Irrigation and collective action: a study in method with reference to the Shiwalik Hills, Haryana

Kurian, M.; Dietz, A.J.

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Mathew Kurian and Ton Dietz

Abstract

In recent years decentralized development approaches have gained prominence in the agricultural sector. A host of community based watershed management projects have been implemented that encourage community organizations to undertake management of previously government controlled irrigation systems and forests. Community organizations have been given the responsibility of managing water distribution, collection of irrigation service fees and undertaking routine maintenance of irrigation infrastructure. In this context, analysis of irrigation management has concluded that groups that are relatively homogeneous may fare better than heterogeneous groups in facilitating collective action. However, this article argues that analysis of the influence of group heterogeneity on collective action is complicated because of its multi-dimensional nature and the presence on non-monotonic effects in mechanisms linking heterogeneity and collective outcomes. The article discusses the importance of context specification in analysis of group heterogeneity through a discussion of elements of a joint management contract in Haryana (India), identification of key variables with a potential to explain collective action in irrigation management and construction of household endowment and water interest scores to account for the influence of group heterogeneity in facilitating collective action. In the process of applying household endowment and water interest scores, the authors highlight the role of local ecological variation and non-farm employment in influencing collective action. Proper specification of local context enables the researchers to rely on household endowment and water interest scores to predict conflicts and potential for irrigation service provision and compliance with irrigation service rules.

Keywords: Irrigation; Collective action; Research method; Watershed management; India.

1. Introduction

In recent years decentralized development approaches have gained wide acceptance in policy circles. In the agriculture sector in particular, farmer-managed irrigation and community-based forest management projects have been promoted with a view to facilitating integrated management of natural resources in a watershed context. Community-based watershed management projects typically encourage participation of rural communities in management of previously publicly controlled forests or irrigation systems (IWMI, 1995: 4). Donor-supported community-based watershed management projects in particular have emphasized the need for collective action by stakeholders to undertake tasks of catchment protection, water distribution, collection of irrigation service fees (ISFs) and routine maintenance of irrigation infrastructure such as water harvesting dams (ADB, 2001).

Studies have pointed out that farmers' groups that are internally differentiated on the basis of income or resources may not be so successful at collective action when compared to groups that are relatively more homogeneous (Chambers et al., 1992; Bandopadyay and Eschen, 1988). This may especially be the case in the context of management of common pool resources (CPRs) such as irrigation canals, fisheries or forests that are characterized by features like non-excludability and subtractibility in use (Ostrom, 1990).

For instance, a study of 10 irrigation reservoirs in India found that the smaller the variance in farm size among farmers, the more farmers were likely to form water user associations (Easter and Palanisami, 1986). Lam (1994) reveals a negative relationship between inequality in landholding and irrigation systems performance. Another study reveals a negative relationship between variance in average family income among irrigators and degree of rule conformance and maintenance activity (Tang, 1992).

In addition to endowments, collective action may also be influenced by distribution of interests within commun-

Mathew Kurian is Associate Expert in Institutions and Policy Studies, International Water Management Institute (IWMI), Kasetsart University Campus, Jatujak District, Bangkok. E-mail: m.kurian@cgiar.org.

Ton Dietz is Professor of Geography at the University of Amsterdam, the Netherlands.

ity groups. Schlager's case study (1990) on fisheries, for example, underlines the importance of a stable economic environment and moderate to high returns for fishermen in sustaining collective action. Other case studies highlight the role of technology and expansion of markets in creating divergent interests among fishermen that lead to a breakdown in collective action. Studies also emphasize the role of heterogeneous distribution of skills and ethnicity in influencing collective action. Wade's case study (1988) of tank management in South India notes the influence of scattering of plots of arable land in sustaining interest by large and small landholders in collective action. However, it must be pointed out that Kanbur's review of case studies focuses primarily on distribution of interests. Examination of distribution of interests and its relationship with distribution of endowments is missing in his analysis. But as Baland and Platteau (1996) point out, analysis of resources and interests should not be carried out in isolation, because, 'groups that are heterogeneous may be able to devise institutions that enable them to draw on complementarities (like homogeneous economic interests) to build a stronger foundation for collective action' (Poteete and Ostrom, 2003: 15–16).[1]

This article is an attempt to discuss the process by which costs and benefits of earthen dam[2] management in the Haryana Shiwaliks are distributed within farmer's groups. From a methodological point of view we raise two questions:

- What variables may be used to define distribution of interests and resources, and how can they be justified?
- What are the local-level processes by which distribution of endowments and resources combine to influence collective action in management of common pool resources?

The remaining sections of the article describe the key features of the Sukhomajiri watershed project in Haryana State of India and the process by which it was scaled out (replicated) in the Shiwalik Hills of Haryana. Issues of transparency and accountability are discussed in the context of the discussion on the functioning of earthen dams in the post-project phase. The article also analyses the role of historically-defined power and social exchange relations, accumulation strategies of farmers and differentiation in access to natural resources.

2. Analyzing collective action in irrigation: grounding concepts in an empirical context

2.1. The Sukhomajiri watershed model. Key features of a joint management contract

Panchkula district has the largest proportion of land under forests in Haryana. As a result, the district has been a particularly important focus of participatory forestry projects. Since the early 1980s a spate of community forestry initiatives have been undertaken: social forestry; joint forest management; and the Haryana community forestry project. The Haryana Joint Forest Management (JFM) Project was responsible for developing an integrated model of watershed management based on experiments that were undertaken in the village of Sukhomajiri between 1975 and 1985 (Arya and Samra, 1995). From the point of view of the Haryana Forest Department (HFD), the Sukhomajiri watershed management intervention was crucial to reduce siltation of the Sukhna Reservoir, located further downstream in the state capital of Chandigarh. The Sukhomajiri model was premised on the idea that a linear relationship exists between the condition of forests located in the Shiwalik Hills and agricultural productivity in low lying plains (see Figure 1). As a result fodder production on private fields was encouraged through provision of irrigation from earthen dams in the expectation that greater fodder and dung[3] production from irrigated fields would obviate the need to use State owned forests for fodder and fuelwood extraction. Between 1984 and 1989 an attempt was made to scale out or replicate the Sukhomajiri watershed model to about 35 micro-watersheds located in Morni-Pinjore Forest Division[4] of Panchkula District in Haryana. An important feature of the scaling-out phase of the project was the creation of institutional mechanisms for sharing revenue from state forests with local communities. Five features of the institutional contract that characterized joint management of watershed resources are worth highlighting (TERI, 1998):

- Water user associations were constituted as hill resource management societies (HRMS) under the Registration of Societies Act of 1900.

[1] Such a perspective may, for example, partly explain how water user associations and individual water contractors have begun to systematically replace traditional forms of village-leader controlled water organizations in China's Yellow River Basin (see Wang et al., 2002).

[2] Earthen dams are made of compacted soil from the Shiwalik foothills. Shiwalik Hills forests serve as catchment of earthen dams. The catchment areas are usually bowl shaped; water from the hills collects in them during the monsoon period, and is used during the winter period for supplementary irrigation, primarily for wheat cultivation. Institutional arrangements that regulate opening and closing the sluice valves are critical; if the sluice valve is left open beyond a certain point the dead storage of the dam silts up. Water is transported to agricultural fields on the basis of gravity flow. The dams are also fitted with spillways to ensure that excess water flows away without damaging the main body of the dam.

[3] Cattle dung is used extensively as a cooking fuel in the Shiwalik region. It was assumed that increased production of cattle dung would reduce pressure on state forests for supply of fuelwood for cooking purposes. An alternative approach to reducing pressure on forests for fuelwood collection has been to facilitate greater adoption of non biomass fuels like liquefied petroleum gas (LPG) technology for cooking purposes by rural populations. This strategy has been attempted at an all India scale by the Indian Ministry of Non-Conventional Energy Sources (see Ramana, 1996).

