Indigenous Water Management Systems in the Andheri Khola Sub-Watershed

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1. INTRODUCTION

With irrigation, farmers can increase their biomass production, minimize the risk of adverse climatic conditions and benefit from nutrient inputs through the irrigation water and associated sediments. Given these benefits and the increase in population growth, the demand for irrigation water has increased rapidly and, as revealed by the socio-economic survey, water shortages are common and increasing in frequency. Given the current infrastructure and population pressure in the Middle Mountains, the only option for feeding the local population is through crop intensification and a greater reliance on irrigation.

The prevailing monsoonal climate creates a distinct annual hydrological regime which can be characterized by an excess of water during the monsoon season, and water shortages during the dry season. The farmers have developed indigenous water management systems to cope with these two extremes. In anticipation of future conflict, it is timely to document the dominant indigenous irrigation systems in the watershed. The Andheri Khola sub-catchment in the Jhikhu Khola watershed was chosen as a case study. An indigenous streamwater diversion system in Baluwa (Devbhumi), and a spring fed system in Bela are examined in this paper.

The main objectives of this paper are to describe the indigenous water management systems in the sub-watershed, determine the amount of water available, document the organization and management of the systems, assess the current problems and future demands on water resources, and identify areas were improvements could be made.

2. BIOPHYSICAL SETTING

The Andheri Khola sub-watershed is situated between 800 m and 1700 m in elevation and covers 1135 ha. It services a population of 6120 individuals, who are divided into three distinct ethnic groups: Tamangs dominate the top of the watershed, Brahmins the middle portion, and Danuwar, the indigenous tribe, are most prevalent in the valley bottom. A subtropical to sub-humid moisture regime is dominant in the low altitudinal zones (<900 m in elevation) and this supports two rice crops followed by a combinations of cereal or cash crops. Sal (*Shoria robusta*) is the dominant tree species in this belt. The second zone (900 m- 1700 m) is characterized by warm temperate conditions with a humid moist climatic regime. Maize and beans followed by wheat and mustard or other cereals are typical crops in this belt. Salla (*Pinus* spp.), katus, banjh (*Castanopsis indica*) and chilaune (*Schima wallichii*) are major trees species (Jackson, 1994). Gurans (*Rhododendron arboreum*) are distinct near the top.

To provide a comprehensive overview of irrigation, it is essential to first describe the rainfall distribution, the hydrological regime and the land use pattern in the study area.

2.1. Climatic and Meteorological Characteristics

Adequate moisture content, tolerable temperatures and modest evaporation rates are important factors that affect plant survival and growth. The watershed receives sufficient water during the summer monsoon season, resulting in a lush green plant cover. In contrast, the winter period is characterized by an absence of rainfall for at least 2 to 3 months during which vegetation cover becomes minimal and plant growth is restricted due to lack of moisture.

2.1.1. RAINFALL PATTERN

Rainfall information collected between 1990 to 1994 from two automated and two standard rain gauges is provided in Table 1, and shows that there is considerable spatial variability throughout the season.

Table 1. Total monthly rainfall distribution at two stations in the Andheri Khola sub-watershed.

	Total monthly precipitation at Bela (elevation 1279 m)					Total monthly precipitation at Baluwa (elevation 830 m)		
Month	1990	1991	1992	1993	1994	1992	1993	1994
Jan	0	29.6	7.4	14.5	51.2	nd	17.0	41.2
Feb	42.7	10.3	14.5	11.1	23.6	nd	11.6	18.4
Mar	36.1	52.9	0	30.1	11.0	nd	40.2	7.8
Apr	70.4	30.4	13.2	58.7	15.3	nd	80.9	9.2
May	165.4	108.8	78.8	150.0	116.9	0.0	83.3	77.6
June	198.7	166.7	143.7	136.4	111.5	180.8	154.6	314.0
July	317.7	275.4	318.5	222.1	267.8	480.0	203.7	248.7
Aug	284.9	185.4	172.9	279.0	305.1	213.0	338.8	310.0
Sept	142.2	182.9	128.7	100.0	168.6	132.0	111.1	215.4
Oct	26.7	0.8	35.2	13.5	0	32.6	9.3	0
Nov	0	0	15.8	0	10.4	12.3	0	12.3
Dec	0	13.2	8.4	0	0	3.9	0	0
Total	1284.8	1056.9	937.1	1015.4	1081.5	nd	1050.5	1254.6

Nb. "nd" indicates missing data.

If we analyze the upland station at Bela it is evident that 75 % of the annual total rainfall is concentrated over a three month period from mid June to mid-September (Table 2). The post-monsoon rains during the October - January period produce less than 7%, and storms during the pre-monsoon season (February - May) make up about 20 % of the annual precipitation.

Table 2. Precipitation distribution during key seasons at Bela station (1400 m elevation).

Year		1990	1991	1992	1993	1994
Annual total (mm)		1219	1036	904	996	1049
% of distribution	Pre monsoon (Feb - May)	22.9	19.1	11.5	24.6	15.6
	Monsoon (June - Sept)	74.9	76.7	81.2	72.6	78.7
	Post monsoon (Oct - Jan)	2.1	4.2	7.3	2.8	5.7

The rainfall intensity and duration relationship is of critical concern for water management since it determines the degree of problems the farmers will encounter in both maintaining terraces and in supplying moisture to each site without creating instabilities and degradation. A summary of the storm patterns and its effect on stream flow was provided by Carver and Nakarmi (1995).

