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A comparative description of two farmer-managed irrigation systems in Nepal

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Abstract. The organization of two farmer-managed irrigation systems in the western hills of Nepal is described by examining the ways in which the activities of water allocation, water distribution, maintenance, and resource mobilization are performed. Due to the topography and environment, these two organizations are structured primarily to mobilize the large amount of labor required for maintenance of the intake and canal. Both organizations precisely define each member's water allocation. In one system, water is allocated in proportion to the area of an individual's land holding, while in the other water allocation is by purchased shares. These two cases were used to analyze the importance of the principle of water allocation for expansion of area irrigated and equity of access to irrigation. Evidence from the two systems shows that in this hill environment water allocation by purchased shares provides the individual incentive and an organizational mechanism for efficient development of irrigation resources. Expansion of area irrigated and equity of access to irrigation were found to be greater in the system which allocates water by purchased shares than where water was allocated in proportion to area irrigated.

Definitions: Agri – Person skilled in tunnel and canal building. Traditionally worked in the mining industry, but also constructed many irrigation canals and tunnels; Bari – Sloping fields which have not been leveled and bunded for irrigation; Khet – Fields which have been leveled and bunded for irrigating rice; Khola – Stream or small river; Kulo – Canal; Maato Muri – Traditional unit of area equal to approximately 1/80 of a ha; Mukhiya – Leader. Often the title of the irrigation organization leader; Ropani – A unit of area used in the hills of Nepal equal to approximately 1/20 of a ha.

Introduction

There is a growing literature which examines farmer-managed irrigation systems[1] in a number of countries and a variety of ecological environments. Studies from the Philippines (Lewis 1971; Siy 1982), Indonesia (Geertz 1980), Thailand (Tan-kim-yong 1983), Sri Lanka (Leach 1961), and Peru (Mitchell 1976) have described a variety of irrigation systems which are managed by farmer groups. This article describes two farmer-managed gravity irrigation systems located in the western hills of Nepal which were studied for 20 months in 1981–83. The discussion will focus on the management institutions for operating the systems, i.e. the organization and the way it accomplishes irrigation activities, and the principle of water allocation. Data from these systems are used to analyze the importance of the principle of water allocation for the expansion of the area irrigated and equity of access to irrigation.

Water, as one of the essential resources in agricultural production, has several unique characteristics, especially in hill environments.[2] Individual farmers in the hills, acting alone, can seldom acquire surface water for irrigation. Construction and maintenance of the structures to divert, convey, and distribute water usually require investments beyond the capacity of a single farmer. Surface water cannot be easily stored, certainly not by the individual farmer, in the way that fertilizer can. It must be used when it is available or it is lost. Farmers generally cannot transport water economically over great distances, and the locations to which it can be conveyed are limited by the topography. One implication of these characteristics is that institutions are needed for the development and operation of irrigation systems. The form and function of these institutions vary depending on the physical, social, and economic environments.

Institutions have been defined as "complexes of norms and behaviors that persist over time by serving collectively valued purposes" (Uphoff 1984). Institutions regulate individuals' actions and consist of significant practices and relationships within a society. In some cases, institutions may be formalized in organizations like cooperatives, local governments, or banks. Examples of institutions which are not organizations are land tenure systems and customary labor exchange relationships.

Institutions of both kinds contribute to production and development processes in several ways. They facilitate the aggregation of resources beyond an individual's capacity and the application of resources to the solution of problems for the benefit of many. Institutions reduce uncertainty by encouraging and enforcing predictability of behavior in various spheres, including the distribution of benefits from collective investments.

Farmers have developed institutions that enable the collective management of water for agricultural production. One institution is the farmer organization itself, an organization which has been vested with legitimacy by the local community.[3] Another important institution is the convention of property rights in water. Property rights include both the principle by which water is allocated among farmers and the responsibilities that individuals have for maintenance of the system. Both institutions, the organization and the convention of property rights, are crucial to the effective management of irrigation systems.

Irrigation management activities

Farmer-managed irrigation systems are found in diverse environments and employ a wide range of technologies to exploit different types of water sources for production of a variety of crops. In all irrigation systems, certain essential tasks must be accomplished. One set of management activities focuses directly on the water. Water must be acquired, allocated, distributed, and, if there is excess, drained.[4] A second set of management activities deals with the physical structures for controlling the water. These structures must be operated and maintained.[5] A final set of activities focuses on the organization which manages the water and structures and includes decision making, resource mobilization, communication, and conflict management. Figure 1 depicts these three sets of irrigation management activities as a three-dimensional matrix.

There is interaction among the activities of the three sets; for example, the organization must *decide* how to *operate* the structures to *distribute* the water.

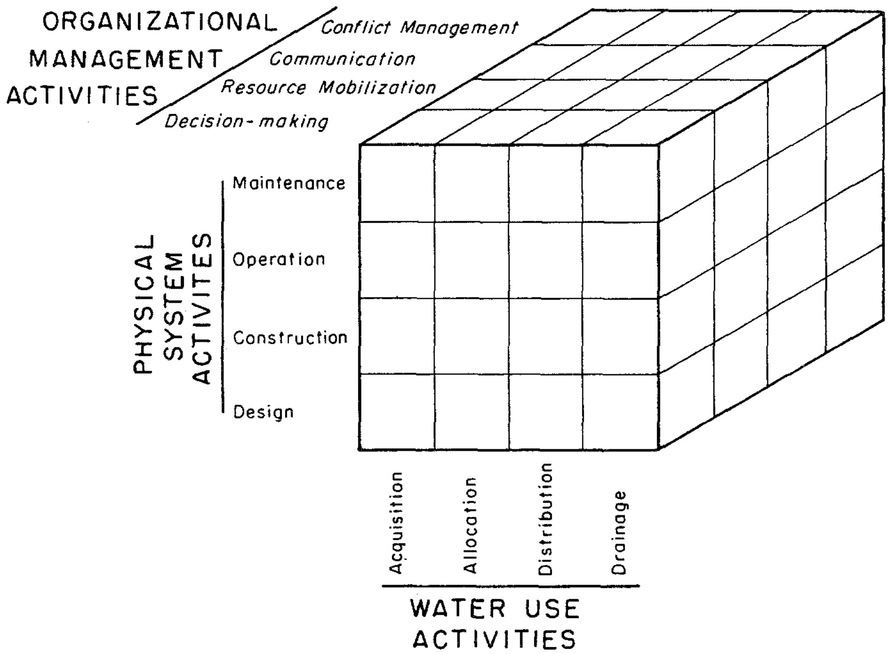

Fig. 1. Irrigation system activities matrix (adapted from Uphoff 1986).

Not all activities are equally important in each environment, and the farmers' irrigation management institutions will reflect the relative importance of activities in a particular location. In the context of the hills of Nepal, *resource mobilization* to *maintain* the system for *water acquisition* is the primary activity which influences the structure of many of the farmer irrigation organizations. In addition, the institutions of property rights in water and the principle by which water is allocated have important implications for the efficiency and equity of the farmer-managed irrigation systems studied in Nepal.

