field channels is twofold: on the one hand, the direct effect is negative, but the indirect effect, working through the cost-sharing rule, is positive.[28] Similarly the effect of NUMUSERS is twofold: the direct effect is negative (though not always significant), but the indirect effect, working through the cost-sharing rule, is positive.

Now we turn to the dependent variable in Table 3, H2OCOOP, i.e. where there has been no intra-village conflict over water over the previous five years. GINI is again significantly negative, but GINISQU is significantly positive, indicating the kind of U-shaped relationship between inequality and cooperative behavior we have discussed in the preceding section. The coefficient for CASTE75 is positive in both cases of Table 3, and significant in one, confirming that social homogeneity (in the form of 75% or more of the farmers belonging to the same caste group) is conducive to cooperation. The urban connection variable, LINKAGE, is, as before, negative in its effect on cooperation, though significant in one of the two cases. Also as before, PGUARD has a positive effect, but it is significant in one of the two cases. The government involvement variable, PWDDECID, did not turn out to be significant in this set of regressions, but again looking at the detailed data, as in the case of the field channel maintenance regressions, in half of the 12 units where PWD takes all decisions, there was cooperation in water allocation and in the other half there was conflict (and the former associated with more equality in land distribution and fewer private pumpsets and open wells than in the latter).[29]

In Table 4 the dependent variable is the opposite of cooperation; it is VIOLH2O, i.e. where water allocation rules are frequently violated by at least one group. (Both for the ayacut as a whole and for the sampled farmers our data definitely suggest that the rule violations are more often by the better-off farmers; one presumes they can get away with such violations more easily).[30] Here the signs of the coefficients for GINI, GINISQU, CASTE75, TAILEND, and OTHIRRIG are as expected from the earlier regressions, but they are not significant.

NUMUSERS is positive and highly significant, indicating the difficulty of preserving cooperative behavior in large groups. AVGACCES, the duration of access to water, is negatively, and in one of the two cases highly significantly, related to violations, indicating that water scarcity encourages violations.

As before, the urban connection variable, LINKAGE, has a negative impact on cooperation, and PGUARD has a positive effect. In one of the two regressions, we have used PMARKET as an alternate outside connection variable to LINKAGE. MARKET is a measure of the extent to which farmers are market-oriented (particularly in terms of sales of produce). Since this may be endogenously determined, we have used PMARKET, the predicted value of MARKET, in the second-stage regression. The first-stage regression is reported in Table 5. The only two variables that are significant (with a positive coefficient) in this first-stage regression are CANAL and WMARKET (indicating cases where there is a market for well water in the village),[31] the two variables chosen as instruments. From the second-stage regression we can see that like LINKAGE, PMARKET increases the probability of violation of water allocation rules.

TOPOGRPH (the case where the topographical nature of the ayacut precludes equal access to water), TAILEND, and OTHIRRIG have coefficients of expected signs, but they are generally not significant.

From the list of independent variables we had to drop PWDDECID and ELITERUL, because in both cases their values perfectly predicted the value of the dependent variable. This means in *all* the villages where PWD decides on water allocation and distribution, frequent rule violations are reported:[32] this may be because the rules are typically rigid and insensitive to local needs, farmers are less normatively committed, officials are bribed to look the other way, and so on. (Lam (1998) reports from his study of irrigation systems in Nepal that in nearly half of the government agency managed systems the extent of rule-breaking is medium or high, whereas the corresponding percentage in farmer-managed systems is only about 12 per cent). In contrast, in the villages where the village elite, rather than government officials, crafts the rules, there is no violation of rules reported. Since, as we have noted before, the better-off are usually the more frequent violators of rules, they tend not to violate rules crafted by themselves.

In all of the 12 PWD-run units there are rotational water allocation rules by which the farmers are allotted a certain number of hours of water access per acre or are allowed access to water only in alternate weeks. In *all* of these 12 units these rotational rules are frequently violated and particularly the rich farmers appropriate more water than is their due. And yet in half of these units (particularly where the inequality in land distribution among the farmers is low), as we have seen before, field channels are well maintained and there was no incidence of water conflicts within the village in the last five years. This means inflexible rules of the government (enforced by corruptible agents) are frequently violated without necessarily damaging intra-village cooperation, suggesting again that when rules do not enjoy the backing of community norms, rule obedience is not necessarily an indicator of cooperation among farmers.

