CHAPTER 4

Diagnosis of the East Rapti River Basin of Nepal

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Introduction

Much research has been done and valuable recommendations made to increase the effectiveness of farmer-managed irrigation systems (FMIS) in Nepal (Gill 1996). However, an integrated approach emphasizes that development policy should not merely work on issues of one sector and resource scarcity but shift attention to multiple sectors and access to resources.

Despite continued government efforts to curb poverty, 42 percent of the population in Nepal still suffer from poverty (Vaidya 1999). There have been many debates and criticisms about the government's welfare interventions in this mountainous country (Jodha 1995; Bandyopadhyay and Gyawali 1994; Giri 1992). In the case of utilization of water resources, state-led development activities have demonstrated a bias in irrigation and rural water supply that ignored or bypassed village communities (Bandyopadhyay and Gyawali 1994; ERL 1988). The cumulative effects of the past efforts can also be illustrated by the national statistics of increased food deficit during 1989–97 that are attributed to decreased agricultural productivity (MDD 1998[xx This is not referenced]). As the conventional development approaches could not meet the expectation placed on them to sustain agricultural productivity and to keep up natural resources systems, a shift in the development paradigm to newer concepts has now begun to gain momentum.

Some of the implications of the above debates and conclusions might have been very instrumental for the government to emphasize in the Ninth Five-Year Plan (1997–2002) for the development of a policy on overall water resources. The baseline document of the Ninth Five-Year Plan puts forth the necessity of discouraging earlier sectoral- or subsectoral-biased policies and developing an overall water resources policy that will emphasize managing the growing inter-sectoral competition over water use (National Planning Commission [NPC] 1997)

Embracing the idea of a basin approach to water resources management and to contribute to the national objective of poverty alleviation, the Water Management Study Program (WMSP) at the Institute of Agriculture and Animal Sciences (IAAS), Tribhuvan University, Rampur, Chitwan, Nepal collaborated with the International Water Management Institute (IWMI), Sri Lanka and the Department of Irrigation, Kathmandu, Nepal for a series of studies on a) the performance assessment of irrigation systems, b) socioeconomic and stakeholder analysis, c) institutional analysis, and d) water accounting of the east Rapti river basin of Nepal for developing effective water management institutions.

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This paper attempts to summarize findings from these studies. The focus is on diagnosis and development of insights within and across the sectoral use and management of water resources, considering the river basin as the unit of analysis. The basin concept is a key to identifying a range of existing or potential natural processes and human activities, especially water use and to promoting development objectives by securing a higher degree of coordination among various stakeholders and related regulatory agencies (IWMI 1999).

The paper has been organized into nine sections. The first section is the introduction while the second section presents the physical characteristics of the basin. The third section discusses important demographic features including ethnicity, pattern of employment, urban versus rural population, growth trends, and poverty. Agriculture being the major basis of livelihood with the basin population, a more detailed discussion is provided in the fourth section focusing particularly on irrigated agriculture. Increasing nonagricultural use of water as identified by the study is presented in the fifth section. An overview of land and water rights is provided in the sixth section. Section seven describes one of the major themes of the paper that links water resources endowment with use patterns by multiple sectors and emerging issues, looking at "stakeholder perceptions." Section eight illustrates the existing institutional structure including the role of multilevel government agencies, constraints, and factors that affect their role in water resource management. The last section concludes the paper with major issues and policy recommendations for improved management and development of water resources in the basin.

Physical Characteristics of the Basin

Situated in the central development region of Nepal, the east Rapti river basin lies between the latitude 27° 26' and 27°54' N and longitudes 84°10' and 85°12' E. It is surrounded by Gorkha, Dhading and Kathmandu districts in the north, the Rautahat, Bara and Parsa districts as well as part of northern India in the south and the Nawalparasi district in the west. Of the total basin area of 3,222 km^2, Chitwan and Makwanpur districts occupy about 58 and 42 percent of the basin area, respectively. Similarly, 82 percent of the Chitwan district and 55 percent of the Makwanpur district are in the drainage area of the basin (Adhikari 2000).

Topography and Soils

The east Rapti river originates in the southern part of Middle mountain (in the Lesser Himalaya) about 25 km southwest of Kathmandu. A sharp gradient in elevation between the origin of the river (1,500 m asl) and the point where it moves out of the basin (140 m asl) contributes to the diverse biophysical environment. The river abruptly descends from the Middle mountain to the enclosed valley of Siwalik and Churia hills, where the valley floors of Makwanpur and Chitwan districts occupy a large part of the basin. The Siwalik hills form a front of Himalayan origin bounded with the Middle mountain range by a distinctive fault zone referred to as the Main Boundary Thrust and comprising thick sedimentary formations of the Tertiary Age. The Chitwan valley is a tectonic depression of widely undulated Siwalik Groups and has been buried beneath thick alluvial deposits (Nippon Koei 1986).

Moderately, steeply, and very steeply sloping hilly and mountainous terrain are laid over slopes of less than 10^{o} to more than 30^{o}. Diversified landforms and soil types as well as dissected hilly terrain slopes and mosaics of alluvial plains, have been formed by the action of the river and gravity. Due to great diversity in climate and topography, an array of soil types is found in the basin, ranging from sandy or cobbly and sandy and loamy skeletal in the sloping areas to the coarse and fine loamy soils in the plains. The depth to water table varies and seasonal ranges of depth to water table also vary from less than 2 m to more than 15 m. A large part of the Middle mountain drains well, whereas drainage in Siwalik is highly variable and is subject to river flooding near the Rapti river and in areas of natural depressions (LRMP 1986). Where settlements occur, they reflect areas with stable soils and consistent year-round water supply. The soils on many slopes are too shallow to terrace, even though gradients may be gentle. In general, most of the soils of Chitwan valley are young without much differentiation into horizons. Proper management and adequate inputs including irrigation water can make the valley soils highly productive (Khatri-Chhetri et al. 1987).