Hill irrigation in Nepal

Irrigation to grow rice in the valleys of the hill region of Nepal has been practiced for many centuries. Groups of farmers with adjacent landholdings have worked together to construct brush and stone diversions. They have dug canals to convey water to fields that they have leveled and bunded for growing irrigated rice. The canals frequently must pass along steep slopes and through rock outcrops. Tunnels a few meters underground are often used to pass vertical cliffs and rocks. Landslides along the canal and floods which destroy the diversions demand high maintenance inputs to keep the systems operating. In some systems each farmer receiving water must contribute 20–30 days of labor each year for maintenance.

In order for a group of farmers to accomplish the various irrigation management activities, their behavior must be organized. All but one of the 25 systems investigated had explicit organizations with designated rules and roles for carrying out these activities. The degree of formality of the organizations varied considerably among the systems.[6] The focus of an organization and its structure are determined, in part, by the activities which are most important. Since the hill environment requires long canals traversing steep, landslide-prone hillsides to bring water from streams subject to flooding during the monsoon season, organizations are structured to mobilize the large amount of labor needed to maintain the intake and canal for acquiring the water.

In organizations that must mobilize a large amount of resources, written attendance records, sanctions for missing work, and audited accounts were found. The rules and minutes of meetings tended to focus on issues surrounding the mobilization of resources, e.g. how much labor and cash members must contribute, the fines for missing work, and circumstances under which one is excused from work. The main functions of the elected officers of the organizations were to organize and supervise the maintenance work on the system, keep accurate records of members' contributions, and enforce sanctions for failure to contribute as required. The level of formality of organizational structure was found to be, to a large degree, a function of how much labor must be

Table 1. Characteristics of the Raj Kulo and Thulo Kulo irrigation systems.

	Raj Kulo	Thulo Kulo
Number of members	159	105
Average *khet* landholding (ha)	0.29	0.33
Hydraulic command area (ha)	103	42
Irrigated area (ha)		
Monsoon rice season	47	35
Winter season	103	42
Pre-monsoon season	103	42
Principle of water allocation for rice	Irrigated area	Purchased shares
Method of water distribution for rice	Proportioning weirs to field level	Proportioning weirs, rotation below secondaries
Length of main canal (km)	3.0	6.5
Maximum discharge (l/s)	330	180

mobilized to maintain the system. If little labor is required, the organization tends to be less formal and vice versa.[7]

Raj Kulo and Thulo Kulo irrigation systems

The two systems to be discussed are both on river terraces 100–200 meters above the Kali Gandaki River at an elevation of about 650 m. The Raj Kulo (Royal Canal) is in Argali Village Panchayat[8] and the Thulo Kulo (Large Canal) is in Chherlung in Baugha Gumha Village Panchayat, both located in Palpa District between Ridi Bazaar and Ranighat (see map in Fig. 2). The command areas of the Raj Kulo and Thulo Kulo are about two hours' walking distance from each other.

The Raj Kulo system has an intake on the Kurung Khola (stream) and a 3 km long canal which conveys water to a command area on the Argali river terrace. The Thulo Kulo system has an intake on the Brangdhi Khola and a canal 6.5 km long to deliver water to the command area in Chherlung. Table 1 presents some basic characteristics of the two systems.

Agricultural production

Farm sizes are small in both systems. The average size of irrigated landholding (*khet*)[9] per household in both systems is about 0.3 ha. In both locations extremely intensive agriculture is made possible by the effective irrigation sys-

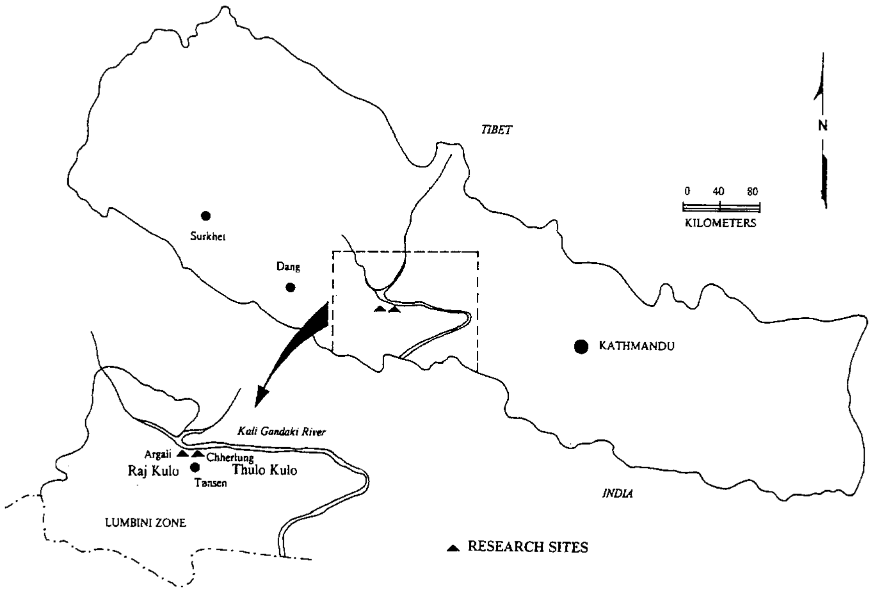

Fig. 2. Location of the Raj Kulo (Argali) and Thulo Kulo (Chherlung) irrigation systems.

Table 2. Grain yields estimated from sample crop cuts in 1982–83 (t/ha).

	Raj Kulo	Thulo Kulo
Khet (leveled and bunded)		
Rice	3.3 (89)[a]	3.5 (121)
Wheat	2.5 (83)	2.5 (95)
Maize	1.7 (92)	2.4 (95)
Total	7.5	8.4
Irrigated *bari* (sloping upland)		
Wheat	2.9 (14)	*
Maize	3.9 (14)	*
Total	6.8	

[a] Number of crop cut samples used to compute the mean yield.
* No crop cuts taken.

tems. Farmers in both systems have developed the same cropping pattern on their irrigated fields. Most farmers grow three crops: monsoon rice, winter wheat, and pre-monsoon maize. Several farmers in the Raj Kulo plant rice on some of their land in the pre-monsoon season. In the Thulo Kulo, however, the water supply is so limited in the pre-monsoon season that if rice were grown, only one-third of the area could be cultivated, leaving the remainder fallow. In order to provide equitable irrigation benefits among the members of the Thulo Kulo, water is allocated on a priority basis for maize. Since maize