Summing up over the seven regressions in Tables 2, 3, and 4, we can say that in our dataset cooperative behavior in an irrigation community is by and large significantly related (negatively) to inequality of landholding, to urban or market connections, and (positively) to duration of access to water, monitoring by guards, and in some cases to social homogeneity, small group size, proportional cost-sharing rule, and collective adversarial relation with other villages over water. PWD involvement in water allocation and maintenance can have a positive effect on field channel maintenance (if farmers do not have much access to their own private sources of water like pumpsets and open wells); but such involvement in this dataset is in more water-scarce areas, and too much water-scarcity may not be conducive to cooperation. Government involvement also encourages violations of specific inflexible rules by the farmers and means fewer cases of ayacut communities appointing their own monitoring guards, which adversely affects cooperation. When the rules are crafted by the village elite, the latter violates the water allocation rules less; otherwise the elite is the more frequent violator of rules. Sometimes when rather inflexible rules are made and enforced by the government, their violations are not necessarily inconsistent with cooperative behavior among farmers themselves. When an average farmer believes that the water rules have been crafted jointly (as opposed to by the elite or by the government), we find that he is more likely to have positive comments about the water allocation system and about rule compliance by other farmers.

Although this paper is primarily meant to understand the factors underlying farmers' cooperation or lack of it, in terms of policy lessons one may particularly point to the need for devolution of decision-making and rule-crafting authority to the local farmers (instead of imposing insensitive external rules on them), for land reform (which, apart from its direct incentive effects on farm productivity, can get the poor farmers more actively involved in local self-governing institutions), and for caution in minimizing the disruptive effects that the expansion of market linkages and of elite access to private sources of water can have on traditional community arrangements.

ENDNOTES

[1] The data used in this paper are from a survey designed with the help of Nirmal Sengupta at the Madras Institute of Development Studies, who has supervised the data collection process and in general been very helpful at the data analysis stage as well. The data analysis was conducted jointly with Laura Giuliano. Jeff Dayton-Johnson helped in the survey design. In the data collection and coding process we have received invaluable assistance from R. Manimohan, A Raman, and J. Jeyaranjan. The data collection effort was funded by the MacArthur Foundation. Thanks are also due to Samuel Bowles, Juan-Camilo Cardenas, Jeff Dayton-Johnson, Gershon Feder, Yujiro Hayami, Elisabeth Sadoulet, and A. Vaidyanathan, and an anonymous referee for comments on an earlier draft.

[2] I have elaborated on this theme in Bardhan (1984), Ch. 16.

[3] Apart from the more well-known accounts in Ostrom (1990), Wade (1987), and Vaidyanathan (1984), see also Jayaraman (1981), Easter and Palanisami (1986), Sengupta (1991), and Vaidyanathan (1994).

[4] For a partially similar analysis of determinants of the adoption of distributive rules and of cooperative maintenance effort with data from 54 farmer-managed surface irrigation systems in central Mexico, see Dayton-Johnson (1998). We also compare some of our results with those of Lam (1998) for irrigation systems in Nepal.

[5] Unfortunately, the data and descriptions regarding some of these organizational variables were not systematic or complete enough to allow reliable coding and inclusion in our subsequent regression analysis.

[6] We shall later comment on how these may not always be good indicators of cooperation among the farmers.

[7] We have also used an alternative variable, NUM_ACRE, the number of households using the irrigation source per acre of the ayacut area. But usually this variable is less significant than NUMUSERS in our regressions.

[8] Of course, other things do not remain the same. We shall see in our data that the existence of guards is positively (though not very significantly) correlated with NUMUSERS, and guards have a positive influence on cooperation.

[9] For a theoretical analysis of some of the complexities, see Baland and Platteau (1997, 1998), and Dayton-Johnson and Bardhan (1998).

[10] For a theoretical analysis of a U-shaped relationship between wealth inequality and cooperation in the context of a two-player non-cooperative model of conservation of a common-pool resource, see Dayton-Johnson and Bardhan (1998).