Land-Use and Climate

The dominant land use and land cover, as shown in figures 1 and 2, comprise mixes of warm temperate, subtropical hardwood and coniferous trees (62.25%), followed by lowland agriculture (18.31%), upland agriculture (8.42%), shrubland (3.67%), grassland (3.61%) and others including urban settlements, swamps, rocky outcrops, and sandy and gravel river banks (3.74%) (Adhikari 2000). Since countrywide land resource maps were developed only once in 1986, a trend analysis of land-use change in the basin was not possible, so land-use data given in this paper represent a one-time piece of information.

The basin has a predominantly monsoonal climate. Because of the great variations in elevation, climates that contribute to the water resources of the basin are characterized by warm temperate (1,000–2,000 m elevation and 15–20 ^{o}C mean annual air temperature) in the Middle mountain regions particularly in the upstream part of the river, and subtropical (<1,000m elevation and 20–25 ^{o}C mean annual air temperature) climate downstream (LRMP 1986). April and May are the hottest months and the average maximum temperature is 35 ^{o}C whereas December and January are the coldest months. Minimum temperature rarely falls below 5^{o} C in most years. The average relative humidity is about 75 percent and varies from 50 percent in the dry season to 90 percent in the rainy season. The average velocity of the wind is 1.6 km/ hr. or 0.4 m/sec. in the plain area.

The use of Class-A pan gave an estimate of the annual evaporation to be about 1,470 mm with a daily average of 1.5 mm/day from December to 6.7 mm/day in May. Long-term rainfall data from the four agro-metereological stations have been obtained. Although it may be small, the variation in annual average rainfall across four stations gives a comparative idea of upstream versus downstream rainfall patterns (table 1). Rainfall records in 1970–88 at the Rampur agro-metereological station indicated that more than 75 percent of the annual rainfall occurred from June through September (Shukla et.al 1993) and more than 90 percent of the annual rainfall occurred from May through October (Nippon Koei 1986). Similarly, the basin-level picture of rainfall distribution is that it is concentrated during the 6-month monsoonal period from the middle of May to the end of October. July and August receive the heaviest downpour and account for nearly half the annual rainfall.

Figure 1. Land-use distribution in the basin.

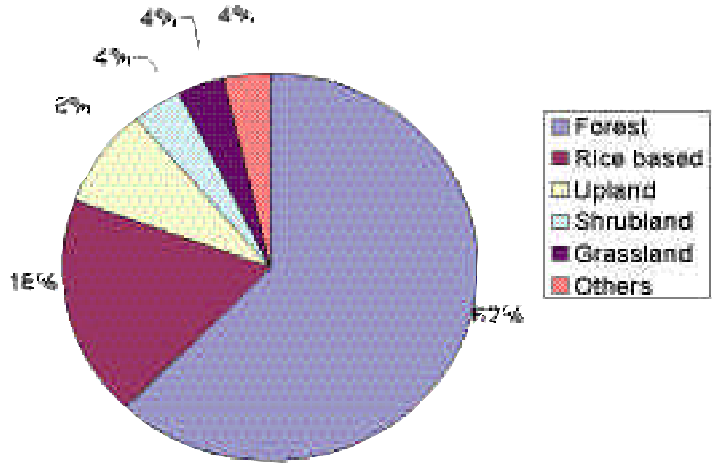


Table 1. Long-term rainfall patterns in the basin.

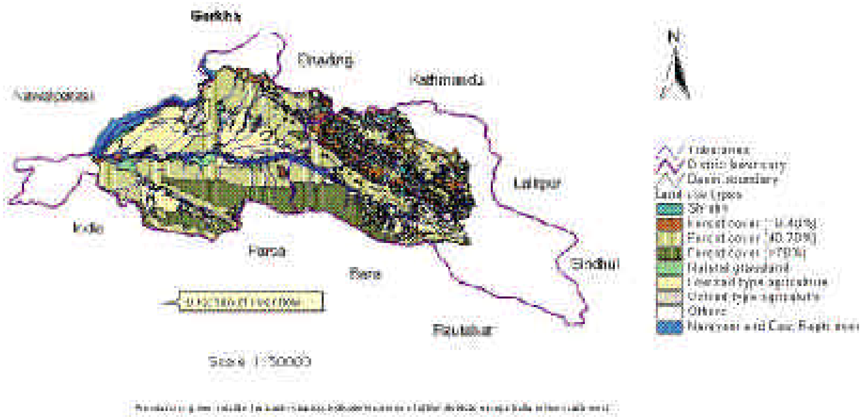
Agro-Meteorological Stations	Average Annual Rainfall (mm)	
	Upstream	Downstream
Chisapanigadhi [a]	2,182	-
Hetauda [a]	2,233	-
Jhuwani [a]	-	1,866
Rampur [b]	-	2,000

[a]Nippon Koei 1986. [b]Shukla et al. 1993.

Hydrology of the Rapti River System

The river course is 122 km long and flows westward to join the bigger snow-fed Narayani river. In the Chitwan valley, it flows about 70 km meandering through the alluvial deposits and gathering many tributaries from the north (Nippon Koei 1986). Most of the tributaries originating in the Churia hillside in the south are ephemeral compared to the tributaries originating in the Siwalik and Middle mountainside in the north. Kali, Rani, Samari, Karr, Manahari, Lothar, Kair, Khageri, Budhi Rapti and Riu Khola form the major tributaries of the river. The total length of the main river including all tributaries is 399 km (RTDB/IAAS/IWMI 2000). Figure 2 shows spatial distribution of land use land cover and river networks in the basin.

Figure 2. Land use and land cover in the east Rapti river basin as of 1978–1979.