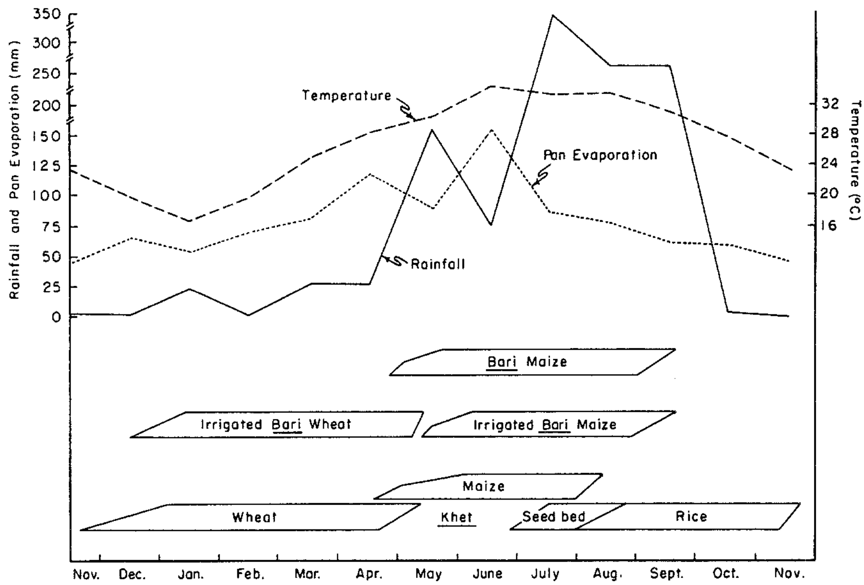

Fig. 3. The Raj Kulo crop calendar, 1982/83.

is a less water-intensive crop than rice, all of the hydraulic command area can grow irrigated maize. Total grain production per year from a hectare of land in each system averaged approximately 8 t. Table 2 presents the results of crop cuts that were taken in the two systems.

Figure 3 shows the crop calender that was observed in the Raj Kulo in 1982/83. The calender for the Thulo Kulo was virtually identical to that of the Raj Kulo. Whereas during the monsoon season all of the *khet* is used for growing rice, in the winter season some farmers grow potatoes, cabbage, or other vegetables in place of wheat on some of the area. In the pre-monsoon season maize is grown on most of the *khet* with a lentil crop, usually cowpeas, intercropped with the maize as a vegetable, fodder, or green manure.[10] In both villages traditional varieties of rice are grown in the monsoon season. However, management-responsive varieties of wheat and maize have been adopted by most of the farmers. The farmers in the Raj Kulo who cultivated pre-monsoon rice planted a management-responsive variety.

Many of the farmers also have some upland fields (*bari*). These may or may not be irrigated during the wheat and maize seasons depending on their location relative to the canal. If the *bari* is irrigated, farmers usually plant winter wheat followed by a long-season maize variety which is not harvested until near the end of the monsoon in September. Most households plant potatoes and vegetables for household consumption on part of their irrigated *bari* during the winter wheat season. A legume is intercropped with the maize and harvested for household consumption and animal fodder. After the maize is harvested, mustard may be planted, but this is not irrigated. A long-season variety of maize is the common crop planted on unirrigated *bari* in both villages.

Historical development

Oral tradition in Argali states that the Raj Kulo was initiated by Mani Makunda Sen̈, the first Sen rajah of Palpa. This would make it over 300 years old. It was originally constructed to irrigate land to support a temple which he had built on the bank of the Kali Gandaki River at Ridi. Part of the production from a small section of the present command area is still given to the temple. Since the original construction took place so long ago, nothing is known of how resources were mobilized and work carried out.

Much more is known about the history of the Thulo Kulo in Chherlung because construction began in 1928. Men who worked on it in their youth are still farming land which it irrigates and remember some of the details of the original construction. Two individuals are credited with initiating and organizing the construction and contributing the bulk of the initial resources needed to dig the canal. An additional 25 households provided some support, but other families in the community doubted the feasibility of delivering water from an intake more than six kilometers away by means of a canal which had to be cut through dense jungle, hard rock, and along the face of sheer cliffs.

To build the canal a contract of Rs. 5,000 and ten *maato muri* (about 0.12 ha) of potential *khet* land was given to four *Agris* from the village of Damuk Khanee in Gulmi District.[11] These four skilled canal builders hired laborers, including people from Chherlung, and each supervised a group of workers. Construction was begun in 1928 and continued for 10 months each year. The work was interrupted when people from Tansen, the District Center, arrested several workers on the charge that they were taking wood from the jungle without authorization and burning it to heat and break rocks. Tansen residents were also concerned that the canal would leak and ruin the road to Ranighat, the place where they traditionally cremated their dead. A settlement was reached when the Chherlung farmers agreed to repair any damage to the road, received permission to cut firewood, and were granted the right-of-way for the canal. Water first flowed through the Thulo Kulo to the Chherlung command area in 1932.

In Chherlung the contractors were retained for an additional four years to maintain and improve the Thulo Kulo. They did this during the monsoon months and worked to construct another canal the rest of the year. The members paid for all of the contract work and in addition contributed labor. Since that time the members have continued to mobilize labor and cash to make improvements. Gradually the canal has been enlarged to deliver a higher discharge, and the intake structure has been improved. In 1967, cement was used in the system for the first time, and since then short sections of the canal have been lined. The district panchayat made small grants to the organization in 1967, 1975, 1981, and 1983. These were used primarily to purchase cement.

It was reported that in the first years only a trickle of irrigation water could be delivered through the Thulo Kulo. Increase in water discharge over the years has allowed the area irrigated to gradually expand, and in parts of the system, farmers can now irrigate their rice by continuous flow. In the early years of the system, it was necessary to distribute water by rotation to all fields throughout the entire system.

Much of the improvement in the Raj Kulo has taken place in the past 25 years. Prior to that, most of the land had been farmed by tenants who were reluctant to invest in improvements to the system because of the insecurity of their tenancy. Those who farmed irrigated rice land, whether owners or tenants, were members of the irrigation organization and were responsible for operating the system. The organization fined persons who were absent from work and who were caught stealing water. At the end of the year, the money collected in fines was spent for a feast for the members rather than used to improve the system.

The tenant operators became land owners after passage of the Land Reform Acts in 1957 and 1964, and the practice of spending the fine money on a feast was discontinued. Since then, this money has been invested in improvements in the system. The canal has been widened, areas with high seepage have been lined, and skilled labor has been hired to cut tunnels through some areas where landslides often damaged the canal.

Evidence of the increased water discharge of the canal lies in the report by many of the farmers in the Raj Kulo that until 10–15 years ago they needed to guard the water to their fields carefully both day and night. This often required that one family member sleep by the canal turnout to their field. Much of the season rotational distribution had to be practiced. Observation of the water distribution in 1982 clearly showed that in an average rainfall year the water supply was now adequate for continuous-flow water distribution to all of the fields in the Raj Kulo system for the entire season. Also, it was no longer necessary for the Raj Kulo members to guard their water carefully.

Water allocation

Rice is the preferred staple food in Argali and Chherlung and is the crop for which irrigation was developed. The technology and organization, i.e. the techniques, rules and conventions, were developed by the farmers primarily for rice cultivation. Membership in the irrigation organization is limited to those who have the right to water for growing rice in the monsoon season, even though other farmers have access to water from the system in other seasons for other crops.

Members of both the Raj Kulo and the Thulo Kulo have a strong feeling of ownership of their irrigation systems. This is a result of their personal investment and the physical danger they faced in developing and operating the systems. Accounts of accidents claiming lives while constructing or maintaining systems form a part of the history of many irrigation organizations in western Nepal.