2.1.2. TEMPERATURE VARIATION

An example of the maximum/minimum air temperature variations over 1994 is provided in Figure 1 (below). Over the 1990 - 1994 period, temperatures never dropped below 2.5 °C and reached levels of up to 35 °C. The diurnal temperature variations are highest during the dry season with average differences between 12-14 degrees. During the winter months, lower temperatures of 2.5-10 °C restrict plant growth. At present, no temperatures below freezing have been recorded in the sub-watershed.

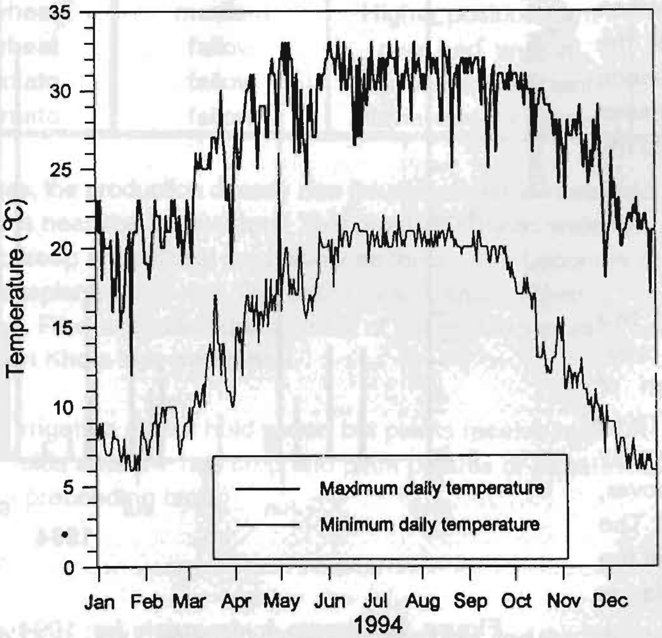

Figure 1. Minimum and maximum daily temperature variations at Bela station for 1994.

The dry season maximum and minimum temperatures have a significant effect on evaporation. Solar radiation is high when ground cover is at a minimum, and there are long breaks between rainfall events. Surface soils and water in ponds dry out quickly. Evapotranspiration, the amount of water transpired in unit time by short green ground-cover crops (Brooks, 1991), combined with evaporation from bodies of open water, represents the amount of water loss from the soil-plant system. It is highly dependent on the available solar energy. The difference between evaporation during the dry season and during the monsoon season is shown in Figure 2. The evaporation data from the Rampur Agro-meteorological station was used since it has similar environmental conditions to Panchkhal, the main agricultural centre in the Jhikhu Khola watershed. From Figure 2 it is evident that evaporation starts to increase in March and attains a peak in the May - June period when monthly rates of over 150 mm were measured. When the vegetation begins to cover the ground (as the monsoon season proceeds), evaporation decreases until it reaches minimum values in the November - February period.

2.2. Hydrological Regime

Stream flow was monitored at two stations, in the headwater sub-catchment and at the bottom of Andheri Khola. The discharge rates are highly variable and greatly dependant on rainfall, surface cover, infiltration rates and topography. The annual hydrograph at station 2 at the bottom of the Andheri Khola is provided in Figure 3.

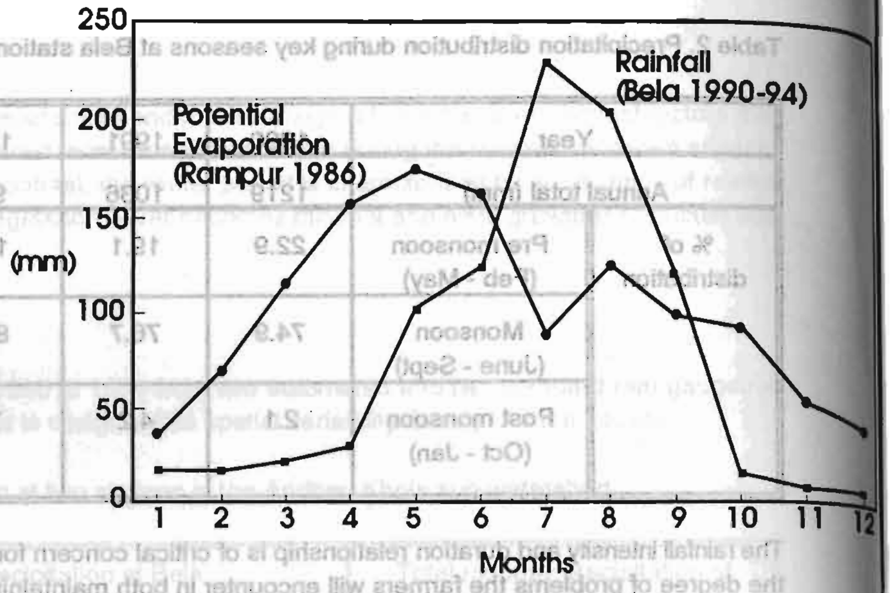

Figure 2. Distribution of moisture deficit in the sub-watershed.