[4] For administrative purposes Morni-Pinjore Forest Division is further subdivided into three forest ranges: Pinjore, Panchkula and Raipur Rani.

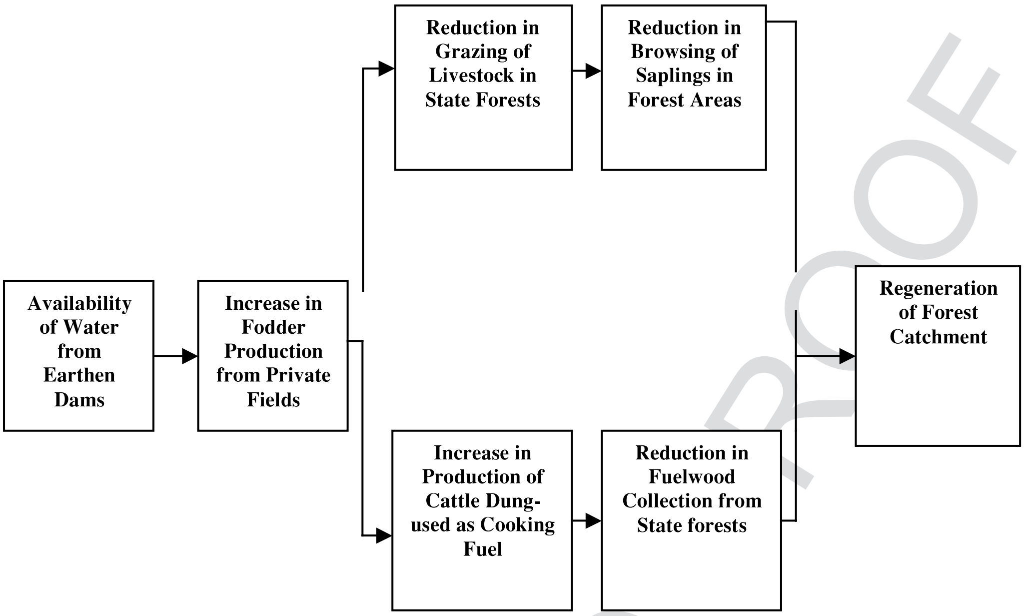

Figure 1. The Sukhomajiri watershed model.

- Landless households were given a share of water from dams provided they were members of the HRMS. Attempts were made to institute a system of tradable water shares so that landless households could sell their share of water to other households.
- An important principle regarding use of HRMS funds was that a proportion of profits from the sale of water from dams (and fibre and fodder grasses) could be used for community development activities. Such activities could take the form of construction of village roads, repair of school buildings or construction of rest areas for labourers.
- At least a third of positions in the managing committee of the HRMS are to be reserved for women. Every woman in a household was entitled to membership distinct from membership of the male head of household in the general body of HRMS.
- The Haryana Forest Department (HFD) facilitates participation of community groups in watershed management by organizing annual elections of managing committees of HRMS and monitoring annual auctions of fibre grass and water harvesting rights to forests under joint management.

2.2. *Rapid survey of HRMS*

As noted earlier, 35 of the HRMS were established in the Morni-Pinjore Forest Division of Haryana under the watershed management project. The study focuses on the Morni-Pinjore division of Panchkula District for two reasons: (i) the watershed management project was initially started in the area; and (ii) external intervention in the form of NGO visits was minimal between 1996 and 2000. Due to logistics difficulties, such as impassable roads during the monsoon rains, this study could cover only 28 HRMS responsible for managing 45 earthen dams.[5] Our survey of the 28 HRMS in the Morni-Pinjore Forest Division was undertaken over a period of one month in which information was collected on variables such as group composition, access to alternative irrigation sources and participation in management of earthen dams. The highlights of the survey included (Kurian, 2003):

- Human populations in Shiwalik villages rely on forest areas to meet a substantial part of their subsistence needs for fuelwood and livestock fodder from forest areas.
- Agriculture is the predominant occupation of Shiwalik villages. However, in villages located near towns and cities, non-agricultural employment usually takes the form of engagement in house construction activity and gatekeepers in factories. Closer to village settlements, employment in stone quarrying and soil and water conservation activities sponsored by the Forest Department is available. Such employment is however, low paying and unpredictable.
- Access to irrigation offers potential to double agricultural yields of wheat during the winter period. Irrigation from earthen dams typically benefits up to 35 households in a micro-watershed. Water distribution is by hourly rotation starting with head-end water users and ending with those with plots at the tail end of an irrigation system. Water user fees are charged by the hour, ranging

[5] It is important to note that a one-to-one correspondence between HRMS and dams does not exist. This is because some HRMS like Sukhomajiri had more than one dam under their management. Further, some dams were constructed in areas where no HRMS existed or HRMS were constituted where no dams were constructed.

Table 1. Post-project analysis of earthen dams in Morni-Pinjore Forest Division

Indicator	Dams for entire Forest Division	Pinjore forest range *(1975–83)*	Dams for range	Panchkula forest range *(1984–89)*	Dams for range	Raipur Rani forest range *(1990–98)*	Dams for range
	(45)		(18)		(14)		(14)
Number of dams silted within 5 years of construction	31.3%	4	22.2%	7	50%	3	21.4%
Number of dams silted within 10 years of construction	33.3%	5	27.7%	3	21.4%	7	50%
Number of dams functioning for less than 1 year	20%	6	33.3%	1	7.1%	1	7.1%
Number of dams functioning in 2000	17.7%	4	22.2%	2	14.2%	2	14.2%

Table 2. Profile of HRMS groups by mode of water provisioning from earthen dams[a]

HRMS	Land ownership pattern (proxy for endowments)	Agriculture is primary source of income[b] (proxy for interest)	Private alternatives to earthen dam exist (proxy for interest)	Caste composition	Evidence of collective action to manage earthen dams	Mode of provision from earthen dams	Land area irrigated by dam (ha)	Number of beneficiaries of irrigation from dam[c]	Percentage of Water Users Complying with Irrigation Service Fees
Sukhomajiri	Even	Yes	Yes	Single	No	HRMS	24	12	None
Dhamala	Skewed	No	No	Multi	Yes	Contractor	16	30	100%
Lohgarh	Skewed	No	No	Multi	Yes	Contractor	18	15	100%
Nada	Skewed	No	No	Multi	Yes	Contractor	12	60	None
Bharauli	Skewed	No	No	Multi	Yes	Contractor	16	35	42.1%
Thadion	Even	Yes	Yes	Single	No	HRMS	15	15	100%
Govindpur Mandpa	Even	No	No	Single	Yes	Contractor	24	23	None
Kiratpur	Skewed	Yes	Yes	Multi	No	HRMS	6	15	100%

Notes:
[a] Where more than one dam was functioning in a HRMS, we focused on the dam which the larger number of households relied on for water. We also overlooked dams that were choked but which households continued to use using a siphoning system.
[b] More than 50% of water users do not rely on agriculture as primary source of income.
[c] Average number of beneficiaries of earthen dams.

from Rs 10 to Rs 25 per hour. Depending on the composition of the village, there are usually multiple caste groups benefiting from irrigation from earthen dams.

- Only eight earthen dams of a total of 45 that were constructed in Morni-Pinjore Forest Division were functioning when data for this study were collected in June, 2000 (Kurian, 2003). The eight functioning dams were under the management of eight HRMS. A large number of dams had silted up or had been washed away much before their expected ‘shelf life’ of about 10–15 years had been attained. This failure was because of a number of technical problems relating to location of head works and quality of construction. Table 1 provides information on the number of functioning dams in the Forest Division.