Farmers carefully protect their right to a limited resource. Although drainage water from the Raj Kulo is used for cultivating several additional hectares of rice, the owners of these fields are not considered members of the system. They are not required to contribute to the maintenance of the system nor can they exercise authority by demanding water or influencing the timing of water delivery. When members of the Raj Kulo (and other similar systems) were questioned about allowing those using drainage water to become members, the answer was universal that since they had not invested in the system they could not become members. Even acquiring access to the canal water for a nonconsumptive use, such as a water-powered mill, was sometimes not possible (Scheuer et al. 1980). A frequently expressed fear was that if irrigation or access for other uses were allowed, rights would be established to the water. If rights were established, then in the event of a drought the crops of the original members would be stressed, and they would not be able to deny water to the new users.

Additional irrigation development from the same stream can usually only take place by other farmer groups constructing their own diversion and canal downstream of the existing intake. The exception is if the new canal does not diminish the discharge in an existing canal. Both Argali and Chherlung have multiple canals conveying water from the same streams into contiguous command areas. In each village the canals can be seen running parallel along a hillside, separated by only a few meters of elevation but serving distinct areas within the command. The construction of multiple intakes and canals is often a result of the allocation of rights of access to water by prior appropriation. This principle was enunciated in the Law on Reclamation of Wasteland in the traditional legal code of Nepal, the Muluki Ain, as follows,

> Water shall not be available for others until the requirements of the person who constructed the irrigation channel at his own expense or with his own physical labor are first met (Muluki Ain 1986).

Walter allocation, i.e. the distribution of entitlements to water from an irrigation system, consists of two dimensions. The first dimension, discussed above, distinguishes the farmers or fields which have access to the system's water from those which do not. The second dimension is a quantitative allocation of the water in the system among the farmers or fields which have been granted access to it, i.e. the designation of the quantity of water, as a proportion of the system's supply, to which each farmer or field is entitled.

The Raj Kulo and Thulo Kulo organizations have clearly defined both aspects of water allocation. In the Raj Kulo during the monsoon rice season, only certain designated fields are allocated water. Fields which have no water allocation, but on which irrigation is hydraulically feasible, have no claim on the water resource from the time seedbeds are established for the monsoon rice crop until the rice is harvested. The amount of water to which each field with an allocation is entitled is defined in terms of its area relative to the total irrigated area. Formerly the unit of area measurement was a *maato muri* (about 1/80 of a hectare), and each field's allocation is still referred to as "so many *muri* of water."

The allocation during the winter wheat season and for maize planting is much less strictly defined and limited. Any farmer whose fields are located where they can receive water from the Raj Kulo is entitled to water in exchange for working on the system one day for each water application. The area that is irrigated during the dry season for wheat and maize is nearly double that which is irrigated during the monsoon rice season.

Access to water for growing rice in the Thulo Kulo system and membership in the organization are limited to households that own at least a fraction of a share in the system. At the completion of the Thulo Kulo construction, the Rs. 5,000 construction contract was divided into 50 shares of Rs. 100 each. Shares in the system were distributed among the 27 contributing households according to the investment each had made and became the basis of water allocation.

Ownership of one share entitled a member to 1/50 of the discharge in the system. Several households had contributed enough cash to receive more shares than they needed to irrigate their fields, while other households received less than wanted. In addition, many people who had been unwilling to risk investing in the initial construction now wanted access to irrigation. This led to the initiation of buying and selling shares. The ownership of transferable shares was thus established and continues as the method of water allocation in the Chherlung Thulo Kulo.

Now there are 105 member households, and the range of share holdings is from one-eighth share to four shares. On the average in 1983, a share of water irrigated one-half hectare of rice. The price of a share has increased over the years with transactions taking place in 1985 at the rate of Rs. 10,000 (US $ 575) per share.[12] In the same year the price of prime irrigated land was Rs. 40–

45,000 (US $ 2,300–2,600) per *ropani*.[13] In 1985 the cost of water for irrigating rice was, thus, about 2% of the cost of the best rice land in the Thulo Kulo command area.

The price of shares is set by the organization's managing committee and somewhat reflects the total investment in the system. Even though the price of a share has increased tremendously, shares are still denominated according to the original price like the par value of stock, i.e. one share is referred to as Rs. 100 of water even though its current price is Rs. 10,000.

Over the years, improvements have been made to the main canal, significantly increasing the total flow in the system.[14] Since a share is a fixed proportion of the flow and not a specific volume, increasing the discharge in the canal increases the amount of water in a share. A member who initially needed two shares to adequately irrigate his land may at a later time require only one share. The member is allowed to sell all or part of a share to another farmer who has no water or less than he wants for irrigating his land. When a sale takes place, the transaction is recorded by the secretary and the water distribution changed to meet the new allocation pattern. This involves changing the size of a notch in a *saacho*[15] if the water is transferred between secondary canals and recalculating the time intervals for rotational distribution. The Thulo Kulo farmers are adept at readjusting the water distribution to match a new allocation of shares.

On one occasion (in 1978) a group of farmers in the Thulo Kulo with land in an unirrigated portion of the command area wanted to purchase shares, but no individual was prepared to sell the number of shares they wanted. The Thulo Kulo organization decided that improvements to the diversion weir and canal were necessary before enough water could be delivered to serve an expanded command area. A decision was made by the organization to sell ten additional shares at the rate of Rs. 2,800 (US $ 233) per share, thereby increasing the total number of shares in the system from 50 to 60. The Rs. 28,000 received by the organization from the sale was then invested in improvements in the diversion and main canal to successfully expand the irrigated area by more than 25% in one year.

Organization for irrigation management

Membership in the irrigation organizations in both the Raj Kulo and the Thulo Kulo is determined by the hydraulic regime. Even though in both locations there is more than one canal from the same source serving a contiguous command area, each canal has a separate organization for its operation.

Both organizations have a *mukhiya* (leader) and a secretary who are elected by the members. The current officers have served for a number of years but could be replaced if members were dissatisfied with their performance. The *mukhiya* is responsible for organizing and supervising work done on the system, and the secretary keeps the accounts, a record of members' water allocation and attendance at work, and minutes of the organization's meetings. As remuneration, the number of workers these officers must supply for maintenance work, based on their water allocation, is reduced. If the number of workers that they would have to provide is less than the remuneration they are due, the balance is paid to them in cash at the local daily wage rate.

Both organizations have a meeting of the members in mid-May. At this meeting plans are made for the major annual maintenance which begins shortly thereafter, new officers are elected if necessary, and the operating rules for the coming monsoon season are reviewed and amended as needed. In the Raj Kulo the accounts are presented for review at this meeting, whereas in the Thulo Kulo this is done at a meeting after rice harvest in the fall. Other meetings may be held throughout the year if decisions about system operation need to be made.

Water distribution

Monsoon rice

Unless an irrigation system has an abundant supply of water allowing all fields to be adequately irrigated without concern for insuring that distribution of water is consistent with the allocation, some method of rationing the water according to each farmer's allocation is required. Farmers in the Raj Kulo and the Thulo Kulo irrigate rice by continuous-flow distribution whenever the supply is sufficient. Water flows continuously in all channels of the system, and farmers apply water to their fields at any time they want. With the exception of the days when they weed the field and apply fertilizer, farmers prefer standing water in their fields until near the end of the season when they dry the fields for harvest.