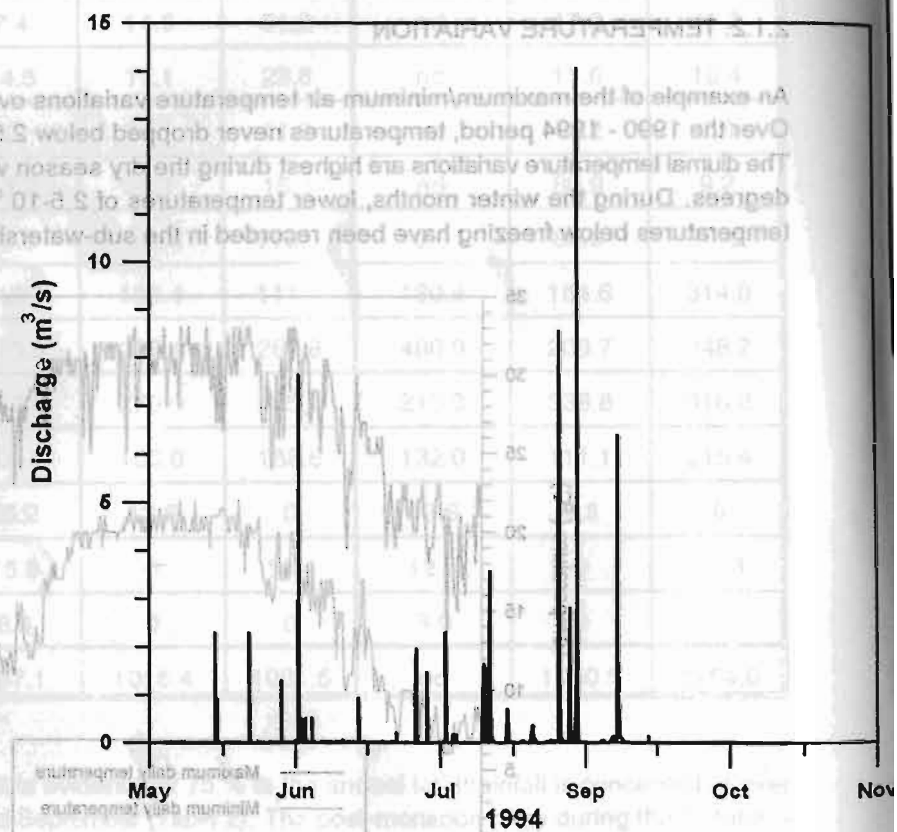

Figure 3. Stream hydrograph for 1994 at station No. 2 in Andheri Khola.

It is evident from this figure that base flow during the dry period is often insufficient for maintaining extensive irrigation. In contrast, excess water must be removed from the land during the monsoon season to minimize landslides and terrace failures. Water available in the stream is the primary source of irrigation water for agriculture.

2.3. Land Utilization

Rice is the main staple food in the watershed and the cultivation and irrigation practices have evolved over many centuries. The key changes in rice cultivation occurred about 10 years ago, when new, short-season rice varieties were introduced. These varieties replaced indigenous varieties such as marasi, taulia, and thapachiniya and resulted in a significant increase in the use of chemical fertilizers and irrigation water. The amount of irrigation water used is dependant on water availability, soil type, site conditions, and cropping system practice. The most commonly used cropping system sequences are provided in Table 3.

Table 3. Cropping sequences under different irrigation systems.

Cropping sequences under heavy irrigation			Position of the field	Water available	Comment
Summer	Winter	Spring			
rice rice rice rice	wheat wheat potato tomato	rice fallow maize fallow	Flood plain, lower level areas	All year round	High labour input
Cropping sequences under light irrigation			**Position of the field**	**Water available**	**Comment**
Summer	Winter	Spring			
maize maize maize maize	wheat wheat potato tomato	mustard fallow fallow fallow	Higher position form river bed, ancient terrace and ancient alluvial fan, foot slope	Irrigation water is restricted to winter	Moderate labour input

Due to water shortages, the production of early rice (hiunde dhan) is restricted during the pre-monsoon period to a few selective plots near the headwaters. This practice creates water shortages for downstream farmers who are compelled to keep agricultural land fallow as the stream becomes dry. As the monsoon rains arrive, all paddy fields are transplanted with rice. The entire family, shared (perma) and hired labour participate in the transplanting process. Rice is flooded during most of the growing season and a total of 58 ha are planted in this way in the Andheri Khola sub-watershed.

The fields under light irrigation do not hold water, but plants receive moisture from monsoon rains. Energetic farmers plough the fields after the rice crop and plant potatos or tomatos, taking advantage of residual soil moisture left from the preceeding crop.

3. METHODOLOGY

The springs and irrigation network were first identified in the field and the information was transferred to 1:5000 scale aerial photos. All wells and irrigation channels, as well as the irrigated fields and check dams, were incorporated into the GIS database. Water flow was measured near the springs and in different locations along the irrigation channels using a measuring cylinder and a Price AA current meter. A number of informal surveys were also carried out to identify the farmers' concerns and to learn about the current water distribution system, for both drinking and irrigation purposes.

4. WATER MANAGEMENT SCHEMES IN THE ANDHERI KHOLA SUB-WATERSHED

About 75% of all irrigation systems and drinking water systems in Nepal are managed by farmers groups (Shrestha, 1995; Pradhan, 1989b). In the Andheri Khola, all irrigation systems are organized and operated by farmers who are responsible for measuring the supplies, water allocation, frequency of use, construction and routine maintenance of the irrigation systems. Jurisdictional arrangements are of particular importance since the dependence on water is increasing due to agricultural intensification and population growth. Rain is the main source of water and most leaves the area as run-off while only a small portion infiltrates through voids into the soil matrix and surficial materials to provide groundwater supplies. The water availability is very uneven in the sub-watershed with the largest communities receiving the lowest quantity on a per household basis. Thirty-five natural springs were identified in the sub-watershed and these serve as drinking water supplies to the residents and provide the only source of stream flow during the dry season.