Based on rainfall data for 21 years (1976–96), annual rainfall inflow varied between 2.482 mm in a wet year and 1,450 mm in a dry year, with average rainfall of 1,937 mm. The analysis of 21 years of rainfall data indicated a perceptible spatial trend from upstream to downstream and very little temporal trend. Rajaiya, one of six stations, was used to derive discharge data for water accounting. The long-term discharge record of the east Rapti river at Rajaiya hydro-station indicated that about 85 percent of the total rainfall occurred from June to October (RTDB/IAAS/IWMI 2000).

Water accounting was computed for three typical years (table 2). Net inflow of water in the basin for normal (1979), dry (1992) and above-normal (1978) years were found to be 6,120, 4,564 and 7,171 m^3x10^6, respectively. Net outflows for these years were computed to be 3,576 and 3,848 m^3x10^6, respectively.[2] The general conclusion that can be arrived at from the data is that it is an "open basin" where only 53 percent of available water is depleted in a dry year and the remaining 47 percent of utilizable flow exits from the basin. Only 6 percent of available

[2]The negative sign in the table indicates addition of water to storage to supplement the deficit of previous normal year. As defined by Sakthivadivel and Molden, IWMI scientists, storage change is the difference between storage at the beginning of the year and at the end of the year. Since data is not available to compute surface and soil moisture storage at the beginning and end of the year, it is assumed that the storage at the beginning of a year is at full potential level (100%) of storage if the previous year is an above normal year, at 75% of its potential storage if the previous year is a normal year, and at 25% of its potential if the previous year is a dry year.

Table 2. Water accounting results for wet, normal and dry years.

Components	Wet Year (Above Normal) (1978)	Normal Year (1979)	Dry Year (1992)
Gross inflow into the basin	7297	5,993	4,564
Groundwater storage change	-126.03	126.03	0
Net inflow into the basin	7,171	6,120	4,564
Depletion: Process depletion	284	249	234
- Non-process, beneficial	1,933	1,561	1,533
- Non-process, Non-beneficial	242	197	198
Outflow (runoff)	3,848	3,576	2,201
Deep percolation	863	537	400

Source: RTDB/IAAS/IWMI 2000.
Volumes are in million m^3.

water is process-consumed. Forests, covering more than 60 percent of the area, consume the bulk of available water. Non-beneficial consumption is only 5 percent. Agricultural water productivity is very low (US$0.09/$m^3$ at the conversion rate of US$1=NRs 70) indicating great scope to enhance water productivity. Although data are scanty, industrial and domestic use is mostly from groundwater and the amount is small. As a significant fraction of utilizable water moves out of the basin during the year, great potential exists to harness this flow for increased water productivity within the basin. Flow dynamics representing wet, normal and dry years in the basin are illustrated using finger diagrams in figures 3, 4 and 5.

Water-Control Infrastructure

The east Rapti river serves as a prime source of livelihoods for scattered settlements in both the Makwanpur upstream and the Chitwan valley downstream. The river has experienced recurrent high flood amplitude in the past, contributed by a large number of ephemeral tributaries originating in mountains upstream. Soil erosion and landslides are prominent upstream and floods downstream. Appropriate water control structures are necessary to safeguard communities, infrastructure, croplands, flora and fauna against unexpected floods as well as for the development of water resources in the basin.

The latest massive flood in the river was recorded in July of 1993, which took lives and property of many, particularly in the Chitwan valley. This was when the east Rapti Irrigation Project (ERIP), Irrigation Sector Program of HMG/Nepal was preparing to construct a huge diversion weir in the river. Local people and environmentalists had raised issues of negative impact of the diversion weir on flora, fauna, Royal Chitwan National Park and on locally made irrigation infrastructure downstream. As a result, in lieu of a weir, a continuous embankment was built along the bank of the Rapti river.

Figures 3–5. Finger diagrams of water accounting results.

Fig 3. Finger Diagram of Water Accounting Result for Normal Year

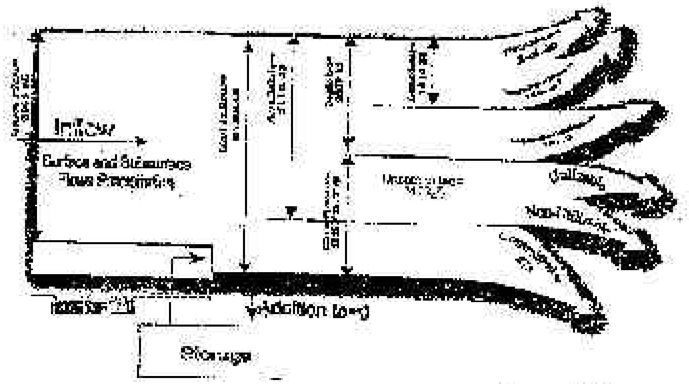


Fig 4. Finger Diagram of Water Account Result for Above Normal Year

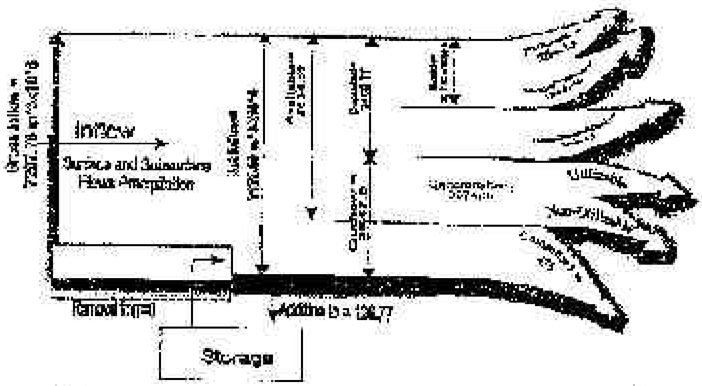
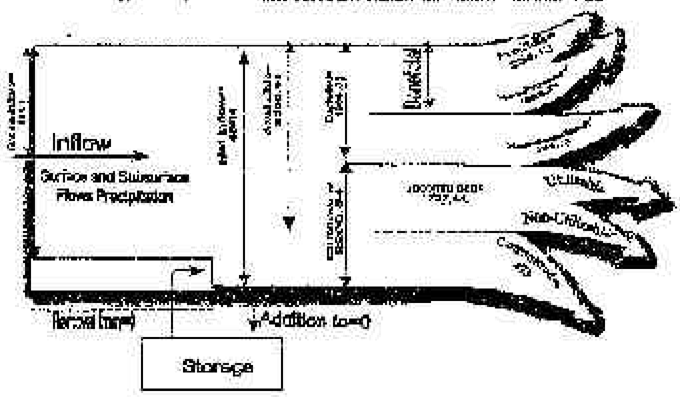