Saachos are used to distribute water by continuous flow. A *saacho* is a weir that the farmers install in the canal with two or more rectangular openings for the water to flow through. By fixing the bottom of each opening at the same elevation, the flow in the canal can be divided into parts that equal the ratio of the width of each opening to the total width of all the openings. Because of its notched shape, the proportioning weir is called a *saacho* (key) in the Raj Kulo and Thulo Kulo systems. Figure 4 shows a *saacho* dividing the flow of one of the main canals in the Raj Kulo into four secondary canals.[16]

In much of the Raj Kulo, *saachos* are used for distributing water from the main canal into secondary canals, from the secondaries into tertiary canals, and from tertiaries to the farmers' fields. They are installed to the field level

Fig. 4. A *saacho* installed to distribute the flow from a main canal into four secondary canals according to the water allocation of each.

when farmers are not able to satisfactorily distribute the water among themselves less formally. Installation of a *saacho* eliminates the conflicts that arise under informal distribution as farmers try to take more, or are thought by their neighbors to be taking more, than their share.

In the Thulo Kulo, *saachos* are used only to distribute water from the main canal into secondary canals. The group of farmers below the *saacho* is then responsible to apportion the water among their fields. When the discharge is adequate, the flow into each field is controlled by adjusting the size of the opening in the earth bund and by placing stones and mud in the canal to divert part of the water.

In both systems, when the supply is insufficient to provide continuous flow to the entire area at once, a timed rotation system of distribution is initiated. In the 1982 monsoon rice season, rotational distribution was not required in the Raj Kulo system. Halfway through the same season in the Thulo Kulo, however, the water supply had diminished to the extent that continuous-flow distribution to all of the fields was no longer possible. It was possible to retain continuous flow through the *saachos* into all of the secondary canals, but farmers within each secondary formed rotational units and decided independently when they wanted to initiate rotational water distribution among the fields served by their secondary.

For water distribution within the secondary, the number of minutes per share was computed by dividing the total number of shares served by the secondary into the number of minutes in the rotation cycle. Each farmer would then receive water for the time period represented by the number of shares he had allocated to that secondary. A typical rotation cycle was 36 h. By setting the length of the rotation cycle at 36 h, the irrigation turn for each farmer alternated from day to night. Although irrigating at night has always been an accepted practice in the Thulo Kulo, it is both more difficult (disrupting sleep) and expensive (requiring the purchase of batteries for a torchlight).

Dry season wheat and maize

Water distribution in the Raj Kulo during the wheat and maize seasons is less precise and formal because the water supply is sufficient to irrigate more than the command area. Water is applied several days before land preparation to make the soil suitable for plowing and planting. Wheat is then irrigated two or three more times during the season. Maize may be irrigated only at planting for quick germination. At the most it is given only one or two additional irrigations, depending on the rainfall. Wheat and maize irrigation is done turn-by-turn with the farmers informally deciding upon the order. From long tradition, farmers wanting water on a particular day will meet at the main *saacho* at the head of the system at 10:00 a.m. to decide the order of irrigation and to do any minor repairs necessary to deliver the desired amount of water.

In the Thulo Kulo, the most demanding irrigation period each year is at maize planting time in mid-April. Most farmers are ready to plant maize at the same time, and they must irrigate to initiate germination. Discharge in the Brangdhi Khola in April is very low, requiring that the total flow of the canal be rotated from one farmer's field to the next at the system rather than secondary canal level. Therefore, full authority for the allocation of water for maize planting – both in quantity and timing – is given to the *mukhiya.* All requests for water must be made to him, and as nearly as possible he assigns water delivery to each farmer's field in the order in which requests are received. A field usually consists of several terraces depending on the slope and size of the field. In order to allow equity in timely planting of every farmer's maize, the *mukhiya* decides, on the basis of requests for water each day, what portion of each farmer's field, i.e. how many terraces, will be irrigated in his turn. In this way water is allocated by turn to farmers, and a portion of their land is irrigated. The farmer must then wait for another one or more turns to complete his maize planting.

Table 3. Comparison of water distribution to water allocation in selected secondaries.

System	Location of secondary	Water allocation (% of total water in system)[a]	Water distribution[b] (% of total water in system)[a]
Thulo Kulo, Chherlung	Head	9.5	10.2
	Middle	11.4	10.5
	Tail	21.8	20.6
Kanchi Kulo, Argali	Tail	16.6	16.9

[a] Since not all secondaries were measured, percentages do not sum to 100%.
[b] Discharge in the main canal and selected secondaries was measured twice daily for 97 days during the 1982 monsoon rice season. The figures refer to the percentage of the total volume of water supplied to the respective secondaries over the season.

Performance of the water distribution system

For an irrigation system to function well, the distribution of water must be done according to the allocation scheme. The precise definition of farmers' water allocation is only useful if the system can actually deliver to each farmer the share of the supply to which he is entitled. Comparison between the amount of water actually distributed and the amount allocated to different parts of an irrigation system provides an evaluation of the system's performance. The portion of the supply delivered to parts of the Thulo Kulo system was measured and compared with the amount allocated to those parts of the systems. The same measurements were made for the Kanchi Kulo system in Argali which distributes water in the same manner as the Raj Kulo. As Table 3 shows, the actual distribution closely matched the allocation, an indication of good system performance.

Maintenance

A critical period for maintenance of most hill irrigation systems, including the Raj Kulo and the Thulo Kulo, is prior to and during the monsoon. Major routine maintenance is done in late May and June to prepare the system for the monsoon season when efficient water delivery for rice cultivation is most important. At this time, the diversion and canal walls are repaired to reduce leakage, silt and weeds are cleaned from the entire length of canal, and sections of the canal are lined with clay to reduce seepage. This usually takes between two and three weeks.

In the Thulo Kulo, because of the low discharge in the stream in April, similar maintenance is also carried out prior to land preparation for maize. After the 1983 maintenance for maize, it was observed that the irrigators had used clay to seal the diversion in the stream. All of the surface water in the stream was captured, and measurements showed that for the short period during maize planting, over 80% of the water entering the canal reached the command area 6.5 km away.

A large amount of maintenance is required throughout the monsoon season. The streams fluctuate tremendously with the monsoon rains, often damaging the diversion structures made of brush, stones, and mud. The heavy rainfall causes landslides on the steep, unstable hillsides along which the canals run, interrupting the flow of water until the canal is repaired. The intake and main canal are patrolled daily so that there is early detection of damage. The Thulo Kulo organization pays two men to do this every day during the monsoon, while in the Raj Kulo the members take turns patrolling in pairs.

The men patrolling the canal will do minor maintenance work such as repairing small leaks. In the Raj Kulo if there is a need for more laborers, one of them will inform the *mukhiya* who then organizes members to do the repairs. In the Thulo Kulo the members are divided into seven groups, and each group is responsible for maintenance on a different day of the week. If laborers are needed, they will first be drawn from that day's group. Sometimes, due to the magnitude of the disaster, an emergency will be declared, and then each member household is required to send one man to work. Work will sometimes continue at night by the light of lanterns until the water is flowing again.