4.1. Springs and Drinking Water Systems

The flow of the springs was measured to determine the size of the available drinking water supply in the sub-watershed. Five wells are located outside the sub-basin and a small portion of the spring water leaves the watershed for consumption by external communities. As shown in Figure 4, the total daily supply was calculated to be 231 m^3/day, of which 89% comes from within the basin and 4% leaves the sub-basin. Most of the wells are located between 1200 and 1600 m elevation. An Intricate network has been developed to supply the widely dispersed residents with drinking water supply lines.

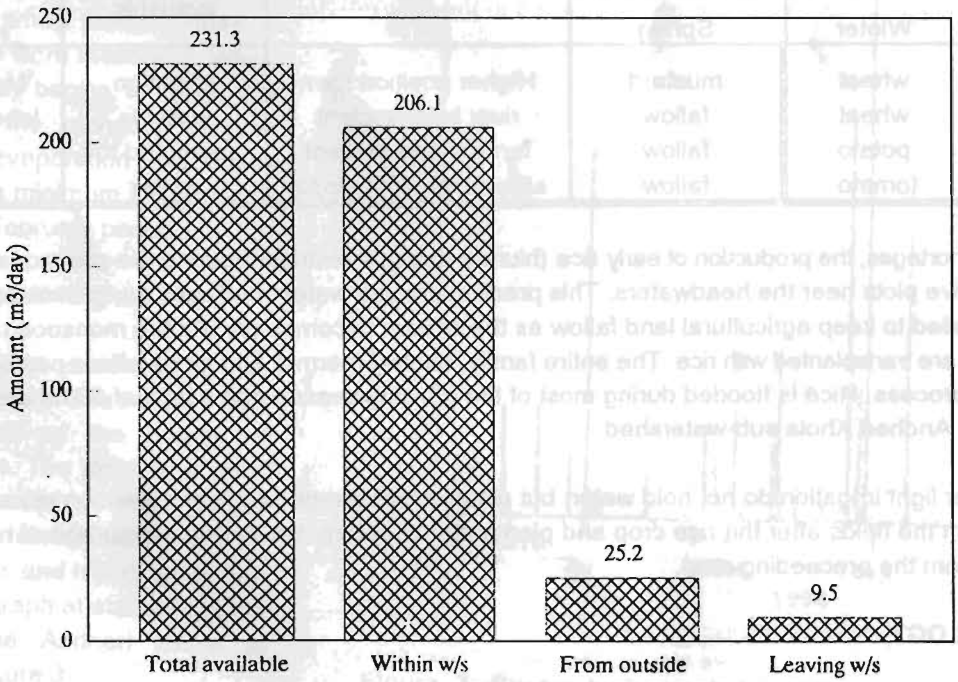

Figure 4. Available drinking water in the Andheri Khola sub-watershed.

Water from springs originating in common or religious lands is available to all. Long time users have greater user rights than a newcomer. Springs located on private land are managed by the land owner, but the spring can be sold in isolation of the land.

Table 4 provides an overview of the amounts of drinking water available to each household in the sub-basin. The community of Baluwa receives the least amount of water at 0.17 m^3 per household per day, while the people near the Kanjale Khet are the most fortunate receiving 3.35 m^3 per day. The supply around Dandaghar was calculated to be 0.4 m^3 per day and Bela has a rate of 0.59 m^3 per day/household.

Table 4. Drinking water distribution in the Andheri Khola Sub-watershed.

Serial #	Number of sources	Spring I.D.	Flow measured (L/min)	Number of households	Community benefitting
1	1	dw15	9.3	4	Kainjale Khet
2	1	dw25	6.5	4	Danda gaun outside w/s
3	3	dw22,23,24	18.6	20	Danda gaun
4	2	dw31,32	8.1	11	Chiuribot
5	1	dw29	4.2	6	Simpatle
6	6	dw2,4,10,12,17a,26	17.2	25	Free flow
7	1	dw18	1.3	2	Chundalya Patal
8	1	dw19	6.9	11	Patle gaun mathillo
9	1	dw28	3.6	6	Dharapari
10	1	dw21	10	20	Phulbari
11	2	dw3,6	16.3	40	Bela & Thumka
12	1	dw27	0.6	2	Jurelithumka
13	1	dw30	3.6	13	Talio Patale gaun
14	3	dw7,8,9	7.7	28	Dandaghar
15	1	dw17b	2.3	9	Dahal gaun
16	1	dw5	3.4	14	Chhaap
17	1	dw11	1.8	8	Dhami gaun
18	1	dw20	2.2	11	Lakaine danda
19	1	dw16	1	5	Patle gaun
20	5	dw1,13,14,33,34	36	307	Baluwa
Total	35		160.6	546	

Baluwa and Bela are two well-organized communities that consume large amounts of water. In Baluwa, spring water is first collected in intermediate chambers (average dimensions 0.6 x 0.6 x 0.5 m) established near the source. Black polythene pipe is used to deliver the water. The water distribution time in Baluwa varies from 3 to 4 hours per day, depending on the season and is directly related to water availability. Twice a day over a four hour period, all 25 taps receive about 35 m^3 of water which is collected in a storage tank with dimensions of 4 x 4 x 2.1 m. The water comes from 5 springs with a combined discharge of 36 L/min. Two springs with combined discharge of 16.3 L/min are used are used for the village of Bela. The water is first collected in an intermediate chamber with dimensions of 0.5 x 0.5 x 0.4 m and is then diverted to a main storage tank with dimensions of 3.7 x 2.4 x 1.4 m. There are two taps drawing water directly from the tank for the residents of Bela and a third tap for the residents of Chhaap down slope.