[11] It is well-known in the irrigation literature that no single-dimensional variable can adequately capture the quality of water supply, which depends on many factors (like volume, timing, crop produced, and cultivation practice). As an alternative to the variable AVGACCES we have also tried a variable indicating if water is ‘sufficient’ for the paddy crop in the primary season, but this variable turned out to be less significant in the statistical analysis than AVGACCES.

[12] Alternatively, the farmers may get involved in cooperation, when the PWD fails to do its job, but this looks unlikely from the details of the description of the irrigation units in the survey.

[13] We have tried another variable to indicate access of farmers to alternative, private, sources of water within the village (like pumpsets and open wells). But in the dataset this variable is highly correlated with variables like CANAL. One possible reason may be that government canals increase the subsoil water for private wells.

[14] Except in the case of MARKET, where the negative effect may be modified by the market opportunities for produce raising the return to cooperation on water.

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[15] Since this is a logit analysis the signs are to be appropriately interpreted as indicating directions of changes in the probability of the dependent variable taking on a particular value with changes in the values of an independent variable, even though in our statement of the results we sometimes do not spell it out fully.

[16] From the data of the 480 sampled farmers it is clear that when an average farmer believes that the water rules have been crafted jointly (as opposed to by the elite or by the government), he is more likely to have positive comments about the water allocation system and about rule compliance by other farmers.

[17] This is also empirically corroborated by Lam (1998).

[18] In the corresponding OLS regressions neither NUMUSERS nor NUM_ACRE is at all significant.

[19] There is reason to believe that the access to irrigation refers more to general accessibility to water sources and structures than to the flow of water through the field channels, so the reverse causation (i.e. better maintained channels implying better access to irrigation water) is an unlikely explanation of the positive coefficient. In fact in general in the canal areas AVGACCES is very low, and yet DISTFDCH is high.

[20] Lam (1998) finds a positive coefficient for his explanatory variable on lining, but in a different context comments thus on the design of irrigation infrastructure constructed by the Department of Irrigation (DOI) in Nepal, which may be relevant for our case:
"Although the unlined canal was prone to damage, it was easy to maintain. Whenever there was leakage, farmers could easily locate the leaks and seal the leaks with mud. Now that the DOI has lined the canals with bricks, farmers find it difficult to locate the leaks at all. Even if they can locate them, it is difficult to seal them. Farmers complain that there is little that they can do to keep the canal in good condition."

[21] Following a suggestion of Gershon Feder we ran a separate regression only for the 30 units which are lined (partially or fully). The results are similar to those reported in Table 2, except that the significance of some of the variables diminishes (partly because of the reduced number of observations).

[22] In four of these six units it seems that the PWD, rather than a traditional village organization, looks after the field channel maintenance as well (though the farmers make some cash contributions). This means good maintenance may not always be simply interpreted as an indicator of cooperation among the farmers.

[23] In some alternative regressions (not reported here) we have found that the interactive effect of PGUARD and NUMUSERS has a significant negative coefficient, indicating that the effectiveness of the guard system in encouraging cooperation decreases as the number of users increases.

[24] Of course, a two-stage regression is somewhat problematic when the second stage is a non-linear logit model. One can use OLS as a check to confirm the results. But the problem with using OLS is that with dependent variables that are grouped, the error terms cannot be assumed to be normally distributed. The assumption is even worse, and the results more biased, if OLS is used when the dependent variable takes on only 0-1 values, as in the case of H2OCOOP and VIOLH2O. In the case of DISTFDCH we have used OLS as a check, and the results are largely confirmed (except for the variable NUMUSERS, as we have noted in footnote 19).

[25] It is also the case that in canal areas the water available to the ayacut is from a flow (rather than from a storage reservoir as in the case of tanks), and guarding against water theft may therefore be more serious in the case of tanks than in the case of canals. In any case the TRADLORG variable is not statistically significant as a direct determinant in the cooperation regressions, and we therefore can legitimately use it as an instrumental variable.

[26] Only about 1 in 5 villages has the proportional costsharing rule in our dataset.

[27] In one-third of the villages in the dataset formal water rights, as opposed to customary rights, exist. Again these are likely to be determined by historical-conventional factors, and we can therefore use this variable as a legitimate instrument.