During the winter wheat and maize seasons, much less maintenance is required because there is very little rainfall. The farmers who want to irrigate on a given day may have to repair the intake to divert more water or plug small leaks in the canal to increase the flow, relatively minor efforts compared to the monsoon season maintenance.

Resource mobilization

Resource mobilization is critical to the effectiveness of an irrigation system, and both the Raj Kulo and Thulo Kulo organizations successfully mobilize significant amounts of resources every year. Most of the labor and cash resources are contributed by the members, although small grants and some technical assistance have been given recently by the district panchayat and Department of Irrigation, Hydrology, and Meteorology (DIHM). Both organizations mobilize between 1500 and 2500 man-days of labor annually, depending on the severity of the monsoon rains and the attendant flooding and landslides. Both organizations have assessed cash contributions from members for the purchase of cement to line portions of the canals.

In both systems resources are generally mobilized in proportion to the benefits that members receive from the system, i.e. according to the water allocation. In the Raj Kulo, where water is allocated in proportion to area irri-

Table 4. Labor mobilized annually for system maintenance (man-days).

Year	Routine maintenance	Emergency maintenance	Total
	Raj Kulo, Argali		
1961	1120	681	1801
1966	1251	92	1343
1967	1120	690	1810
1968	1085	371	1456
1969	1120	825	1945
1970	1453	[a]	[a]
1971	1135	161	1296
1972	1003	159	1162
1973	1032	543	1575
1974	1287	205	1492
1975	1104	358	1462
1976	1203	294	1497
1979	1264	1378	2642[b]
1980	1087	638	1725
1981	1322	985	2307
1982	1179	822	2001
1983	1271	599	1870
1984	926	449	1375
Average	1165	544	1692
	Thulo Kulo, Chherlung		
1981	[c]	[c]	1811
1983	[c]	[c]	3541[d]
1984	[c]	[c]	1362
1985	[c]	[c]	1740
Average			2114

[a] Missing.
[b] Construction of a road above the canal began in 1979, resulting in more than usual damage to the canal for several years.
[c] Routine and emergency maintenance not separated in records of the organization.
[d] Damage caused by a major landslide required much more than the average amount of labor.

Source: The Raj Kulo and Thulo Kulo organizations' attendance records.

gated, labor and cash are also contributed according to area served. Members must contribute labor for routine maintenance work at the rate of one man for each 40 *maato muri*[17] of *khet* each work day. A household with only 20 *maato muri* is required to provide one worker every other day.

Members in the Thulo Kulo contribute labor and cash according to the number of shares they own in the system. A household with one share is required to supply one man each day of routine maintenance, while one with two shares must provide two workers each day. Table 4 presents the number of man-days of labor mobilized annually by the two organizations.

In 1982, members of the Thulo Kulo organization were assessed cash contributions at the rate of Rs. 250 (US $ 19) per share, raising a total of Rs. 15,000 (US $ 1,140) from 105 member households owning a total of 60 shares.[18] In 1983, Rs. 34,800 (US $ 2,400) was raised by assessing the members at the rate of Rs. 580 (US $ 40) per share. Most of this was spent to build a masonry wall several meters high to support a section of lined canal following a severe landslide.

The one exception in both systems to the rule of proportionality in resource mobilization is when an emergency is declared. Each member household must then supply one man, irrespective of its water allocation. At the annual meeting in May 1983 in the Raj Kulo, some members with small water allocations strongly protested that it was unfair for them to have to provide the same number of workers in an emergency as households with a much larger water allocation. After much discussion the decision was made to leave the rule unchanged but to be careful to declare an emergency only when it is real.

In order to mobilize the resources needed to maintain the system, the organization must have sanctions which can be applied and enforced when members fail to contribute their share of labor and cash. Both systems levy cash fines against members who are absent from work. The fine for missing a day of routine maintenance is set near the local daily wage rate in the Thulo Kulo, Rs. 10 (US $ .75) in 1982 and somewhat lower in the Raj Kulo, Rs. 6 (US $ .45). In the Thulo Kulo when a major emergency is declared, the fine rate is increased to encourage a higher rate of attendance. If a person is absent from the community when the emergency is declared or has another acceptable excuse such as illness, the fine is reduced to Rs. 6 per day, even for a major emergency.

Fines, when levied, are paid. As one farmer in the Raj Kulo said,

> If the fine is not paid, the organization can deny the offender water.

Also, the community of members can exert social, as well as physical, pressure on members to pay fines. In the Thulo Kulo it was reported that in an early year of operation of the system, one man did not report for emergency maintenance for several days. When his fine was levied and he refused to pay, members confiscated his cooking pots and threatened to sell them to pay his fine. Within a day or two, he paid the fine and recovered his cooking pots. Other members witnessed how serious the organization was about enforcing its rules and collecting fines, and payment was reported to be 100% of all fines levied.

At a December 1982 meeting of the Raj Kulo organization, two members were appointed to collect the fines from the previous monsoon season and any that were outstanding from previous years. As remuneration for this work, they were entitled to keep 6% of the amount collected. In both organizations, the cash that is raised through fines is invested in maintenance and improvement of the system. Until it is spent, the money may be loaned to members who pay interest to the organization.

Implications of the principle of water allocation

Efficiency and area expansion

The principle of allocation has important implications for the efficiency of water use and the expansion of the irrigated area. Allocation of water in proportion to area irrigated provides no incentives for efficient water use nor a mechanism for expanding the area irrigated.[19] In the Raj Kulo there have been significant improvements made in the canal, and the amount of water supplied to the command area has increased considerably in the past 25 years. However, there has been little increase in the area irrigated. DIHM invested approximately Rs. 400,000 (US $ 30,300) in the system in 1982 with no change in the irrigated area or cropping intensity. The main impact of the improvements made over the past 25 years, including those by DIHM, has been to reduce the water distribution costs.[20] Much less effort is now required to distribute water. Whereas the farmers once had to use a rotation system of distribution and go out to irrigate at night, sometimes sleeping in the field to guard their water, now the water flows continuously to all fields. It is recognized that there is plenty of water to irrigate additional land,[21] but the Raj Kulo members have no incentive to allocate water to fields owned by nonmembers. To maintain their yields, they would have to work harder to manage a smaller amount of water more efficiently, i.e. change to a rotation system of distribution, and would receive nothing in return.

On the other hand, allocation by purchased shares in the Thulo Kulo provides both the individual incentives for efficient water management and a mechanism for expanding the irrigated area. As the system improved, the amount of water delivered and, consequently, the amount of water per share increased considerably. Shareholders can decide whether to keep all their shares and reduce their management input or to sell part of the additional water. Because the individual can sell part of his water, he is aware of the opportunity cost of his use of water, and there is a financial incentive to manage his water efficiently. In addition, if an individual sells part of his allocation, the amount of labor that he must contribute to maintaining the system is reduced. Since the Thulo Kulo requires a large amount of labor each year for maintenance, this provides another incentive to reduce the number of shares one owns and to use the water more efficiently.