4.2. Irrigation Distribution Systems

Untapped spring, waste water, surface and subsurface flow areas are the main sources of irrigation water. Farmers tap the stream water from every possible site through a network of 72 diversion dams for irrigating 58 ha of paddy land. These irrigated areas act as a temporary water reservoir, holding approximately 29,000 m^3 of water (58 x 100 x 100 x .05 m, assuming only 5 cm of water depth). There is a general understanding that a new dam can only be established if it is at least 100 m upstream or downstream from an existing dam. The 72 dams were established at variable distances along the river, depending on ownership, channel conditions and topography. Given the current density, construction of new dams is difficult, but the farmers can and do readily modify existing dams, weirs and channels.

As shown in Figure 5, about 65% of the 72 irrigation systems are used on a year round basis, while the remainder are only used during the dry season. The channel cross sections of the indigenous system vary from 0.1 m to 0.8 m and the average size of a dam is 0.85 m in height and 5.8 m in length. Stream response to storms can have serious consequences in a high gradient river like Andheri. Peak flows can destroy all the dams (e.g. July/ August 1992, August 1993), and the resulting damage can require massive reconstruction efforts (Pradhan, 1989). Farmers may be compelled to shift the dam in response to heavy modification of stream channel by big flood event.

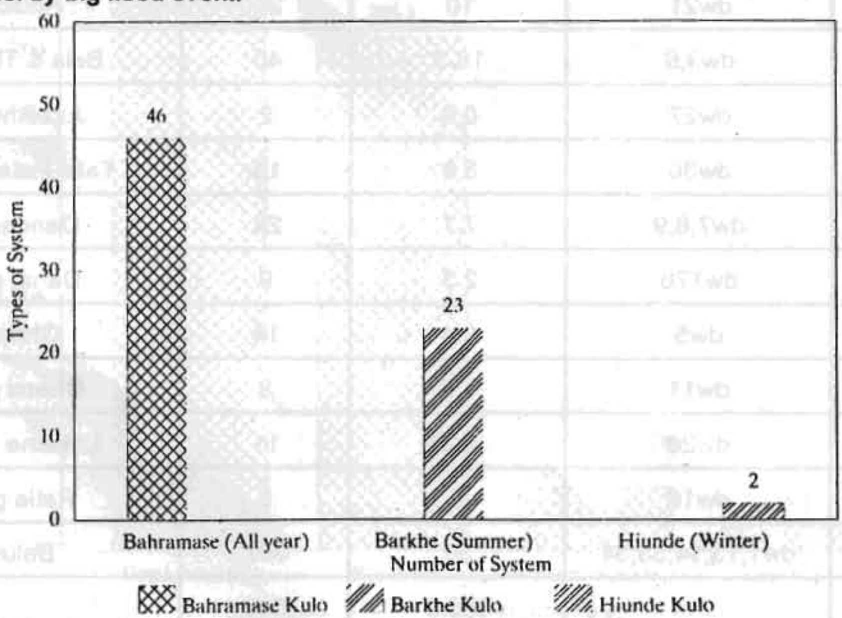

Figure 5. Distribution of springs, drinking water and irrigation systems in the Andheri Khola sub-watershed.

Local materials are used in the construction of the dams, with emphasis being placed on simple construction that can be repaired rapidly. As shown in Figure 6, diversion dams consist of simple stacking of rounded and sub-rounded stones which are interlocked by twigs. Gravels, sands and grass are used as packing material to minimize seepage. The weir sticks are usually 8 - 10" higher than the canal height to ensure that adequate amount of water can be provided to each irrigation canal. During flooding periods water can easily overflow the dam and canal.

Figure 6. Typical diversion dam used for irrigation in the Andheri Khola sub-watershed.

Only three dams were built with a gabion system (galvanized wire mesh filled with rocks). These are stronger and survived both the 1992 and 1993 flood during which most of the other dams were destroyed. Depending on the time of the flood, the dams are reconstructed very rapidly. The oldest irrigation system is more than a century old, and most of the other dams have been in operation for the past 50 to 65 years.

Depending on the season, water availability and the crop to be grown, farmers select different water application methods. Several methods of irrigation are used in the watershed and they include basin irrigation, furrow and corrugated irrigation, and wild flooding. In basin irrigation, small earth banks (levees, bonds or ridges) of 25-50 cm in height are constructed around each field and this forms a basin with an inlet and outlet to control the water (Stern, 1987). The basin is filled with water to about 15 cm of the top of bond. Regular input of water is needed to maintain puddling, and the excess is drained off. Rice is flooded because it provides adequate moisture to the plant at all times, the temperature can be maintained and the crop is partially protected from rodents. In furrow irrigation, a series of 25 to 40 cm size bonds are created. Cash crops such as potato, tomato, radish, cauliflower, and cabbage are planted on the ridge and water is applied to the furrows twice a day. The corrugation method consists of a system of closed channels about 5 - 10 cm deep laid down across the slope without raised bond ensuring equal distribution of water in a plot. It is well suited to soils ranging from medium textured silt loam to clay loams, which permit easy flow. This method can handle steeper slope than the furrow method. Wild flooding is carried out on steep slopes for low value crops where a uniform distribution of water is not a primary concern. This system is very common in the rain fed terraces (bari land) under wheat, maize and millet production.