2.3. Collective action in earthen dam management: the embedded nature of irrigation institutions

Our review of eight HRMS with functioning dams revealed two systems of water provisioning. The first system is that of the HRMS being involved in framing water distribution rules, collection of irrigation service fees and undertaking of routine maintenance. The second system is contractor-based provision. Under this system, an individual leases out water distribution rights at an annual auction organized by the HRMS. The contractor is then held accountable for water distribution, collection of irrigation service fees and undertaking routine maintenance.

An examination of the socio-economic profile of HRMS reveals some interesting facts relating to collective action (Table 2). For instance, we find that of the eight groups with functioning dams, five showed evidence of collective action.[6] Of these five groups, four were heterogeneous in caste composition and one was homogeneous. Further, of the four heterogeneous groups, all had adopted a system of contractor-based water provisioning. In the case of the homogeneous group as well (Govindpur Mandpa), a contractor had assumed responsibility for water provisioning.

[6] Collective action was evident in relatively higher levels of compliance with water distribution rules, expenditure on repairs and labour contributions towards maintenance of dams. The criteria we used to evaluate compliance with water use rules were as follows: number of water users as a percentage of total complying with irrigation service fees. Later on in this paper we provide an elaborate justification for choice of variables in analyzing collective action in irrigation management.

It is also interesting to note that of the three groups that showed little or no evidence of collective action, two were homogeneous and one was heterogeneous. In the case of the two homogeneous groups, the HRMS was responsible for water provisioning. In the heterogeneous group (Kiratpur) too the HRMS was responsible for water provisioning. Therefore, it is possible to notice a pattern between group composition, type of water provisioning and evidence of collective action.[7] Groups that are heterogeneous facilitated water distribution by a private contractor, the result being that compliance with collective action rules tended to be greater. On the contrary, groups that are relatively homogeneous relied on HRMS provisioning and consequently failed to ensure compliance with collective action rules. However, two groups in our sample appear as exceptions to the general rule: Govindpur Mandpa, despite being homogeneous, has resorted to a private contractor and succeeded in collective action. Kiratpur, despite being heterogeneous, has relied on HRMS provisioning and failed to provide evidence of collective action.

Each of these cases offers lessons on the importance of group composition in analysing collective action. First, the Govindpur Mandpa case highlight*s* a methodological issue. The fact that a contractor has emerged to provide irrigation services in Govindpur Mandpa despite it being a homogeneous group suggests that choice of variables is critical in determining levels of homogeneity or heterogeneity. Previous studies of influence of group heterogeneity in CPR management have tended to rely on static analysis based on variables like land ownership or caste composition (see Baker, 1998; Bardhan, 2000). But we argue that an approach that combines analysis of process variables (such as land area irrigated or rainfed, livestock composition, or household size) with analysis of socio-economic processes that reflect changes over time in process variables may better explain the underlying conditions of collective action. Socio-economic processes may include historically defined power and social exchange relations, accumulation strategies of farmer households or differentiation[8] in terms of access to natural resources such as land and water.

Second, the Kiratpur case highlights the importance of factoring in ecological variation and non-farm employment in understanding the role of interests in shaping collective action. We note that Kiratpur, despite being a heterogeneous group, has relied on HRMS water provisioning. This is primarily due to two reasons. One is that less than half of water users in Kiratpur rely on agriculture as their primary source of income. This reflects their involvement in non-farm labour markets, which could imply that landholders spend considerable time away from the settlement and are therefore in no position to monitor water use rules, should they decide to serve as water contractor. The second reason is that farmers interest in using water from earthen dams is not as intense as it would be in the absence of private alternatives. Most farmers using water from the earthen dam also have access to a private tubewell. In the ensuing discussion we will highlight the role of groundwater depth (a critical feature of local ecology in the Haryana Shiwaliks) and its effects on cost of tubewell adoption with a view to highlight its influence on collective action in irrigation management.[9]

2.4. Case study approach

We used five criteria to arrive at the choice of Bharauli and Thadion HRMS for a detailed case study: (i) water harvesting dams must be operational; (ii) HRMS must be functional; (iii) one HRMS must be relatively heterogeneous and show evidence of collective action in comparison to another that is relatively homogeneous and fails to show evidence of collective action with regard to dam management; (iv) HRMS must be situated in close proximity to each other to reduce differences in contextual factors like distance from markets, slope, elevation and forest type; (v) HMRS must be situated in Raipur Rani forest range, where rural livelihoods depend to a greater extent on agriculture and animal husbandry.

2.5. Overview of case study sites

2.5.1. Group size, ethnic composition and forest area

Bharauli is a relatively large village with 80 households, compared to Thadion with its 50 households (see Figure 2). Bharauli has a population of 476, compared to 318 in Thadion. Bharauli is a multi-caste community that includes: *gujjars*, *tarkhans*, *rajputs* and *harijans*. By contrast, Thadion is homogeneous with respect to caste with only *gujjar* households.

[7] This relationship still needs to be statistically tested using a larger number of cases. This study by using case study evidence attempts to clarify a relationship between provision, group composition and rule compliance in natural resource management. We hope such an analysis would provide sufficient basis for future studies that attempt to statistically examine this relationship using a larger data set.

[8] White (1989) describes a process of differentiation as involving emergence or sharpening of differences within the rural population, but it does not in itself consist of (and in some cases, at least in the short term, may not involve) increasing income inequalities. It is not about whether some farmers are becoming richer than others but about the changing kinds of relations between them in the context of development of commodity relations in the rural economy.

[9] Analysis of influence of group heterogeneity on collective action is complicated because (a) it is multi-dimensional and (b) the mechanisms linking heterogeneity and collective outcomes are recursive and non-monotonic. Heterogeneity is multi-dimensional because it includes wealth inequality and heterogeneity of interests (see Dayton-Johnson and Bardhan, 2002). Bardhan and others examine the multi-dimensional nature of influence of group heterogeneity on collective action by employing a multi-variate analytical framework. There have also been attempts to test the non-monotonic effect of heterogeneity (i.e. inequality might harm collective action, but beyond a certain level, increasing inequality might enhance collective action) (Bardhan and Dayton-Johnson, 2002).

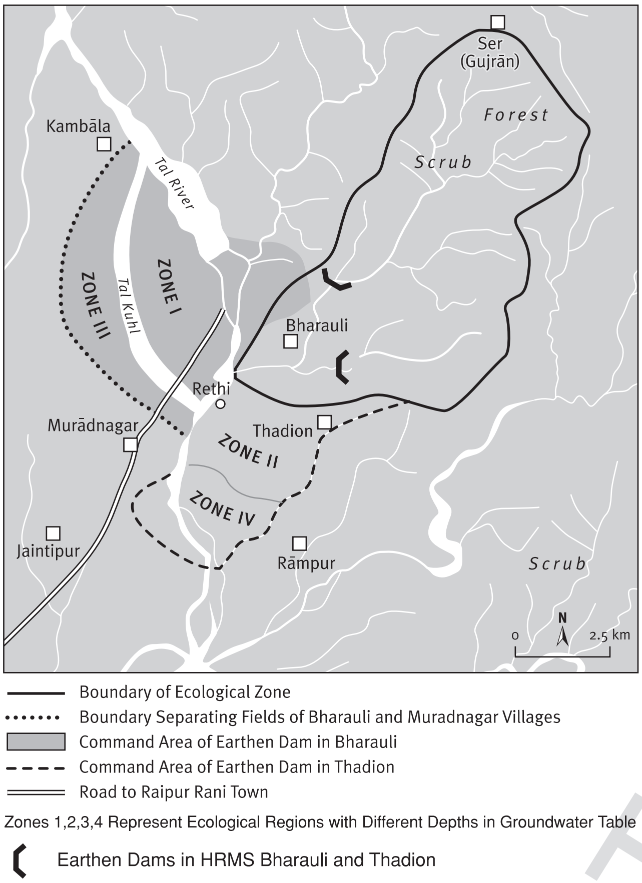

Figure 2. Watershed areas of HRMS Bharauli and Thadion

2.5.2. Caste basis for occupational specialization and social segregation

Given the greater diversity of castes in Bharauli, some occupational specialization based on caste identity is evident. For instance, the *tarkhans* or blacksmiths undertake work for other caste groups. In return for their services, they are usually paid in grain. Only two *tarkhan* households own arable land and they avoid rearing livestock. Likewise, the *harijans* have traditionally worked as hired labour on other people's fields or as domestic helpers in the homes of large landholders. The *rajput* caste households in the village form a distinct group because they have monopolized the petty transport business. Caste-based notions of impurity and hierarchy in Bharauli prevent *harijans* from using drinking water taps, ponds and temples frequented by members of other castes. Caste also influences separate residential locations for different caste groups within the village. Harijans when invited to marriages in the village are usually expected to sit at a distance from others and use separate utensils. No such caste-based pattern of occupational specialization or social segregration exists in Thadion.