Fig 5. Finger Diagram of Water Account Result for Below Normal Year



Source: RTDB/MAAS/IWMI, 2000

The construction of an 18-km long flood embankment extending from Lother to Kumroj was completed in February 1996 with a loan assistance of NRs 272.72 million from the ADB. Besides rehabilitation and improvement work for irrigation, the ERIP also erected 50 spurs around Sauraha and some in bridge sites at Lothar to protect the banks from river cutting. Spurs at both sites incurred a total cost of NRs 8.56 million (ERIP 1998). Before ERIP intervention, permanent (8%), semipermanent (46%) and brushwood (46%) diversion structures were observed in 88 FMIS (Shukla et.al. 1993) in the east Chitwan valley. To date, ERIP has been the largest project in the area to support water control structures. In some irrigation canals water regulators were established to control flood and silt load.

Demographic Features

Basic Characteristics of the Population

Thirty-two Village Development Committees (VDCs) out of 36 VDCs of the Chitwan district and 23 out of 43 VDCs of the Makwanpur district lie within the physical boundaries of the basin. In Nepal, VDC refers to the lowest administrative unit of the government. The total population of the basin as a whole is 536,031. Data on basin population by sex was not available. However, as the basin includes 79 percent of the total population of both districts, the population of the districts, about 50 percent each for female and male, might represent the basin.

Population distribution by district and basin. Table 3 indicates that, as of 1993, a larger proportion of the basin population resides in Chitwan (63%) than in Makwanpur (37%). The basin total represents 2.9 percent of the national population and 79 percent of the combined population of both districts for the respective year, whereas the combined population of both districts represents 3.66 percent of the national population. Since there are 75 districts in the country, this population value indicates a high density and appears to be above the national average.

Table 3. Population distribution by district and basin.

Districts	Basin-Wise (%)	Basin Total	% of District in the Basin	District Total
Chitwan	63	336,934	93	361,892
Makwanpur	37	199,097	63	314,599
Total	100	536,031	-	676,491

Source: CBS 1993.

Population distribution by ethnicity within the basin. Diverse ethnic groups with distinct costumes, cultural and occupational values and traditions exist in the basin. The population of Bramhin and Chhetri is the largest (38%), followed by Mongols (29%), Tharu (8%), Indigenous (7%), Lower cast (7%), Bote (1%), and Others (4%). The massive scale of their migration from surrounding hills within the last four decades might have contributed to the large population of Bramhin and Chhetri in the basin.

Population distribution by employment pattern within the basin. Most of the population (both male and female) in the basin are employed in farm work and businesses, followed by services, and the least in technical or professional jobs (table 4). However, the lower proportion of women in services and professional jobs and their higher contribution to farm work than their male counterparts indicate social inequity related to access to resources and opportunities prevailing in the basin.

Table 4. Employment patterns (%) by sex within the basin.

	Technical/ Professional	Services	Sales	Farm Work	Others
Male	2.9	12.8	5.3	67.1	11.9
Female	0.8	7.2	2.6	87	2.4
Total	2	10	4	76	8

Distribution of Population

Population distribution by rural and urban areas within the basin. In this paper, municipalities are considered as urban centers. There are two municipalities, Bharatpur and Ratnanagar, in the Chitwan part of the basin, and one municipality, Hetauda, in the Makwanpur part of the basin. Most of the people reside in the rural areas of the basin in both districts (table 5).

Table 5. Population distribution (%) by rural and urban areas within the basin.

	Rural	Urban	Total Population in the Basin
Chitwan	76	24	336,934
Makwanpur	73	27	199,097
Basin	75	25	536,031

Population density and literacy. The annual population growth rates in Chitwan and Makwanpur districts are 2.92 and 2.68 percent, respectively, as against the national average of 2.38 (CBS 1999). Population density was consistently higher in Chitwan than in Makwanpur over 30 years between 1971–2001 (table 6).

Table 6. Trend of population density per km^2 in the basin districts.

District	Year			
	1971	1981	1991	2001[a]
Chitwan	83	117	160	211
Makwanpur	68	100	130	167

Source: CBS 1981, 1991 and 1999. [a] Predicted population.

With some variations, literacy rate of 6-year olds and above increased by 19 percent in the Chitwan district and by 14 percent in the Makwanpur district between 1981 and 1991 (table 7). Within the basin, hill people appear to have a lower literacy rate than the people in the plain and valley areas. As table 8 shows, women in the hilly areas appear to have much less access (19%) to education (table 9) than women in the plain areas (81%).

Table 7. Trend in literacy rate (%) by basin districts.

District	1981	1991	Change
Chitwan	34	53	19
Makwanpur	24	38	14

Source: CBS 1991 and 1999.

Table 8. Distribution of literate population by sex and region within the basin.

Gender	Region		Total
	Hill	Plain	
Male	34,840	95,368	130,208
	(27%)	(73%)	(61%)
Female	15,884	68,065	83,949
	(19%)	(81%)	(39%)

Source: CBS 1993.

Population Growth Trends in the Basin Districts

As the population census in Nepal is taken once every 10 years following the administrative and district boundaries, data on the basin-level population were not available. Therefore, district-level data were used in this paper because most (79%) of the districts' population resides within the basin. Table 9 indicates that the total population of both districts rose from 1981 to 1991, though the rate of increase was slowing.