4.3. Water Loss

One of the key problems with irrigation is the significant losses of irrigation water along delivery channels through seepage and evaporation. Farmers claim that half of the irrigation water is lost through seepage. The losses are greatest when the channel must cross areas of fractured bedrock, sections of sand and/ or gravely soil materials. An example of such losses is demonstrated in Figure 7, where the water flow in the distribution system was measured in two delivery channels. In the upper channel, almost 35% of the water is lost through seepage over a distance of 500 m. In the lower distribution system, the initial losses were small but the flow was reduced by more than 90 % over a distance of less than 1 km during a period when no water was diverted at any of the upstream measurement points.

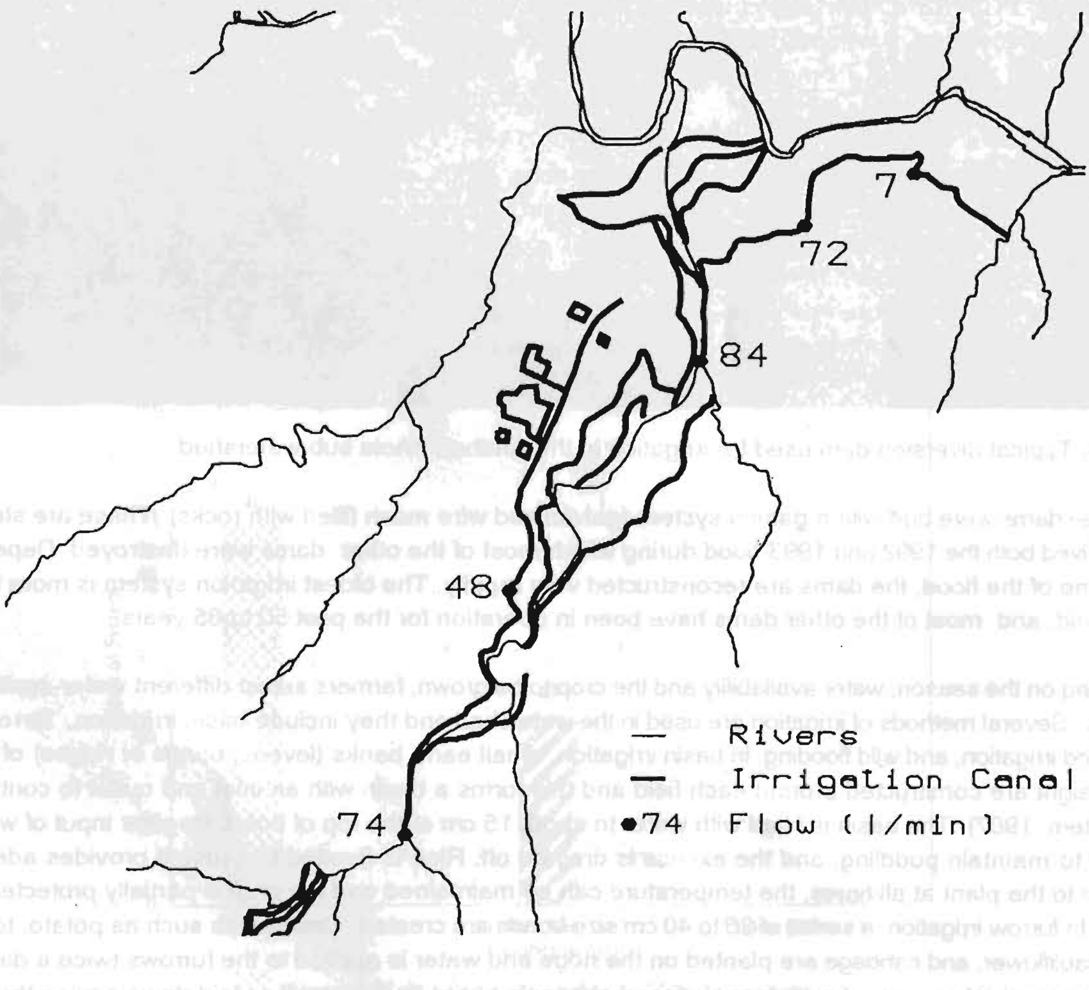

Figure 7. Seepage losses in two irrigation canals near Baluwa.

4.4. Organizational Structure and Water Allocation Policy

A proper and timely water supply depends upon how well the water allocation system is organized and managed. In a broad sense, three categories of farmer managed organizations are recognized within the study area: well managed organizations, informal organizations and anarchical groups.

In the well managed system, the farmers form a committee and conduct assemblies. Money is collected to maintain the system and the amount of water delivered to each field is based upon land holding. The committee is fully empowered to raise money and to make decisions regarding who will get water first. One year the distribution starts from top to bottom, and the next year the delivery sequence is reversed. The smooth operation of the system is dependent on the full control of the system by the community (Acharya, 1989; Pradhan, 1989a).