2.5.3. Earthen dams

There are two earthen dams in the study area, each constructed by the state forest department. In both cases the Shiwalik forests serve as their catchment. The catchment area of the dam at Bharauli is 39 ha, while the area of the dam at Thadion is 15 ha. Further, the command area of the dam at Bharauli is 40 ha compared to 20 ha at Thadion. Thirty-five households benefit from irrigation from the dam in Bharauli while fifteen households benefit from dam-assisted irrigation in Thadion.

2.5.4. Water use rules

Water in earthen dams is harvested during the *kharif* (rainy, monsoon) season (June to September). Harvested water is then used during the *rabi* (dry) season (winter) primarily for the wheat crop. Tariff rates for irrigation water from the dam are fixed in consultation with water users who associate a higher charge with greater assurance of predictable water supplies. Three to four rounds of watering are possible in both Bharauli and Thadion. Rules stipulate that water distribution should take place on a rotational (hourly) basis for the wheat crop. During each round farmers whose lands are situated closer to the dam are supplied water first, after which water is released for use by farmers farther down the distribution channel.[10]

2.5.5. Water transport

Water is transported by plastic pipe from earthen dams. The pipes are buried about three feet in the ground. At strategic locations in the command area, vertical exit valves are placed. At the ends of the plastic pipeline, farmers dig artificial water courses to transport water to their fields. Water transport is dependent on gravity flow and usually has to crisscross several fields. As a result, water transport in some cases involves negotiations between farmers to facilitate the digging of channels to divert water towards their fields.

2.5.6. Alternative irrigation on dam-irrigated land

In Bharauli, households have access to *kuhls*[11] for land that is irrigated by the dam. But the *kuhls* run dry by early

[10] A system of tradable water shares was introduced by the JFM project, whereby landless households in particular who did not have a need for irrigation water could sell their share of water to other households. But our study indicates that the system of water-tradable shares was not being implemented in Bharauli.

[11] Each family or *gotra* is allocated water from the *kuhl* by rotation for a 12-hour period. One water user is given the responsibility of monitoring the rotation. For his services he allocated six hours of water from the *kuhl* in excess of his designated share of 20 minutes of water. The number of hours a household receives water is determined by the size of land holding. For example, in the Poswal family there are seven households with a total water availability of 12 hours per rotation. One among the seven households with land size of 20 acres is allocated six hours of water while the remaining six households with land size of three acres each are allocated water for one hour only. In case of subdivided land within a household the number of hours of water distribution is likewise reduced. The water users of Bharauli meet twice annually to decide on minor repairs to be undertaken to the *kuhl*. Although the management of the *kuhl* bears no connection to the HRMS organization that has been established by the state for management of the earthen dam in Bharauli, a number of beneficiaries of the *kuhl* also receive irrigation from the dam.

February and, if rains do not arrive by early March, the supply of the last round of supplemental irrigation for wheat depends on water from the earthen dam. If the rains fail altogether (in the period from November to March), reliance on water from the dam becomes even more critical. The higher drilling costs associated with groundwater exploitation in Bharauli had limited access to private tubewells. In Thadion by contrast groundwater can be tapped at higher reaches, thereby lowering drilling costs. As a result a relatively larger number of dam water users have access to private tubewells for irrigation.

3. Construction and application of nature-based household endowment and water interest scores

3.1. Nature based household endowment scores

From our discussion in the previous section it becomes clear that crop agriculture and animal husbandry are important sources of rural livelihoods in the Morni-Pinjore Forest Division in Haryana. Non-farm employment as casual labour in stone quarrying and house construction activities are important in that they supplement income from agriculture-based activity. This is particularly the case with land-owning households. Landless households derive a significant part of their income from non-farm sources. But considering that landless households do not constitute more than 15% to 25% of households in Shiwalik villages, we can safely assume that most households derive their livelihoods from farm-based activity (TERI, 1998). Thus, we chose to construct nature-based household endowment scores based on agriculture and animal husbandry.

In the process of constructing household endowment scores we considered four variables: (i) total rainfed land owned; (ii) total irrigated land owned; (iii) type of livestock owned; and (iv) size of household. In constructing household endowment scores we devised weights for each of the assets outlined above. The weights were decided based on food productivity assessments undertaken in Shiwalik villages (Appendix 1). In devising weights for caloric value of cereal crops and average milk production, we made certain assumptions that are outlined in Appendix 1. Based on average food productivity assessments for cereal crops and milk, we calculated household endowment scores for households.[12]

[12] One weakness of the household endowment score which we acknowledge is the assumption that adults and children have the same activity levels and similar calorie requirements. Theoretically household endowment scores could also incorporate supply of calories from consumption of produce from home gardens and non-timber forest products like wild berries and honey from forest areas. In the Haryana Shiwaliks though, we find supply of calories from such sources to be insignificant.

3.2. Construction of household water interest scores

To examine patterns of farmer interest in earthen dams, we constructed interest scores[13] for water-using households in Bharauli and Thadion HRMS. In calculating interest scores for farmer households, we made some assumptions based on preliminary data analysis and discussions with key informants. First, we assumed that the larger the area irrigated by the earthen dam, the greater the interest in its use; conversely, the smaller the area the lower the interest. Second, the greater the reliability[14] afforded by alternative sources of irrigation for dam-irrigated land, the smaller farmers potential interest would be in participating in management activities like repair and maintenance of the earthen dam. This relates to our third assumption: the greater the area under irrigation outside the dam command area, the lower the potential interest would be in participating in collective action (e.g. purchasing water distribution rights, complying with water user charges, water distribution rules).

Interest scores of 1, 2, 4, 8 and 16 were decided based on findings of household food productivity assessments. We noted that access to irrigation could increase wheat production per acre by a factor of two. Likewise, irrigation could increase the number of people who can be fed from one acre of land by a factor of two. In determining weights for (i) area irrigated by dam, (ii) alternative sources of irrigation for dam-irrigated land and (iii) land area outside dam command area, therefore, we allocated weights that differed by a factor of two.

3.3. Applying nature-based household endowment and water interest scores — empirical observations

3.3.1. Non-farm income and interest in earthen dam management

Non-farm income is becoming an important source of supplementary household income. However, although this study collected information on non-farm income we did not use it in our calculation of household endowment and water interest scores for three reasons. First, with the exception of a couple of households in Bharauli and Thadion non-farm employment was limited to about four to five months, mostly during the dry season. It is irrelevant to ask whether non-farm income earned during this period had the potential to adversely impact on collective action in dam management. Second, the majority of non-farm jobs were low

[13] Recent research has pointed to the importance of rigorous appraisal methods to enhance the quality of project selection and the financial viability of donor-supported interventions (see Walle and Gunawardene, 2001). As a result, multilateral development banks have begun to experiment with the use of qualitative codes and weights to predict farmer participation in management of common pool resources and project monitoring (see Dayal et al., 2000; Pincus, 1996).