A comparison of the seasonal relative water supply for the two systems gives an indication of the efficiency of water use. The relative water supply is estimated by dividing the total water supply by the total demand for water over the season.[22] Seepage and percolation in both systems was measured to be approximately the same, with the daily average over the rice season being approximately 35 mm. Computation using data collected twice daily over the rice season gives a seasonal relative water supply of approximately 1.0 in the Thulo Kulo system and 1.3 in the Raj Kulo system. In neither system was there any indication of moisture stress, but the Thulo Kulo farmers had to practice rotational distribution while the Raj Kulo farmers were able to distribute water continuously. The relative water supply calculation suggests that water was managed more efficiently in the Thulo Kulo than in the Raj Kulo, lending support to the hypothesis that allocation of water by the sale of shares results in more efficient management of water than allocation in proportion to area irrigated.

The sale of shares, either by individuals or from the system at large, provides a mechanism for expanding the area irrigated. Water is not tied to a specific land area but is distributed within the command area to wherever those owning shares want it. In the Thulo Kulo the system has expanded through the sale of water shares to the point where it now irrigates 85% of the potentially irrigable area. The chairman of the Thulo Kulo organization estimated that the area irrigated during the monsoon season doubled between 1967 and 1982 as a result of continual improvements to the system and subsequent sales of shares. In comparison, only 45% of the Raj Kulo's potentially irrigable area receives irrigation for the monsoon season rice crop.

Interestingly, the Raj Kulo organization has recognized that the sale of water shares would be an effective means of expanding the area served. Most members accept that there is surplus water in the system and that the work DIHM did in 1982 has made the supply more reliable, i.e. less subject to major interruptions by landslides. In 1983, it appeared that the government was going to reduce by half its contribution to the local school's budget, precipitating a financial crisis for the school. The Raj Kulo organization decided after much debate, that it would sell 200 *muri* of water (about 10% of the supply) and give the money to the school as a permanent endowment. Requests for the water were solicited, and 40 households applied to purchase nearly three times the amount offered for sale. The price was set at Rs. 2,000 (US $ 138) per *muri*; only two households were able to raise the necessary cash. Based on the flows in the Raj and Thulo Kulos in the monsoon of 1982, the price per unit of discharge, i.e. liter per second, set in the Raj Kulo was ten times higher than the rate in the Thulo Kulo at that time. Before the price or conditions of payment could be renegotiated, the government restored its contribution to the school's budget to the original amount, and members of the Raj Kulo organization lost interest in the sale of water.

Equity

The allocation principle also has equity implications. In the Raj Kulo the only way that a person can gain access to water to irrigate rice is for the household to inherit *khet* land with a water allocation or to buy some irrigated land. It is, thus, nearly impossible for the poor, including almost all low caste households, to acquire access to irrigation for the important monsoon rice season. In the past, no low caste households had land with an allocation of water. One Damai[23] has been able to buy a small parcel of *khet* with earnings from work in India. He is the only low caste person in all of the Raj Kulo with land that has a water allocation for monsoon rice. Irrigated land is extremely expensive (Rs. 400,000 (US $ 27,500) per ha in 1983), and the poor have little possibility of buying any.

In the Thulo Kulo 20% of the members of the organization are low caste households, and gaining access to irrigation is much more feasible. A person with unirrigated land in the hydraulic command area has only to purchase a fraction of a share of water in the system and through hard work gradually convert his *bari* to *khet* and realize more production on it. He does not need to buy expensive, already irrigated land to acquire access to the benefits of irrigation as he would in the Raj Kulo. Most of the low caste members' fields are in the area to which irrigation was first supplied after the number of shares in the system was increased by the sale of 10 additional shares in 1978.

Conclusion

In this paper we have described the organization of two hill irrigation systems in Nepal and analyzed the impact of the principle of water allocation. Farmer control of the entire irrigation systems and the need for farmers to rely on themselves for the operation and maintenance have resulted in the development of sophisticated institutions for management of the water resource. These institutions have enabled effective use of irrigation, making extremely intensive agricultural production possible with three crops cultivated per year in both systems.

Irrigation institutions are designed to enable the accomplishment of certain activities related to: the water, the physical structures for control of the water, and the organization of farmers which manage the irrigation system. In the hill environment of Nepal, the activity of resource mobilization for maintenance of the system for acquisition of water was found to be the most critical activity which influences the structure of an irrigation organization. The principle of water allocation was found to have significant implications for the efficiency and equity of utilization of irrigation resources.

The Raj Kulo of Argali and the Thulo Kulo of Chherlung exhibit many of the institutional characteristics common to a number of irrigation systems which were observed in West Nepal during the 20-month period of field research in 1981–83. The structure of the farmer organization in both systems is similar. Membership is limited to those households with a right to use water during the monsoon rice season, officers are elected by the members, regular and special meetings of the members are convened, resources are mobilized according to members' water allocation, sanctions are applied for failing to provide the required amount of labor for maintenance, and written records of attendance at work, accounts, members' water allocation, and minutes of meetings are maintained by the secretary. Both systems require a large amount of labor to maintain intakes, which are often damaged by floods, and the main canal which must traverse steep, landslide-prone hillsides. Between 1,500 and 2,500 man-days of labor are mobilized annually in each system for routine and emergency maintenance.

The water allocation of each member is precisely defined in both systems. The Raj Kulo organization allocates water to each member for monsoon rice in proportion to the area of irrigated land owned. To acquire water rights for the monsoon season, households must buy land which already has water allocated to it. The Thulo Kulo organization allocates water by the sale of shares, and property rights in water are, thus, separate from ownership of land. Most transactions of water shares take place between individuals, but on one occasion, the organization sold shares, increasing the total number of shares in the system.

A measure of the performance of an irrigation system is a comparison of how closely the actual distribution of water matches the water allocation. Measurement of water distribution to different parts of the command areas showed that water distribution very closely matched the pattern of water allocation. Continuous flow through *saachos* (proportioning weirs) and timed rotation are the two methods used to distribute the water in accordance with the allocation.

The comparison of the Raj Kulo and Thulo Kulo systems demonstrates the importance of the principle of water allocation for efficient and equitable development of irrigation resources. If water is to be utilized efficiently and irrigated area increased, there must be incentives for efficient water management and mechanisms for expanding access to the water. Water allocation by purchased shares, as practiced by the Thulo Kulo organization, provides the individual incentive and an organizational mechanism which enables the efficient development of resources, while allocation in proportion to area irrigated does not. In contrast to the Raj Kulo system, the Thulo Kulo system has:

- expanded the area irrigated during the monsoon season to a greater extent,
- achieved more efficient water utilization through more intensive management of the distribution, and
- realized greater equity in access to the irrigation resource.