Informal systems are used for rice production. Before the rice plantation season, all beneficiaries of an irrigation system get together either at a dam site or on a field. They inspect the system and assess the amount of work required to fix it for the season. Contributions are made either in the form of labour or cash, the amount depending on the size of one's land holdings. If a farmer defaults on his participation for whatever reason, he can provide labour during the next term. Mutual understanding is the basis for smooth operation of irrigation systems in this category. Water distribution is made according to need or whose field is ready at the time. Farmers consult each other and adjust transplanting schedules accordingly. During the transplanting period, this system works reasonably well. Once all members have transplanted their rice, water distribution is decided according to need. During the monsoon season, there is frequent destruction of dams and canals, and the farmers' response is rapid. Everyone gets together at short notice to repair any damage and ensure the vital crop production.

The anarchical groups are common and have many beneficiaries, but they are often very disorganized. Once the water begins to flow at the end of the dry period, everyone has the right to water. In this situation farmers near the headwater draw water first, and the farmers below must wait. The system is unfair, but still operates. Frustrated farmers occasionally destroy the system.

4.5. Managements of Conflicts

When water is not delivered as expected, conflicts arise. These are human induced conflicts, which arise when one farmer steals water, destroys a structure, or operates an unauthorized dam. Such violations are generally rare, because water is very precious during winter and the supply is closely monitored. Violations result in crop failure and have devastating effects on the livelihood of the farmers. Attempts to resolve conflicts are first made at the farmers' level. Unresolved matters will be taken to a village chairperson. Complex problems are forwarded to the district office.

4.6. System Maintenance and Financial Arrangements

Continuous maintenance and repair is needed in order to guarantee a good rice crop. Therefore, the entire family participates in the management by providing physical labour and/or financial support. The proper management of water therefore becomes one of the most important tasks in the farmers' life. All water allocation systems in the study area are the result of either individual initiative or community efforts. Only one out of 72 systems received government funding for upgrading. Repair and maintenance is usually the responsibility of the beneficiaries.

4.7. Case Studies In Bela and Baluwa

To provide more detailed information, a brief description of case studies of the indigenous systems at Bela and Baluwa are presented.

4.7.1. BELA, A SPRING-FED DRINKING WATER AND IRRIGATION SYSTEM

Bela represents a community of 23 households and they receive their water from the Thulo Khola, 0.9 km above the village. Every drop of water is harnessed by systematically collecting inputs into a series of small ditches. A one inch-diameter black polythene pipe is used to conduit the water down to Bela were it is collected in storage ponds. Fresh water from Timure Kholchi, 0.8 km above the village, is collected in a distribution tank (3.7 x 2.4 x 1.4 m dimension) for human consumption. The overflow from the distribution chamber is directed into the first pond. Two taps connected to the distribution tank provide water at a central washing station to all community members, 24 hours per day. Waste water is directed to the second pond. Water thus collected in two ponds is reused for irrigation. Irrigation water users are divided into two major groups:

1. The Tripathi group includes three farmers who are located at elevations higher than the pond level, which means that pond water cannot be used to irrigate their fields. Each farmer is permitted to draw 5 hours and 20 minutes of water every fourth day (in turn), between 7 am and 12:30 pm, from the most convenient point in the supply line.

2. The Pathak group is comprised of 16 farmers who share water from the two ponds between 12:30 pm and 7 am. Every 17th day, a farmer is permitted to repeat his turn of taking a 6 hour supply of water. In both cases, it is the responsibility of the individual to ensure that the maximum amount of water is delivered to his fields. Should the farmer fail to use his turn, he will not get a replacement.

The irrigation water in Bela is primarily used for winter crops such as garlic, onions, radishes, tomatoes, cabbage, cauliflower and potatoes. Farmers use the limited water resources cautiously, respect other farmers' rights and follow the routine agreed upon. The total area under this irrigation system is about 100 ropani (5 ha).

All of the members have family relations in the community and have lived here for generations. It is a close knit community where everybody knows the agricultural activities of every farmer. Just after Dasain (which usually falls in October) the members of the irrigation system get together in a general assembly to discuss the troubles that they had faced over the past season. They inspect the problematic sites and identify solutions in a joint manner. Collective efforts have adequately solved all problems to date. Being a small group in a small area, the system functions very well. Any misunderstandings are solved through mutual consultation. No serious conflicts have arisen since the initiation of the system in 1960.

There is no provision made for collecting regular fee contributions according to land holding or crop yield. When need arises all members make a shared contribution. In 1992, each member provided NRs 500 to upgrade the irrigation system. A one inch black polythene pipe was laid between the water source and the collection pond to minimizing seepage loss along canal. Being a winter system, maintenance work is simple and easy. Farmers' response to problems is immediate and effective. They are prepared to make contributions once the matter is settled collectively.

4.7.2. BALUWA, A STREAM FED IRRIGATION SYSTEM

The Baluwa (Devbhumi tar) irrigation system supplies water to 22 ha of ancient alluvial terrace land in Baluwa at the bottom of the sub-watershed. The area is located at an elevation of 800 m and with irrigation it is possible to grow a wide range of crops. According to agreements made with downstream users, the Baluwa irrigation system uses stream water from only mid-October to mid-March. The system is organized through a farmer's committee of 7 individuals, which are elected by the water beneficiaries themselves. Meetings are called once a year in order to evaluate the magnitude of problems. Repairing costs are estimated, money is raised, and an experienced local person is contracted to do the repair work. The committee keeps track of the work progress and expenditures.