[14] By reliability we refer to the number of months irrigation is forthcoming from different sources. Tubewells provide water all year round and Tal *kuhl*/Nadi river for eight months between July and early February.

paying — enough only to sustain non-food purchases of consumptive value (like bathing soap or toothpaste) during the dry months. Thirdly, cultivation of family-owned plots under dam-assisted irrigation actually facilitated building up a food stock of wheat that enabled male members to go out in search of non-farm jobs during the dry season.[15] Therefore, contrary to what one may assume, non-farm employment may diminish the potential for collective action in irrigation management; cultivation of farm plots under dam-assisted irrigation was actually sustaining engagement in non-farm labour markets during the critical dry season period.

Another shortcoming of relying too heavily on non-farm income data arises from the often-stated criticism of use of income data in poverty analysis. This is because of the tendency of household income data to vary across seasons: pre-sowing to post-harvest and summer to monsoon, depending on when the inquiry is conducted (Ravallion, 1992). As Sen (1999: 81) points out, ‘In any choice of criteria for evaluative purposes, there would not only be use of value judgments, but also, quite often, use of judgments on which full agreement would not exist. But the real issue is whether we can use some criteria that would have greater public support, for evaluative purposes, than the crude indicators often recommended, such as real-income measures.’

To overcome this criticism, we chose to use nature-based household endowment scores. Household endowment scores implicitly acknowledge that access to irrigation can boost per acre productivity of cereal crops. We clarify our point with an example from Bharauli HRMS. A household with four family members, 0.2 acres of non-irrigated land and ownership of one adult cow had an endowment score of 2.4 and a food production capacity of 60% (i.e., 2.4/4 = 0.6). The household had a food deficit of 40%, but it also had access to non-farm income of Rs 19,200 per year. With wheat costing Rs 7.00/kg, this household could purchase a total of 2,743 kgs of wheat using its non-farm income.

Access to irrigation can prove critical in determining the extent of household interest in complying with rules relating to management of earthen dams. Household interest scores by considering ‘irrigated land area’ as an important variable in the analysis captures this dimension of household survival strategy.

What constitutes collective action? Collective action may take two distinct forms: provision of collective goods by an individual entrepreneur; and concerted action by a group of resource users to comply with rules regulating use of a common pool system. From the point of view of irrigation management in the Haryana Shiwliks, we observed four types of collective action: (i) compliance with water distribution rules; (ii) compliance with payment of fees for water use and lease payment by contractors (where applicable); (iii) compliance with rules that stipulated contribution of money or labour to undertake routine maintenance of the dam; and (iv) negotiation and sanction over contractors appointment, setting of water fee rates and mode of payment.

Measurement challenges presented themselves in our attempt to categorize HRMS depending on their levels of collective action. For example, it was difficult to arrive at a standard measure of what constitutes high level of compliance with water distribution rules. Instead level of compliance with water distribution rules were more observable using conflict as a proxy variable. Here again it was important to distinguish between conflicts that were related to routine working of the irrigation system (like minor delays in releasing water to neighbouring fields) and those that had the potential to disrupt the functioning of the system (like systematic pilferage during the night). These were issues that could be captured using a locally focused case-study approach.

The difficulty with arriving at a standard measure of comparative value also arose in relation to compliance with routine maintenance activity. Here we found that contributions towards maintenance were bound to vary depending on factors such as size of the dam, quality of dam construction and state investment in repairs. For example, we noticed in the case of Lohgarh and Dhamala HRMS, relatively high state investment in dam maintenance had ‘crowded out’ community contributions towards repairs. Does that mean that these groups had low potential for collective action? Empirical studies of these two groups suggest the contrary (see Sarin, 1996). Therefore, controlling for differences in these factors was important to understand the motivations behind community participation in maintenance activity.

One measure which made it possible to arrive at a categorization of HRMS depending on levels of collective action relates to compliance with irrigation service fees. Here we notice operation of the ‘all or nothing’ phenomenon. People complied with fee payments if they were convinced that others were paying up as well. If some did not pay fees on time, no one in the group paid. Similarly, in cases where water users did not comply with payment schedules, contractors were reluctant to engage in providing services for fear of forfeiting their lease deposit with the HRMS. Levels of compliance with irrigation service fees also had an effect on other parameters of collective action. For example, when fee compliance was low, it was not uncommon to observe conflicts that prevented orderly water distribution. Moreover, contributions of labour and money towards routine maintenance activity also tended to be low. This was because users perceived high discount rates associated with collective action and their conclusion that norms of fair distribution were not in operation (see Ostrom, 1990). Therefore, we chose the parameter of level of compliance with irrigation service fees to categorize HRMS depending on their levels of collective action.

[15] Although paddy is cultivated in the area, it is not consumed locally, but is reserved exclusively for sale. Wheat and maize serve as the staple diet of local populations.

Table 3. Changes in household endowment scores between 1996 & 2000

HRMS	Distribution in 1996	Distribution in 2000
Bharauli	61.4	69.1
Thadion	46.6	33.6

4. What do nature-based household endowment and water interest scores tell us about collective action?

In section 2 of the article we argued that our understanding of collective may be enriched by combining an analysis of process variables (such as those used in calculation of endowment scores) with an examination of socio-economic processes that reflect changes over time in process variables. In this section we turn to an analysis of the latter set of issues: historically-defined relations of power and social exchange, accumulation strategies of farmer households and differentiation in terms of access to natural resources such as land and water.

4.1. Access to irrigation from dams serves as a basis for differentiation

Earlier on in the discussion we suggested that explanations of collective action in irrigation may benefit from an analysis of process variables. Our examination of household endowment scores based on two data sets from 1996 and 2000 reveals two interesting patterns (Table 3):

- Group heterogeneity in Bharauli is greater than in Thadion at both points in time (1996 and 2000); and
- Bharauli appears to be becoming more heterogeneous over time while Thadion is becoming more homogeneous.

A useful way to understand reasons behind such trends in group heterogeneity is to examine each of the four variables that went into calculations of household endowment scores. We examine the coefficient of variation of each of the following variables: average land irrigated; average size of rain-fed land owned; livestock composition; and average family size. We observe that patterns of variance are comparable for all variables except for average irrigated land. We therefore argue that the land area irrigated by the earthen dam in Bharauli had the greatest explanatory power for understanding trends captured in the movement of endowment scores for both water user groups.[16]

4.2. Distribution of interest and conflicts over water use

The limited access to private sources of irrigation (tubewells) in Bharauli has meant that dependence on common pool resources (dams) is critical for the supply of supplemental irrigation during the *rabi* (dry) season.[17] This is reflected in a relatively high mean level of interest in earthen dams in Bharauli. A high level of interest is also reflected in data relating to share of income from irrigated agriculture, cropping intensity rate and area irrigated by dam for households drawn from different endowment categories (Table 4). In Thadion, by contrast, we found a lower mean level of interest in use of the earthen dam. This is primarily because half the water users have access to tubewells. The same group of water users with access to tubewells also has their farm plots located at the head of the command area of the earthen dam. Further, most of the households with access to tubewells are drawn from a single family lineage. These facts indicate that households at the head-end of the earthen dam command area could cooperate among themselves to monopolize water and deny farmers with plots located at the tail-end their share of water from the dam. Other studies have documented such examples of powerful families co-opting the benefits of irrigation projects (see Bandopadhyay and Eschen, 1988).

Conflicts arise primarily due to differences in priorities of water users. For example, in Thadion differences in priorities have been reflected in households belonging to a single extended family that constitutes about 60% of all water users using water from dams to irrigate rice during the rabi season (Table 5). Farmers with access to tubewells tend to view earthen dams as a supplemental source of irrigation for rice cultivation.