[28] In some alternative regressions (not reported here) we have found that the interactive effect of SHRPROP and GINI is positive in the DISTFDCH regression, suggesting that the higher the level of inequality the more positive is the influence of proportional cost-sharing on the quality of maintenance.

[29] Exactly the same pattern is observed in the other 12 canal-based units.

[30] For example, in 29 out of 48 villages rule violations are mainly by the rich farmers/upper castes, as reported in the ayacut-level survey. Also at the level of the sampled farmers, the average farmer perception is that the rich (landholding-wise the top 4 out of the 10 sampled farmers in the village) comply with rules significantly less than the poor (the bottom 4 out of the 10 sampled farmers), particularly in water allocation and financial cost-sharing.

[31] About 44 percent of the villages in our dataset have a market for well water.

[32] We also have evidence in our dataset that the farmers contribute to the village collective fund much less when the government is involved, presumably because the government is then assumed to be the financier of last resort.

Table 1

Dependent and Independent Variables

Variable Name	No.of Observations	Mean	Standard. Deviation	Min	Max	Description of Variable
DISTFDCH	45	1.31	0.92	0	2	Index of Quality of Maintenance of Distributaries and Field Channels
H2OCOOP	48	0.67	0.48	0	1	No Conflict over Water Within Village in the last 5 Years†
VIOLH2O	48	0.52	0.50	0	1	Water Allocation Rules Frequently Violated by at least One Group†
NUMUSERS	48	52.67	54.29	11	279	No. Of Beneficiary Households Using this Irrigation Source
NUM_ACRE	48	0.36	0.02	0.06	1.07	No. Of Beneficiary Households per acre of Ayacut Area
GINI	48	0.41	0.11	0	1	Gini Coefficient of Landholding of Beneficiary Households in Ayacut
CASTE75	48	0.69	0.47	0	1	At least 75% of Sampled Farmers are Members of the Same Caste Group†
AVGACCES	48	3.65	1.20	2	7	Number of Months there is Access to Irrigation
TOPOGRPH	48	0.46	0.50	0	1	No equal Access to Water Because of Topographical Nature of the Ayacut†
LINED	48	1.96	0.82	1	3	If System is Partially or Fully Lined
CANAL	48	0.50	0.51	0	1	If Ayacut is in a Canal System†
PWDDECID	48	0.25	0.44	0	1	If PWD Takes All Decisions on Water Allocation†
TAILEND	48	0.75	0.44	0	1	If Village is Situated at Tailend of the Irrigation System†
PRIORAPP	48	0.44	0.50	0	1	No Conflict with Other Villages over Water†
LINKAGE	48	2.46	0.74	1	3	Index of Connection with Urban Areas
MARKET	48	2.39	0.70	1	3	Measure of Extent to which Farmers are Market Oriented

OTHIRRIG	48	0.26	0.18	0	0.66	Estimated Fraction of Total Irrigated Land Held by Sampled Farmers Outside the Ayacut
TRADLORG	48	0.56	0.50	0	1	Where Irrigation Organization Has Been There for 20 or More Years†
GUARD	48	0.38	0.49	0	1	There Exists at least One Guard in the Ayacut†
SHRPROP	48	0.19	0.39	0	1	Cost-sharing Proportional to Landholding†
LEGALRGT	48	0.33	0.48	0	1	When Formal Water Rights Exist, as opposed to Customary Rights†
WMARKET	48	0.44	0.50	0	1	If there is a Market for Well Water†

† in the description of a variable indicates that the variable takes only two values, 0 and 1.