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Notes

1. Farmer-managed irrigation systems are operated and maintained collectively by groups of farmers. Management of the whole system from source of water to the fields where it is used is the responsibility of the farmers. Irrigation systems of this type are often referred to as "community-managed" systems (Coward 1980). The term "farmer-managed" is used to avoid the ambiguities inherent in the term "community."
2. Some of these characteristics do not apply to the case of irrigation from ground water sources, but ground water is not an important source of irrigation in hill environments.
3. The degree of formal legitimation by civil authorities varies among countries.
4. Water "allocation" and "distribution" are often used interchangeably in the irrigation literature to describe the delivery of water. However, they sometimes refer to different activities. Water allocation is the assignment of entitlement to water from a system, both identifying the fields and farmers with access to water from the system and the amount and timing of the water to be delivered to each. Water distribution refers to the physical delivery of water to the fields and may or may not conform to the water allocation.
5. The structures must also be designed and constructed, but these are not usually considered to be management activities. The design and construction of the physical structures certainly have implications for the management of a system, however. Not all types of management practices are possible with every design, and both the design and quality of the construction may limit the effective management of a system.
6. Indicators of the degree of formalization of organizational structure were the number of designated roles, regular meetings, established sanctions and the extent of written records such as minutes of meetings, work attendance records, accounts, rules, and listing of members' water allocation.
7. This conclusion is examined and supported by statistical analysis in Martin (1986).
8. Nepal is divided into several levels of political and administrative units. The village panchayat, which consists of nine wards, is the lowest level. There are more than 3,000 village panchayats in Nepal. These are aggregated into 75 district panchayats. The national panchayat is the equivalent of a national parliament. Members of the panchayats are elected by the adult constituency which they represent.
9. *Khet* is the Nepali term for fields which have been leveled and bunded into terraces for the cultivation of flooded rice. *Bari* is the term for upland fields which have not been leveled and bunded.

10. As the yields reported in Table 2 indicate, maize suffers in the three crop pattern on the *khet* yielding less than half the yield of maize grown on irrigated *bari*. *Khet* maize was harvested before maturity so that rice, the priority crop, could be planted soon after the onset of monsoon rains. It was in the field less than 95 days on average compared to 115 days for *bari* maize.
11. Persons who spent time working in the once flourishing mining industry of western Nepal became known as *agris*. Numerous ethnic groups and castes were involved in this work. Man Bahadur Kami, one of the four who took the Chherlung contract, is credited with constructing a number of irrigation canals in Palpa and Gulmi Districts.
12. This is the cost of a one-time purchase of a share, not an annual or seasonal rental charge.
13. One hectare is about 20 *ropani*. At 1985 prices (Rs. 17.4 US $ 1.0), land sold for more than US $ 45,000/ha.
14. Improvements in the canal have been made on an almost annual basis. This has resulted in increased discharge from a mere trickle in 1932 when the canal irrigated only a few small plots, to a maximum discharge of 180 l/s in 1982. The average discharge, measured in the main canal on a twice daily basis over the 1982 monsoon rice season, was 160 l/s (Yoder 1986).
15. A *saacho* is a proportioning weir used to divide water from one canal into two or more smaller canals. It is described more fully on the page 159.
16. This same type of device for proportioning water distribution is found in many of the irrigation systems studied in western Nepal. In some communities they were called *pani dhara* (water spout) or *khat bunda* (wooden closure). Similar devices are also found in other countries. In Indonesia they are referred to as *penaro* (Coward 1985), in Sri Lanka, *karahankota* (Leach 1961), and in Thailand, *tae wai* or *mai wai* (Tan-kim-yong 1983).
17. A *maato muri* is a traditional measure of area. Forty *maato muri* equals approximately half a hectare.
18. The exchange rate at the time was Rs. 13.2 = US $ 1.
19. An exception to this statement is the warabundi systems of Northwestern India. In these systems water is allocated in proportion to land area, but each farmer receives considerably less water than needed to irrigate his whole farm. Farmers, thus, have an incentive to use water efficiently and to expand their irrigated area.
20. Construction of a road above and parallel to the Raj Kulo is largely the cause of the higher maintenance labor between 1979 and 1983 shown in Table 4. Rocks and mud excavated by the contractor during construction were dumped down the hillside into the canal. Since the cut for the road was made, the hillside is less stable resulting in more landslides. The Rs. 400,000 invested by DIHM in 1982 was used mainly to install hume pipe through this vulnerable area.
21. Several farmers reported that if they owned all of the potentially irrigable land, they would irrigate the entire area by rotational distribution, thus doubling the area of irrigated rice land. While some members did not agree that all of the potential area could be irrigated, all accepted that some additional area could be served with the present supply without any reduction in yields.
22. The elements of supply are irrigation and rainfall while demand consists of evapotranspiration and seepage and percolation.
23. The Damai are an untouchable caste who traditionally work as tailors.

References

Coward E.W., Jr. 1980. Irrigation and Agriculture Development in Asia: Perspectives from the Social Sciences. Ithaca: Cornell University Press.

Coward E.W., Jr. 1985. Property, persistence, and participation: The state and traditional irrigation systems. Paper prepared for the 1985 meeting of the Society for Economic Anthropology. Airle House, Warrenton, Virginia.

Geertz C. 1980. Organization of the Balinese Subak. In: Coward E.W. (Ed) Irrigation and Agricultural Development in Asia: Perspectives from the Social Sciences. Ithaca: Cornell University Press.

Leach E.R. 1961. Pul Eliya a Village in Ceylon: A study of Land Tenure and Kinship. Cambridge: University Press.

Lewis H.T. 1971. Ilocano Rice Farmers. A Comparative Study of Two Philippine Barrios. Honolulu: University of Hawaii Press.

Martin E.D. 1986. Resource mobilization, water allocation, and farmer organization in hill irrigation systems in Nepal (Unpubl. Ph.D. dissertation). Ithaca: Cornell University.

Mitchell W.P. 1976. Irrigation farming in the Andes: Evolutionary implications. In: Halperin R. and Dow J. (Eds) Studies in Peasant Livelihood. New York: St. Martin's Press.

Muluki A. 1986. Of Land Cultivation. In Laws Relating to Water Resources. HMGN Water and Energy Commission Secretariat, Kathmandu, Nepal.

Siy R.Y., Jr. 1982. Community Resource Management: Lessons from the Zanjera. Quezon City: University of the Philippines Press.

Scheuer H, Metzler R. & Yoder R. 1980. Small water turbine: Instruction manual for the construction of a crossflow turbine. Eschborn, West Germany: GATE.

Tan-kim-yong U. 1983. Resource mobilization in traditional irrigation systems of northern Thailand: A comparison between the lowland and the upland irrigation communities (Unpubl. Ph.D. dissertation). Ithaca: Cornell University.

Uphoff N. 1984. Analyzing Options for Local Institutional Development. Special Series on Local Institutional Development. No. 1. Ithaca: Rural Development Committee, Cornell University.

Uphoff N. 1986. Improving International Irrigation Management with Farmer Participation: Getting the Process Right. Boulder, Colorado: Westview Press.

Yoder R.D. 1986. Performance of farmer-managed irrigation systems in the hills of Nepal (Unpubl. Ph.D. dissertation). Ithaca: Cornell University.