4.3. Potential for irrigation service provision

Success with dam management in Bharauli is explained in large part by the effectiveness of contractor-based water provisioning. In Bharauli a water contractor has been in charge of water distribution, collection of ISFs and routine maintenance for three years (1997–2000). The ability of the contractor to successfully bid for water distribution rights at open auctions has been aided by surpluses he has derived from irrigated agriculture. From a livelihood perspective, the agricultural surplus that the contractor derives is critical to ensuring well-being, especially since there was no other male in the household earning income from non-farm employment.[18] From the contractor's point of view, sustaining

[16] In the absence of alternative sources of irrigation in Bharauli the relationship between total land area under irrigation and that which benefits from supply of water from the dam can be examined in a relatively straight forward manner. To test the explanatory power of dam-assisted irrigation we ran a regression using total land area irrigated (dependent variable) and area irrigated by dam (independent variable). We found a robust relationship between variables.

[17] Wade's study of South Indian tank irrigation also concludes that resource scarcity can serve as a powerful incentive for organizing collective action. But Bardhan points out that extreme resource scarcity may prove detrimental to collective action since farmers may choose to abandon their lands and migrate in search of better pastures (Bardhan, 1993).

[18] Customarily, women in the Shiwalik region do not participate in nonfarm labour markets. This is primarily because of community norms that prevent them from engaging in work in the presence of men.

Table 4. Share of household income from farm and non-farm sources and level of interest in use of earthen dams

Endowment cluster	Net farm based income (mean)	Non-farm income (mean)	Non-farm income as percentage of total household income (mean)	Cropping intensity rate	Area irrigated by earthen dam (in acres)
High	28,666	10,000	28.9	196	3
Medium	17,405	13,933	44.4	175.4	2.1
Low	13,381	17,158	60	185.7	1.2

Table 5. Rice cultivation: HRMS comparison

HRMS	Percentage of water-using households growing rice	Mean gross cropped area under rice (in acres)
Bharauli	9	8.3
Thadion	46.6	30.9

Table 6. Distribution of household endowments: a comparison

HRMS	Coefficient of variation	Gini-coefficient
Bharauli	96	0.49
Thadion	64.2	0.35

agricultural surplus is critically tied to ensuring compliance with institutional rules that regulate use of the dam. Success with ensuring rule compliance is influenced by three factors:

- Alternative irrigation sources in the form of private tubewells did not exist in Bharauli due to high drilling costs. By contrast, approximately 53% of water users in Thadion had access to private tubewells.
- The farm plots of the water contractor's household were located at the end of each of the three distributary channels. The water contractor had the largest acreage under irrigation from the dam in Bharauli.
- Distribution of household endowments was relatively more unequal in Bharauli compared to Thadion (Table 6).[19] This was primarily because of the fact that, in the absence of tubewell irrigation, not all plots received irrigation from the dam. Greater heterogeneity in distribution of household endowments in Bharauli in the context of relative homogeneity of interest in earthen dam management also minimized the potential for factional conflicts among large land holding households.[20]

[19] From a methodological point view, it is important to note that analysis of endowment distribution produces different outcomes depending on the analytical method we adopt. For example, when we use land ownership as a basis for analysis, distribution of household endowments appears relatively more equal. However, when we adopt a method based on analysis of nature based household endowments we get a picture of relatively greater inequality in distribution of endowments within the group.

[20] The relative heterogeneity of endowments is evident in a much higher coefficient of variation of 20.4 in Bharauli compared to 2.9 in Thadion.

The above discussion highlights the importance of a specific set of socio-economic, ecological and political conditions in facilitating contractor-based water provisioning. First, strong leadership may result in economic interests overriding caste-based differences and can facilitate collective action in natural resources management. (see also Vaidyanathan, 1986; Vedeld, 2000) Second, in a milieu that discourages an extensive women's role in the public sphere, the number of males of working age in a household may influence the potential for non-farm income diversification. This factor is highlighted in the decision of the water contracting household to maximise gains from farming at the expense of non-farm employment. Third, specific ecological conditions like location of arable plots of land in relation to irrigation sources may critically influence an individual's decision to contract out water distribution rights.

The specific conditions of the contractor in the Bharauli case contributed to the contractor-based water provisioning. A different personality with weak leadership qualities and with arable plots located at the head end of the irrigation system may have led to a different set of outcomes with regard to collective action. Further, the presence of an effective leader like the water contractor with arable plots located at the tail end of the irrigation system may have changed the fate of collective action in Thadion.

4.4. Compliance with irrigation service rules

The relatively greater access of the water contractor to arable land and more specifically to irrigated land has accorded him a powerful place in the village power structure. Historically the water contractor has been a source of credit for landless households, especially in times of droughts and floods. He has also been a source of employment for marginal land-owning households. The contractor has played an important role in regional politics by being leader of Bharauli *panchayat* (local government) between 1995 and 2000. The contractor's power within the village, together with the fact that a substantial number of water users are reliant on irrigated agriculture as a primary source of income, has influenced level of compliance with water use rules. The contractor has devised an intricate web of exchange relationships whereby payment of water fees is tied to services like agricultural labour that marginal landowners owe to the water contractor (see Bardhan, 1984: 61).

Table 7. Water predictability difference

HRMS	Water predictability among users at head end of distribution network	Water predictability among users at tail end of distribution network	Difference in water predictability between head-end and tail-end users
Bharauli	1.8	1.3	0.5
Thadion	1.7	0.1	1.6

Moreover, the contractor has been able to dissuade members of his extended family from bidding at water auctions due to his predominant position in the power structure. Finally, survey data indicate that most households relying on non-farm incomes belong to low endowment category and continue to be heavily reliant on cultivation of farm plots to meet a substantial part of domestic food requirements.[21]

4.5. Water distribution rules

We adapted Ostrom's use of 'water availability difference' to examine predictability in availability of water among farmers at the head-end and tail-end of the dam distribution network (Ostrom 1994: 552).[22] The difference in predictability of water supply between head-end and tail-end farmers was lower in Bharauli than in Thadion (Table 7). This reflects the higher level of effectiveness of water distribution in Bharauli that is explained in large measure by greater clarity about water use rules.

Another indication of the effectiveness of the water distribution system is the difference between average water requirement and water availability. Based on rule of thumb calculations of water requirements during the rabi season and mean land sizes we arrived at the difference between water requirements and water availability.[23] In Bharauli, relatively effective water distribution rules guaranteed a relatively large number of households access to water from the dam. In Thadion, by contrast, because a few households have a monopoly on use of water, the difference between water requirement and water availability is greater. The important point that emerges from this discussion is that caste and endowment based heterogeneity (like the case in Bharauli) need not necessarily prevent farmers from cooperating to meet secular economic interests. On the other hand caste and endowment based homogeneity in Thadion masks a deep rooted process of social restructuring (driven particularly but not exclusively by private tubewell proliferation) that erodes potential for collective action in irrigation (Gupta, 2000).

Greater effectiveness of water distribution from the water-harvesting dam is also reflected in the expansion of the Bharauli distribution network. In response to growing profits from water sales, the contractor expanded the distribution network in 1999/2000 to provide irrigation to 15 additional households. As a result, a total of 19.5 acres were brought under irrigation. We must emphasize here that within the constraints imposed by command area topography and availability of water in the dam, the dam contractor does attempt to balance the needs of a wide constituency of water users. The contractor attempts to supply farmers from other caste groups and those with smaller land holdings as well. The interests of large landholders who can wield enormous political clout are accommodated in the expansion plan. Further, 40% of the new beneficiaries were either his brothers or belonged to his extended family. This suggests that the contractor is playing a strategic leadership role by coordinating the interests of a group with a substantial stake in the functioning of the irrigation system.