Table 9. Population trends in the basin districts.

Year	Chitwan		Makwanpur		Total	% Change
	Number	%change	Number	%change		
1961	69,000	-	-	-	69,000	-
1971	184,000	167	163,766	-	347,766	-
1981	259,000	41	243,411	49	502,411	44
1991	355,000	37	314,599	29	669,599	33
2001 [a]	467,809	32	405,952	29	873,761	30
2011 [a]	596,494	28	510,785	26	1,107,279	27

Source: CBS 1993 and 1999. [a] Predicted population.

Other criteria like migration, age structure and birth rate also bear equal significance in analyzing the demography. These data are available for only for the Chitwan part of the basin. Although data on migration exist at the level of a much broader development region (DR), which comprises a number of districts, it might still offer some indications given the lack of other data. It is interesting to note that the central DR, of which Chitwan forms a part, exhibited net positive migration (male 97,429, female 87,991) for 1981–1991 compared with net negative migration (male -24568, female -22834) between 1971 and 1981 (CBS 1991).

For the Chitwan part of the basin, excluding the Bharatpur municipality, the GIS unit of the National Planning Commission (1997) reported that in-migrated households exceeded (843) than out-migrated ones (791) during 1991–1996. This indicated a significantly dynamic rural migration pattern in this district. Analysis of the rural population structure by age revealed that the population of 10-year olds or those below had the largest proportion (29%), followed by the population of those between 11 to 19 years (22%), 20 to 29 years (18%), 30 to 39 years (12%), 40 to 49 years (8%), 50 to 59 years (5%), and 60 or above (5%). The population in the age category 10 years or less also reflects, although indirectly, relatively high birth rates or better nutritional status in the district or both.

Poverty

The term "poverty" is a buzzword for many in these days. The dictionary meaning of poverty is "state of being poor," "inferiority," "deprivation," "disadvantaged," "inadequacy," or "lack of access to resources or benefits" and so forth. It appears that its meaning is broad, but many of us understand or use it frequently in a narrow monetary sense. Can we apply these broader meanings in a water resource use and development context? Certainly, the basin population is rich in culture, tradition, ethnicity, coexistence, natural resources including biodiversity, as well as land and water resources. Then, what is critical for the basin population in relation to poverty? This section provides some information related to what we understand by poverty in the context of Nepal and in the basin.

National and regional poverty. Based on income, individuals with annual income levels below Rp 3,900 in the hill and Rp 2,500 in the *terai* (plains) are considered as poor in Nepal's 1995 Plan. No reference is made in the plan as to how this monetary value is related to international poverty standards (APP 1995). The calculations by the National Planning Commission indicate that the relative concentration of poor people in Nepal is higher in the hills than in plains (Vaidya 1999). Referring to the Agricultural Census of 1991, Vaidya says that if measured by landholding sizes, acute poverty is found more in the plains than in the hills. However, regardless of region, poverty in Nepal is recognized as an agricultural phenomenon. The current food-deficit situation and the scarcity of employment have aggravated poverty in Nepal.

District-level poverty. The International Center for Integrated Mountain Development (1997) used 39 key indicators to rank districts on the basis of a composite index of development. Differential access to resources, employment and facilities, child deprivation, gender discrimination, disadvantaged groups and food production were the key indicators used for ranking districts (worst, intermediate, best) on a poverty and deprivation scale. Chitwan was ranked as one of the best and Makwanpur as one of the intermediate poverty districts according to this scale.

Distribution of poverty within the basin districts. Poverty of different magnitude and nature prevails both in the plains and the hills of the basin. According to both the National Planning Commission and the International Center for Integrated Mountain Development criteria, poverty is concentrated more in the hills than in the plains of the basin. The aggregate population of disadvantaged ethnic groups like Chepang, Magar, Kami, Kumal, Damai, Sarki and Danuwar communities is 17.8 percent within the entire basin, clustered in the hills. The Bote, a traditionally specialized fishing community, which is also one of the disadvantaged groups, lives downstream along the east Rapti river. This group comprises another cluster of 2,173 people in the plains of the Chitwan part of the basin. The man-land ratio of this community is 14 times smaller than that of the upper caste Brahmin community (Poudel 2000). All these communities, including the Bote, belong to lower castes in the traditional society of Nepal. They do not generally expect to progress or fare well in their traditionally and culturally established specific professions. They think that their professions are not rewarding anymore in terms of money in the face of a competitive world. Neither do they have access to adequate education and alternate employment opportunities. Despite government efforts to curb poverty through a host of approaches, such as participatory social activities, fund raising, and saving and credit in the village, their family size still remains larger than those of the relatively upper caste. This further aggravates the poverty by pushing family separation and land fragmentation.

Poverty is also more concentrated in rural areas in the basin. This finding is supported by Silwal (1997) who explains that 66 percent of the population in the National Park Buffer Zone[3] is below the poverty line, 50 percent of which faces food deficit in most years. In addition to the communities mentioned above, the Tharu and Darai, both indigenous to the basin valley, also form a poverty concentration in the Buffer Zone.

The Agriculture Sector

Importance of Agriculture in the Basin

Agriculture has been the predominant occupation of the majority in the basin. Although current statistics should be significantly different due to population explosion and development activities, back in 1978–79, the area under agriculture (rice-based lowland and upland) was calculated to be 27 percent (figure1), the second largest land-use type after natural forest (62%). As of 1992, the agricultural sector alone provided employment to 76 percent of the basin population (table 5). More females (87%) were found engaged in agriculture than males (67%).

The basin comprises both hills and valley systems with unique biophysical environments suited to diverse agriculture and allied enterprises. Until the early 50s, large parts of the valley were under dense forest. A small number of scattered communities of Tharu and Darai in the valley floor as well as Chepang and Magar in the slopping hills were the indigenous people. Those in the valley floor lived on traditional wetland rice cultivation, animal rearing and fishing while those in the sloping hills survived on collecting wild food and fishing. Still another sector of society, Bramhan, Chhetri, and people of other castes, lived higher up in the hills and mountains. They cultivated uplands for crops like maize and millet and grew irrigated rice by making bench terraces where they could tap water from the nearby ravines.