The sole source for the Baluwa irrigation system is stream water from the Andheri Khola. Semi permanent weirs made of gabion wire mesh filled with rocks make up the diversion structure. The command area is divided into four zones, each embracing 110 ropani (5.5 ha) of land. The distribution follows a strict routine agreed to in the general assembly. During the first year of operation the farmers near the source get the water first, and the order is reversed following year. The farmer is responsible for diverting water to his field during the allocated time. Failure to obtain water during the allocated time is the responsibility of the farmer. Farmers are extremely alert when their turn for irrigation arrives. They put in additional effort to ensure an uninterrupted water flow to their fields. Water access time is proportional to the land holding size, 90 minute per ropani (.05 ha). In case of natural disasters, repair decisions are made by the committee.

A wide range of crops are grown on different landforms, each demanding a different portion of water at different times. The irrigated crops include tomatoes, wheat, mustard, potatoes, cauliflower, cabbage, okra, garlic, onion, broad mustard, and off-season capsicum.

There are few conflicts as far as dam repair, maintenance and canal cleaning are concerned. Farmers plan their crops according to irrigation water availability, which is rotated on a three week interval. Since their is no other water source, everyone relies on each other and it is rare for a farmer to steal water by diverting it during the night. In such cases the solution is to cut back the water allocation for the offender by twice the amount he stole and this is given to the other farmers. If the same farmer is caught for the same offence a second time, his turn is relinquished for the year. Third-time violations lead to expulsion from the committee. As far as we were told, only a couple of first level violations have occurred in recent history. Another problem is that downstream farmers may break the dam to draw water into their system. In such a case, the farmers prefer to fix the dam, make frequent inspections and ensure smooth water flow rather than to identify the rule breaker.

The Baluwa irrigation system was established some 100 years ago to irrigate sugar cane. The irrigation system was upgraded with significant technical and financial support by the government. The farmers were required to pay 12% of total cost in form labour and cash. Stone filled crate dams were built and the canals were cemented and covered in places. In 1990, the irrigation system was handed over to the user group who is now fully responsible for its operation and maintenance. Farmers raised NRs 5 per ropani of land in 1992. The money collected was enough for the 1993 repair work. In 1994, it was agreed to pay NRs 2 per ropani. Some farmers have lost interest in the system as water is becoming more scarce during the critical dry period. Since there are severe shortages, they don't consider the investment to be worthwhile, unless major changes are made in the collection method.

4.8. Farmers' Perceptions and Comments

Farmers are aware of diminishing stream flow and increasing water demand due to the introduction of vegetables for market production. They believe that some structures should be improved by using gabion and cement. A dam torn apart by a major flood may take from 50 to 150 person days for repair. Cement lining in the canals is another area that farmers feel could improve the efficiency of irrigation. This would reduce the seepage losses, providing a larger amount of water to the crops during the critical pre-monsoon period. Added storage capacity by the construction of a collection pond at higher elevation to capture more run-off at critical times is also a desired option. Most often these options are beyond the reach of the subsistence communities since the appropriate materials are expensive and unavailable in the watershed.

Farmers suggest that water shortages for both drinking purposes and irrigation have increased over the past 10 years. They feel that these shortages will become the main problem in the task of increasing biomass production for the rapidly increasing population in the basin.

5. CONCLUSIONS

Nepalese farmers know the value of water and have developed fairly elaborate indigenous water management systems. Many systems have been in use for centuries but there is clear evidence that the water supplies in the dry season are becoming limited due to crop intensification and a significant expansion of irrigated agriculture. Of the systems identified in this study, the community owned system with equal participation of all beneficiaries functions better than the privately owned and unorganized systems.

The diversion systems are built of local materials and can be repaired on short notice. Most systems function well and are adapted to the difficult environmental conditions. However, the maintenance of such systems is very labour intensive and two areas have been identified where improvement could be made. The seepage losses along the canals are significant and lining canals in critical areas with plastic pipes or cement would reduce these losses substantially. The problem with these improvements are cost and access to key materials. The second area is in the type of irrigation practiced. Most irrigation is based on flooding either the fields or furrows within the field. This requires large amounts of water and leads to large losses by seepage and evaporation. Trickle irrigation is an option that is currently being examined as part of the MRM project and its feasibility for the production of high value cash crops needs further investigation.

6. RECOMMENDATIONS

The introduction of gabion wire to the dam construction will improve water acquisition and reduce labour input for dam repair. Such structures can also be used to protect stream banks from undercutting irrigation distribution canals. They usually require little external material and can be built locally without difficulties.

Certain sections of canal need to be concealed by polythene pipe to reduce excess amounts of water loss. It is not possible to line the entire irrigation canal in these mountainous systems, but plastic or cement linings should be considered in critical sections of fractured bedrock zones and in areas were the canal must pass through coarse texture materials or unstable terrain.

The water collection ponds in Baluwa are on common land at the end of the canals. They should be improved and trees could be established around them to reduce evaporation losses. Water collected during the few winter rains could be used for winter vegetable crops.

Maintenance and a regular supply of water is essential. The drinking water committees are having difficulties providing water to the rapidly increasing population during the dry season. More reservoir storage capacity must be built for this season.

In many villages there is no provision for reusing the waste water locally. A better recycling system, such as that used in the Bela village, should be encouraged.

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