Household surveys in Bharauli revealed that 91% of dam users received water for four to five months during the *rabi* season (November to March) compared to only 28% of water users in Thadion. Further, 89% of water-using households in Bharauli reported that supply of water from the dam was predictable, compared to 83% of households in Thadion. Therefore, one may argue that it is not the position of the contractor in the village power hierarchy alone that resulted in greater rule compliance in Bharauli. Contrary to the mafia like image that such an interpretation may offer, the contractor had leveraged his position in the village power hierarchy to ensure that water distribution from the dam met users expectations of a fair distribution. To quote Fafchamps, 'It is not so much private accumulation of wealth that pre-industrial societies combat but the fact that some

[21] We observe that low endowment category households derived the highest livestock based incomes when compared to medium and high category households. Livestock based incomes were facilitated by access to fodder from private fields under dam assisted irrigation. As a matter of fact low endowment category households had access to the highest area under dam assisted irrigation as a proportion of total land owned.

[22] We allotted weights to qualitative assessments by farmers of how predictable their access to water from earthen dams was in Bharauli and Thadion. By predictable we refer to how confident a farmer was that dam water users with plots adjacent to his would release water to him for his use. Accordingly, we allocated weights depending on whether a farmer's access to water was high (2), medium (1) or low (0).

[23] During a period of normal rainfall three waterings are required for a wheat crop. Four hours are required to water 1 acre of wheat crop from the dam. Mean land size among water users in Bharauli is 4.7 acres. Therefore, mean per-capita water requirement for wheat for water users in Bharauli is 18.8 hours (4.7 × 4). But in 1999–2000 a total of 555 hours of water was supplied in Bharauli at a mean per-capita rate of 16.1 hours. In Thadion mean land size is 5.8 acres. Therefore, mean per-capita water requirement for water users is 23.2 hours (5.8 × 4). But in 1999–2000 a total of 479 hours of water was supplied in Thadion at a mean per capita rate of 32 hours. This leads us to conclude: 1. that per-capita use of water from the dam in Thadion was greater largely due to greater demand for irrigation to compliment supply from private tubewells for paddy cultivation in the dry season and 2. That a larger number of farmers in Thadion could potentially benefit from dam assisted irrigation for wheat cultivation in the dry season if use of the dam for complimentary paddy irrigation were curbed during the same period.

Table 8. Compliance with water fees: comparison of HRMS groups

A: HRMS Bharauli

Head	1995/96	1996/97	1997/98	1998/99	1999/2000
Lease amount committed by contractor (in rupees)	N/A (under HRMS provision)	N/A (under HRMS provision)	3,000	2,500	5,000
Amount deposited in HRMS account	Nil		3,000	2,500	5,000
Hourly user charge (in rupees)	25/hr	25/hr	25/hr	25/hr	25/hr
Profit from water leasing (i.e., difference between lease amount and total dues collected by contractor on hourly basis)	N/A (under HRMS provision)	N/A (under HRMS provision)	no profit	7,500	5,000

B: HRMS Thadion

Head	1995/96	1996/97	1997/98	1998/99	1999/2000
Lease amount committed by contractor (in rupees)	N/A	N/A	850	6,800	N/A (under HRMS provision)
Amount deposited in HRMS account	Nil	Nil	Nil	1,500	Zero compliance with irrigation service fees
Hourly user charge (in rupees)	N/A (no charges levied)	N/A (no charges levied)	10/hr	10/hr	10/hr
Profit from water leasing (i.e., difference between lease amount and total dues collected by contractor on hourly basis)	N/A	N/A	Nil	Nil	N/A

of its members may accumulate while others are in need' (1992: 153).

4.6. Collection of water fees

Greater compliance with rules regarding payment of water fees is reflected in data on payment of water lease fee by the contractor to the HRMS (Table 8). We observe that in 1995–96 the HRMS monitored water distribution from dams in Bharauli and Thadion. In Bharauli water users complied with payment of hourly water charges of Rs 20 while in Thadion, where the hourly water charge was only Rs 10, compliance was nil.[24] In 1996–97 both dams were under HRMS management and the trends with compliance with user charges were similar. In 1997–98 both HRMS adopted contractor-based water provisioning. In Bharauli the contractor paid the lease amount of Rs 3000 to the HRMS whereas in Thadion the contractor failed to do so. However, due to poor rains the contractor could not net a profit from water sales in 1997.

In 1998–99 both water user groups adopted contractor-based provisioning once more. In Bharauli the contractor paid the lease amount to the HRMS while in Thadion three individuals who combined to bid for the lease could only pay only 22% of the lease amount owed to the HRMS. That same year higher levels of compliance with payment of water user fees enabled the contractor in Bharauli to net a profit of Rs 7500. The same trend was repeated for 1999–2000 but in Thadion a history of non-compliance with water user charges resulted in reversion to HRMS water provisioning. But as in previous years (1999–2000), water provisioning by the HRMS failed to elicit compliance with irrigation service rules.[25] The repeated failure of the institutional mechanism for managing the dam in Thadion led to its siltation in 2001.

4.7. Participation in repair and maintenance of earthen dams

We find that farmers in Bharauli readily cooperate with the contractor in undertaking routine maintenance activities. Between 1995 and 2000, the mean number of labour days contributed towards maintenance of the distribution network in Bharauli was 3.7, compared to 2.3 in Thadion. Further, the mean monetary contribution towards maintaining the distribution network was Rs 377, compared to Rs

[24] It is important to point out here that a higher water charge in Bharauli reflects a higher value placed on irrigation water. In that sense therefore, a higher value for irrigation water may be viewed as a fundamental promoter of collective action.

[25] Two households with fields in the head end of the irrigation system removed distribution pipes on the pretext of leveling their fields. Despite repeated requests from households with fields in the tail end of the system the pipes were never replaced. One of the large landholders offered to circumvent the problem by installing a siphoning system. But his uncle, another large landholder refuted the idea of siphoning as it would silt up the dam. He instead offered to desilt the dam and charge water users for water use to recover his investment. However, he did not carry out desilting work but continued to charge users for water use. His nephew objected to this practice and began a parallel scheme of siphoning water and distributing it to farmers and insisting that his uncle should keep his promise of undertaking de-silting work on the dam. Continuing conflict between these two households resulted in the dam falling into disrepair in March 2001.

156 in Thadion. We also observe, through regression analysis, that large landholding households made the largest monetary contributions towards maintenance of the distribution network; farmers with smaller areas irrigated by the dam made more labour contributions towards maintenance activities.

5. Conclusions

The central argument of this article is that, contrary to conventional wisdom, heterogeneity of nature-based endowments, such as arable land, proportionate to household size may facilitate collective action in irrigation management. Collective action in irrigation management may take the form of service provision by an individual entrepreneur and concerted action by a group of resource users to comply with rules regulating use of a common pool system. But for heterogeneity to facilitate collective action, certain minimum conditions must be met. First, local ecological conditions must ensure a favourable benefit stream to a critical number of resource users. Our case study evidence highlights the fact that in the absence of alternative tubewell irrigation in Bharauli, water users placed a higher economic value on irrigation from the dam when compared to Thadion.

Our case study evidence also highlights the role of historically defined power and social exchange relations in facilitating collective action under conditions of relative heterogeneity of endowments. These include: the importance of caste and hierarchy in the village social order; gender and exclusion of women from access to non-farm employment; tying credit to mobilization of labour for repair of the dam and compliance with payment of irrigation service fees; and intra family rules that forbid competition in bidding for purchase of water distribution rights. Further, we also highlight the fact that land ownership *per se* does not ensure political power. Family size critically determined the extent of surplus that could be sold in external markets and influenced a person's standing in the community. Our endowment score calculation indicates the absence of factional conflicts in Bharauli. The absence of factional conflicts is seen to be an important motivating factor for the contractor to provide irrigation services in Bharauli.