When the government opened the Chitwan valley in early 50s for planned settlement for those who suffered from landslide and flooding in the hills, people migrated into the valley on a massive scale from the surrounding hills. That is the major reason why population increased by 167% in Chitwan between 1961 and 1971 (table 7). The government cleared a significant forest area for resettlement under the Rapti Valley Multiple Development Project. The valley now experiences diverse and intensive agricultural systems by communities of mixed culture, tradition, norms and values.

Rice, wheat, maize, and oilseeds are the major crops of the basin. Besides traditional crops, commercial vegetables are emerging as a cash crop, particularly in the valley floor. Since basin-level data were not available, a combination of trends of area and production of major crops of both districts (1980/81–1997/98) is presented in figure 6. Data that were published in 1981, 1991 and 1999 by the Central Bureau of Statistics/HMGN were used for this presentation.

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[3]The Buffer Zone refers to the belt of the National Park area along the sides of east Rapti river where wild animals from the sanctuary, by their movement, affect the adjoining agricultural land uses of the surrounding farm families and vice versa. Park and People, a UNDP-supported international NGO and several others are working in this area in close association with the local communities and government line agencies towards achieving a balance between forest and riverine ecology of the basin with the rural community.

Figure 6. Area and production of major crops in the basin districts (combined) between 1980/81 and 1997/98.

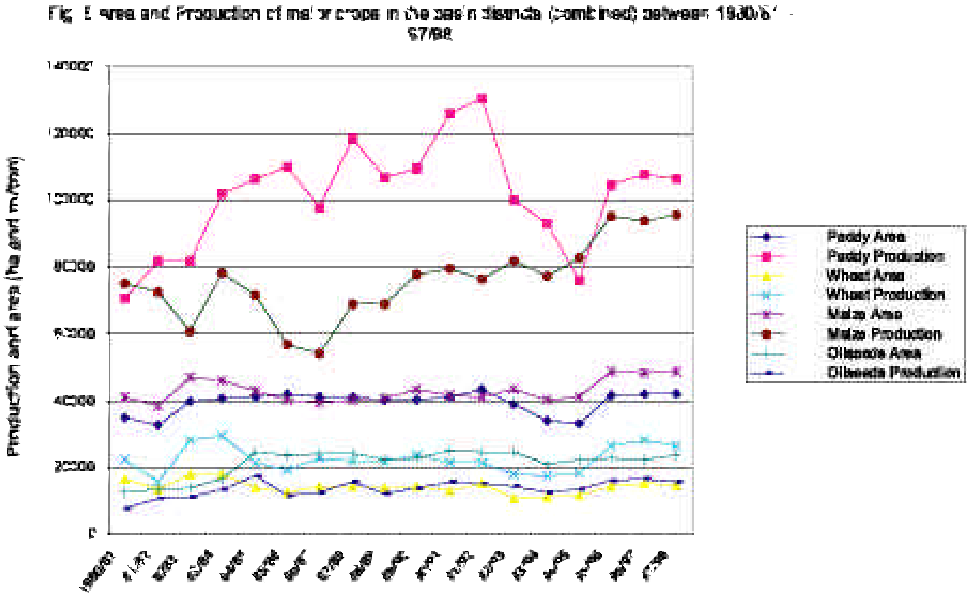


Figure 6 indicates that paddy and maize are the leading crops supplying the increasing food requirements of the district population. With stagnant area, paddy production increased from the year 1980/81 to 1991/1992, but it decreased afterwards. Maize production, although low during 1984–86, has shown a steadily rising trend thereafter. No significant increase in area and production in wheat and oilseeds was observed. In view of the ever-increasing population (table 7) and with the majority of the population still engaged in agriculture, the question of food security appears more challenging.

Irrigated Farming Systems in the Basin

FMIS and government policy. Initiation of some of the farmer-managed irrigation systems (FMIS) in Nepal dates back to at least 1750 (Pradhan 1986). Irrespective of size, 178 and 156 irrigation systems in the Chitwan and Makwanpur districts, respectively, have been recorded (Adhikari et al. 2000). In the present context, they include farmer-developed and farmer-managed as well as government-developed and jointly managed irrigation systems. In the case of FMIS, farmers have developed local institutions to enable the collective management of water for agricultural production. Based on water source, landholding pattern, terrain types and management complexities, Narayini Lift (8,600 ha), Khageri (3,900 ha), Pithuwa (1,600 ha) and Rapti-Pratappur (1,005 ha) in the Chitwan district can be considered as large irrigation systems. Each system in the Makwanpur district is smaller than 500 hectares. This indicates that except in a few cases, almost all irrigation systems in the basin are small.

The government's effort in irrigation to improve food security in the country dates back to the early 1950s. The irrigation policy publicized in 1992 emphasized users' participation at all stages of project implementation including decision making and cost- sharing for developing the needed infrastructure. The policy puts forward the vision of implementing joint management for systems larger than 500 hectares in the hills and 2,000 hectares in the plains. Systems smaller than these sizes would be completely turned over to the users.

Access to irrigation. Today, the development of irrigation systems concentrates more in the valleys than in the hills. Rice, being the staple food crop, receives top priority so long as constraints of topography and water acquisition do not exist. District-level information related to irrigated area and access of households to irrigation resources is given in table 10.

Table 10. Access to irrigation by holdings.

	Chitwan	Makwanpur	Combined
Total cultivated area (ha)	42,814	31,547	74,361
Irrigated area (%)	57	18.9	41
No. of total holdings (No.)	53428	48676	102,104
Reporting access of holdings to irrigation (%)	63.6	32.8	49

Source: CBS 1993.