Table 2: Ordered Logit Estimates
Dependent Variable: DISTFDCH

Variables	(A) Coefficients	(A) Level of Significance	(B) Coefficients	(B) Level of Significance	(C) Coefficient	(C) Level of Significance
NUMUSERS	-.0308	@ 20%			-.0339*	@ 10%
NUM_ACRE			3.5369	@ 20%		
GINI	-31.1481*	@ 5%	-12.0576	@ 15%	-23.2620*	@ 5%
AVGACCES	5.0160*	@ 5%	3.3115*	@ 5%	4.5637*	@ 5%
LINED	-2.0352	@ 15%	-6.2620*	@ 5%		
PWDDECID	8.0913*	@ 5%	10.8124*	@ 5%	4.8454*	@ 5%
TAILEND					1.5790	Insignificant
PRIORAPP			-6.0943*	@ 5%	-2.2385	Insignificant
LINKAGE	-4.2195*	@ 5%	-4.7874*	@ 5%	-4.2900*	@ 5%
OTHIRRIG	-4.8767	Insignificant	-4.7635	Insignificant		
PGUARD	9.0919*	@ 5%	7.1193*	@ 5%	10.3531*	@ 5%
PSHRPROP	11.6709	@ 15%			9.6847*	@ 10%
ELITERUL	-8.8760*	@ 5%	-6.6006*	@ 5%	-7.9717*	@ 5%
No. of Observations	45		45		45	
Log Likelihood	-15.4788		-14.6912		-16.5396	
Pseudo R-sq.	0.5900		0.6109		0.5619	

* indicates significance at 10% level or below

PGUARD and PSHRPROP are predicted values of the variables GUARD and SHRPROP respectively.

Table 3: Logit Estimates
Dependent Variable: H2OCOOP

Variables	(A) Coefficients	(A) Level of Significance	(B) Coefficients	(B) Level of Significance
NUMUSERS	-.0868	@ 15%	-.0533*	@ 5%
GINI	-106.6778*	@ 5%	-77.4133*	@ 5%
GINISQU	76.2725*	@ 10%	59.8977*	@ 10%
CASTE75	2.9169*	@ 10%	2.1678	@ 15%
AVGACCES	1.4893	@ 20%		
LINKAGE	-3.2398	@ 20%	-2.0861*	@ 10%
PGUARD	22.4376	@ 15%	15.3198*	@ 10%
No. of Observations		48		48
Log Likelihood		-10.3061		-11.7129
Pseudo R-sq.		0.6627		0.6166

* indicates coefficients that are significant at 10% level or below.

GINISQU is the square of the value of the variable GINI

Table 4: Logit Estimates

Dependent Variable: VIOLH2O

	(A)		(B)	
Variables	Coefficients	Level of Significance	Coefficients	Level of Significance
NUMUSERS	.0350*	@ 5%	.0289*	@ 5%
GINI	25.3600	Insignificant		
GINISQU	-34.9862	Insignificant		
CASTE75	-.8536	Insignificant		
AVGACCES	-.8960	@ 15%	-1.0435*	@ 5%
TOPOGRPH	1.1632	Insignificant	1.1202	Insignificant
TAILEND			-.4413	Insignificant
LINKAGE	2.1425*	@ 5%		
PMARKET			.499*	@ 10%
OTHIRRIG	5.8283	@ 15%	4.5255	@ 15%
PGUARD	-7.5257*	@ 5%	-3.4537*	@ 5%
No. Of Observations	48		48	
Log Likelihood	-15.7310		-20.0658	
Pseudo R-sq.	0.5266		0.3961	

* indicates coefficients that are significant at 10% level or below.

GINISQU is the square of the value of the variable GINI; PGUARD and PMARKET are the predicted values of the variables GUARD and MARKET respectively.

Table 5: First-Stage Logit Estimates

	Dependent Variables					
	GUARD		SHPROP		MARKET	
Independent Variables	Coefficients	Level of Significance	Coefficients	Level of Significance	Coefficients	Level of Significance
NUMUSERS	.0305	@ 20%	.0265*	@ 5%		
GINI	9.8339	@ 15%	9.8831*	@ 10%	-4.5713	@ 15%
AVGACCES	-.8961	@ 15%			.4339	Insignificant
CANAL	-4.2407*	@ 5%	4.1930*	@ 5%	2.8389*	@ 5%
LINKAGE	1.5349*	@ 10%				
TRADLORG	3.0781*	@ 5%	2.6285*	@ 5%		
LEGALRGT			2.0355*	@ 10%		
WMARKET					2.0298*	@ 5%
No. Of Observations	48		48		48	
Log Likelihood	-13.6321		-13.7212		-32.8864	
Pseudo R-sq.	0.5707		0.4076		0.2917	

* indicates significance at 10% level or below.

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