From a policy perspective we emphasize three points made by Poteete and Ostrom with regard to the discussion on the influence of group heterogeneity on collective action (Poteete and Ostrom, 2003: 22). First, public officials (including NGO field workers) should not presume a determinate relationship between heterogeneity and the level of collective action. Second, there is no blueprint to elicit community participation in natural resource management. Given the wide variety of characteristics that groups possess as well as the diversity of ecological conditions they face, rules that work well to facilitate collective action for one group may or may not work well when used by others. Third, the design of institutions that help a group to distribute the benefits and costs of participation is more important than the particular attributes of the group itself.

From a methodological point of view this article adopted a three step approach to analysis of collective action in irrigation management. First, the article outlined the key features of the joint management contract that embodied elements of participatory irrigation management. Second, the article examined the process by which several of those policy guidelines were implemented by state parastatals such as the forest and irrigation departments. The lack of transparency and accountability in procedures of government agencies was evident from our post-project analysis of earthen dam management in the Haryana Shiwaliks. Only eight of the 45 dams that were constructed were functioning when data for this study were collected (see Table 1). The final step adopted by the study was to examine collective action in eight HRMS with functioning dams. In this context, we found that watershed groups that were relatively heterogeneous in distribution of nature-based endowments facilitated provision of water from earthen dams by the contractor. We also found — although this is not statistically proven, due to the small sample size — that contractor-based water provisioning tended to ensure greater success of compliance with irrigation service rules such as payment of user fees, conflict-free water distribution and routine repairs of dams. This was in contrast to relatively more homogeneous watershed groups where compliance with irrigation service rules was not as successful.

The construction of household endowment and water interest scores was undertaken with a view to understand the conditions that made contractor-based water provisioning a relative success. We justified the use of household endowment scores to overcome the over reliance on caste or land ownership as indicators of group heterogeneity. We argued instead for an approach that combined analysis of process variables (such as rainfed and irrigated land and livestock composition proportionate to household size) with an analysis of socio-economic processes that reflect change over time in process variables. Socio-economic processes we pointed out may include historically defined power and social exchange relations, accumulation strategies of farmers and differentiation in access to natural resources. In the course of applying nature based water interest scores, we found that increasing reliance on non-farm income need not necessarily pose a threat to collective action in management of a common pool irrigation system. Further, in the course of applying nature-based household endowment scores we emphasized the importance of specifying what constitutes collective action. A clear specification of what constitutes collective action could enable the use of household endowment and water interest scores to predict conflicts and indicate potential for service provision and compliance with irrigation service rules.

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Appendix 1

Variables

In the process of constructing household endowment scores we considered four variables: (i) total rainfed land owned, (ii) total irrigated land owned, (iii) type of livestock owned and (iv) size of household. Total irrigated land owned refers to land irrigated by tubewells, earthen dams and *kuhls* (seasonal water channels). The principal livestock types considered in constructing the endowment scores are adult cows, buffaloes, bullocks, goats and camels. Household size refers to total number of members in a household.

Weights

In constructing household endowment scores we devised weights for each of the assets outlined above. The weights were decided based on food productivity assessments undertaken in Shiwalik villages. Four criteria guided the allocation of weights for variables:

- per-acre productivity of corn/rice and wheat under non-irrigated conditions
- per-acre productivity of corn/rice and wheat under irrigated conditions
- average milk production by buffaloes in summer, monsoon and winter months
- average milk production by cows in summer, monsoon and winter months

Assumptions

In devising weights for caloric value of cereal crops and average milk production we made five assumptions:

- Each adult requires a minimum of 2,300 kilocalories (kcal) per day.
- The annual average kcal requirement for an individual would therefore be some 850,000 kcal.
- A kg of a cereal like corn, wheat or rice contains on average 3,500 kcal.
- Cow's milk contains 700 kcal per litre.
- Buffalo milk contains 900 kcal per litre.

Cereal crops caloric equivalent

Household-level assessments of crop and milk production were undertaken for which the following measures based on production under irrigated and non-irrigated conditions were used:

- One acre of rice or corn in *kharif* (monsoon) season under non-irrigated conditions yields 1,200 kgs per acre on average.
- One acre of wheat in *rabi* (winter) season under non-irrigated conditions yields 500 kgs per acre.
- Therefore, under non-irrigated conditions annual average yields per acre are approximately 1,700 kgs (i.e. 1,200 + 500).
- A yield of 1,700 kgs per acre under non-irrigated conditions is equivalent to some six million kcal per year (i.e. 1,700 * 3,500).
- Following from our earlier assumption regarding a minimum calorie requirement per individual of 850,000 kcal per year, six million kcal would sustain seven members of a family.
- Under irrigated conditions one acre of corn in *kharif* season yields 1,800 kgs per acre.
- Under irrigated conditions one acre of wheat in *rabi* season yields 1,600 kgs per acre.
- Therefore, under irrigated conditions total yield per acre is approximately 3,400 kgs (i.e. 1,800 + 1,600).
- A yield of 3,400 kgs per acre under irrigated conditions yields a caloric equivalent of 11,900,000 kcal per year (i.e. 3,500 * 3,400).
- Assuming a minimum annual calorie requirement of 850,000 per individual, 11,900,000 kcal would sustain 14 members of a family.

Milk production and calorie equivalent

Milk production in Shiwalik villages varies by season. In the summer months between March and May an adult buffalo produces about 5 litres of milk per day. During the monsoon period between June and October, milk production peaks at about 10 litres per day. In the winter, between November and February, average milk production per day is about 4 litres. However, as no milk is produced for a few weeks in a year we assume that average annual milk production is approximately 2,000 litres. Two thousand litres of milk produced by an adult buffalo translates into a caloric equivalent of 1.8 million kcal annually; thus the 1.8 million kcal contained in buffalo milk can sustain 2.5 persons annually.

On the other hand during the monsoon season, a cow produces some 750 litres of milk. During the summer season, milk production falls to approximately 450 litres. Therefore, total annual milk production by a cow would be in the range of 1,200 litres. This 1,200 litres of cows milk translates into a caloric equivalent of 840,000 kcal. This 840,000 kcal contained in cows milk could sustain one family member annually.

Based on average food productivity assessments for cereal crops and milk we calculated household endowment scores as follows:

$$(7Lr + 14Li + 2.5B + 1C + 0.5C + 0.1G)/H.H.\ Size$$

where Lr = acres of rainfed land, Li = acres of irrigated land, B = no. of adult buffaloes, C = no. of adult cows, Ca

= no. of camels, *G* = no. of goats, *H.H. Size* = no. of members in a household.

If the household score equals one it means that the household can just feed its members with grown food and home produced milk assuming all land is used for food production and half of all adult animals are milk producing.[26]

Parameters for calculation of interest scores

Parameter	Non-irrigated land	Irrigated land	Increase by factor of
Food (wheat)	500 kg/acre	1,000 kg/acre	2
Wheat from 1 acre can feed	7 People	14 People	2
Fodder grass can sustain	2.5 people if milk is consumed	5 people if milk is consumed	2

Household water interest score calculation

Area irrigated by dam		***Score***
a) Less than 1 acre	:	1
b) Between 1 and 3 acres	:	2
c) Between 3 and 5 acres	:	4
d) Greater than 5 acres	:	8
Alternative sources of irrigation for dam-irrigated land		***Score***
a) Tubewell		1
b) Tal *Kuhl*/Tal Nadi		2
c) None	:	4
	:	
	:	
Land irrigated outside dam command area		***Score***
a) Greater than 3 acres		1
b) Between 2 and 3 acres	:	2
c) Between 1 and 2 acres	:	4
d) Between 0.5 and 1 acre	:	8
e) None	:	16

[26] For a related discussion on caloric terms of trade (see Dietz et al., 2001).