Irrigated area and access to irrigation in Chitwan are much more than in the Makwanpur district. However, aggregation of district data revels that 49 percent of households have access to irrigation and 41 percent of the agricultural area is irrigated.

Water management in irrigation systems. Water User associations (WUAs), formal or informal, are responsible for carrying out operation and maintenance (O&M) activities related to acquisition, control, distribution and use of water for irrigation. Farmers contribute substantial levels of labor resources for repair and maintenance of the systems. With some deviations from one system to another, awareness of a sense of ownership and incentives has been the prime driving force to create institutions, for resource mobilization, record keeping, sanctioning, water fee collection, and account auditing, for achieving distribution and production equity among farmers in the basin.

Crop Production and Cropping Patterns

Cropping patterns. Rice, wheat, maize, mustard, lentil and potato are the major crops grown in the basin. Depending on water availability, terrain types and level of management, these crops are grown in different types of rotations. Table 11 provides all possible combinations of crops in a cropping sequence under three water adequacy regimes. This information is based on the WMSP survey of 88 FMIS from the East Chitwan valley in 1993. Current dominant cropping patterns reported for the Makwanpur district are given in table 12.

Table 11. Cropping sequences.

Perennial Water Source	
Water adequate	Water limited
Spring paddy–Monsoonal paddy–winter maize	Monsoonal paddy–mustard–spring maize
Spring paddy–Monsoonal paddy–winter wheat	Monsoonal paddy–lentil–spring maize
Spring paddy–Mosoon paddy–mustard	Monsoonal paddy–mustard+lentil–spring maize
Spring paddy–Monsoonal paddy–lentil	Monsoonal paddy–mustard+lentil–fallow
Spring paddy–Monsoonal paddy–mustard+lentil	Monsoonal paddy–wheat–fallow
Spring paddy–Monsoonal paddy/lentil	Monsoonal paddy–winter maize–summer maize
	monsoonal paddy–fallow–spring maize
	Monsoonal paddy–potato+wheat/
sConditionSpring maize	
	Monsoonal paddy–fallow–fallow
	Monsoonal paddy/lentil–fallow
Seasonal Water Source	
Water deficit	
Spring paddy and spring maize–Monsoonal paddy–lentil	
Spring paddy and spring maize–Monsoonal paddy–mustard	
Spring paddy and spring maize–Monsoonal paddy–winter maize	
Spring paddy and spring maize–Monsoonal paddy–wheat	
Spring paddy and spring maize–Monsoonal paddy–mustard+lentil	
Spring paddy and spring maize–Monsoonal paddy/lentil	

Table 12. Cropping pattern reported in the Makwanpur district.

Spring paddy–Monsoonal paddy–wheat/maize

Spring paddy–Monsoonal paddy–mustard/lentil/fallow

Spring maize–Monsoonal paddy–wheat/potato/linseed

Spring fallow–Monsoonal paddy–wheat

Spring fallow–Monsoonal paddy–wheat/maize

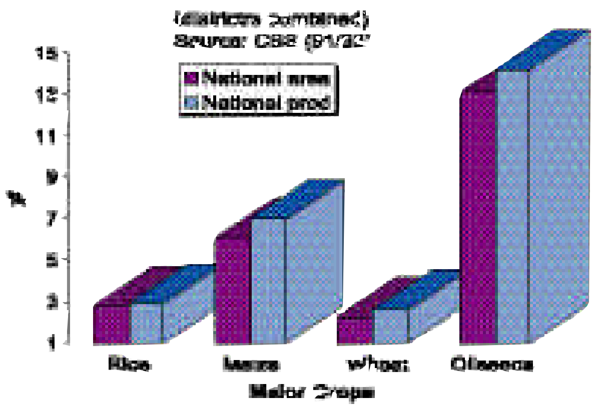
The above cropping patterns suggest that regardless of reliability of water availability in terms of timeliness and the needs of farmers, cropping intensity tends to approach 300 percent. However, the major cropping patterns under adequate, limited and deficit water conditions are spring paddy–monsoonal paddy–mustard; spring paddy and spring maize–monsoonal paddy–mustard; and spring maize–monsoonal paddy–mustard, respectively. The recent Makwanpur survey suggested additional cropping patterns like spring paddy–monsoonal paddy followed by wheat during winter in water adequate systems; and monsoonal paddy–winter wheat/maize/fallow followed by paddy/maize/fallow in water limited and deficit systems or deficit parts within the systems.

Contribution to national agricultural production. Figure 7 reveals that oilseeds contribute the most to the national agricultural production, followed by maize, rice, and wheat. It is interesting to note that the contribution is more in terms of production than in terms of crop area. This does not mean that rice is of lesser value. Crops other than rice are practiced both in uplands and lowlands and contribute to more production. Rice is restricted mostly to wet or irrigated area only.

Performance of Irrigated Agriculture

Overall basin-level performance of irrigation systems. Descriptive statistics of 37 systems were obtained for their overall performance in the basin (table 13). With a mean value of 264 percent, cropping intensity varied from 142 to 300 percent. Yields of spring rice and monsoonal rice varied between 2 t/ha and 5 t/ha. However, mean yield of the spring rice (3.52 t/ha) was slightly more than that of monsoonal rice (3.41 t/ha). Given the same level of water supply and input use, spring rice performs better than monsoonal rice because of cool nights, hot days and low winds favorable for net carbon assimilation during the spring season (Mallik 1981/82). Yield variation and production risk was observed more in winter crops (wheat, lentil and mustard) than in spring and monsoonal crops in the basin.

Figure 7. Contribution to national area and production.



Yield comparison with national average. Out of 37 systems, monsoonal rice yield in 35 systems was found to be above the national average. Because the mean yield of spring rice was higher than monsoonal rice in the basin (table 13), it is obvious that the yield of the former also exceeds the national average. The majority of systems (10 in 13) produced wheat yields above the national average. The opposite was the case with maize yield. In 12 out of 17 systems yields were lower than the national average.

The generally held notion is that maize is sensitive to excess soil wetness and that poor drainage could hamper its yield. However, looking at the data related to the water supply situation in these twelve systems, it was found that many of them fell in the tributary-fed water-deficit category (table 14), which implied a situation where systems had little or no water to irrigate a maize crop during the spring/dry season. This indicates that the cause of lower maize yields, among others, has been shortage of water for irrigation.

Table 13. Descriptive statistics, whole basin.

Indicators	N	Min.	Max.	Mean	Std. Deviation
Cropping intensity (%)	37	142	300	264.05	30.81
Monsoonal rice yield (t/ha)	37	2	5	3.42	0.65
Wheat yield (t/ha)	13	1	6	2.46	1.33
Lentil yield (t/ha)	21	0.1	1	0.5	0.21
Mustard yield (t/ha)	10	0.18	0.85	0.43	0.23
Spring rice yield (t/ha)	23	2	5	3.52	0.85
Spring maize yield (t/ha)	17	0.3	2	1.22	0.55

Mustard and lentil were combined as one category of oilseeds and pulses so as to make their productivity values comparable with national crop categories and values. Yields ranged from 0.2 t/ha to 1.2 t/ha with the majority producing below 1.0 t/ha. The higher proportion of east Rapti river-fed systems contributed to such lower yields. Out of fourteen systems observed, eleven had yields below the national average. This corresponds to the farmers' experiences that oilseed and pulses have been declining over time in this valley probably due to the intensified cropping systems, imbalanced fertilizer use and changed weather conditions.

Table 14. Water availability in selected irrigation systems.

Water availability	Rapti systems	Tributary systems
	(No. of irrigation systems)	
Adequate*	19	0
Limited**	1	17

*As per farmers' need **Below farmers' need

Performance by size of systems and source of water supply. The performance of 37 irrigation systems by their sizes and types of water supply (fed by main river versus tributaries) was assessed in terms of cropping intensity, gross margin, weighted mean of input cost, and gross value of outputs in major crops like rice, wheat, maize and oilseed.

Regression analysis revealed a nonsignificant or weak dependence of stated dependent variables on the variation in service area. However, yields and gross margin of monsoonal rice, as well as impact of level of fertilizer use (weighted mean of N, P and manure) were found significantly higher in systems that took water directly from the east Rapti river than those that took water from tributaries (table 15).

Table 15. Mean comparison of system performance by type of water source.

Indicators	Mean		Mean		Difference	t-statistic
	Off the river	N	Tributary	N		
Monsoonal rice, yield (t/ha)	3.74	20	3.19	17	0.55	2.88*
Gross margin, rice (Rs/ha)	20,123	20	15,181	17	4,942	1.79*
Nitrogen (kg/ha)	56.2	20	38.4	17	17.8	3.59*
Phosphorus (kg/ha)	20.3	20	12.7	15	7.6	2.2*
Animal manure (kg/ha)	1,474	20	1,055	17	419	2.0*
Input cost (NRs)/ha/yr.	17,121	20	14,498	17	2,623	2.39*

N=No. of observations. *=Significant at 0.05 confidence level.

Farm Incomes

Farm income from sources other than crop production was not available. To manage the uncertainty, some indicators of farm income have been used to gain an insight at the basin as well as the household level. First, since farm income has a positive correlation with crop productivity, figure 6 presents a trend between 1980/81 and 1997/98. However, except for rice and maize, the production of wheat and oilseeds has remained stagnant in these basin districts. This indicates that there has not been an appreciable increase in basin-level farm income due to agriculture. The high dependence of farm income on crop productivity is explained by the fact that most people of the basin (75% of the population) are engaged in agriculture and are also supported by off-farm employment.

Second, data analysis from a survey of 814 households in the basin valley representing 37 irrigation systems indicates that there is a strong correlation (r=0.83) between size of landholding and off-farm employment. The reason might be that most of the larger landholders, irrespective of their family size, have a tendency to lease out land to smallholders. By so doing, the larger landholders can look for easy and clean jobs that utilize time saved from leasing out the land. Another underlying reason for leasing out is that under the current status of resources and technology available to the farmers, agriculture (especially raising field crops) does not seem to be a lucrative business. On the other hand, smallholders, who are mostly poor, must dig the soil for a living and also seek wage earnings.

The average number of off-farm employment per household is 4.1. The average family size is 7.4 and the ratio of average family size per household to average off-farm employment per household is approximately 2:1. On the other hand, 75 percent of the household population is composed of small holders (<1 ha) (table 16). By relating the r-value with the percentage of smallholders and percentage of the total population engaged in agriculture, it can be concluded that the major source of household income is through agricultural production. In many households surveyed, it was observed that livestock and poultry have, to a certain extent, contributed to sustain the rural economy. According to a sample survey in irrigation systems with interventions in East Chitwan, the Project Completion Report of ERIP (1998) reported that income from livestock is nearly equal to 18 percent of income from crop sales.

Third, at the individual system or user level, gross margins from different crops grown in the Panchkanya irrigation system, Chitwan were also obtained through field survey by Ghimire et al. (1999). In this survey, data from 27 households surveyed from head, middle and tail reaches of the system were averaged. Margins from rice, maize, oilseeds and wheat were calculated to be NRs 24,695, NRs 5,117, NRs 3,167, and NRs 1,580 per hectare, respectively.

In 72 agency-intervened FMIS from the East Chitwan valley, the Project Completion Report (1998) of the east Rapti Irrigation Project (ERIP) indicated that average annual income per household was NRs 49,272 with a surplus of NRs 15,421. The major sources of income were crop sales (NRs 12,976) followed by off-farm activities (NRs 114,222) and livestock (NRs 2,304) and other sources (NRs 41,181). This computation was based on sample households that represented farmers from the service areas of irrigation systems that were assisted by ERIP for infrastructural improvement. Although the ERIP report does not mention sources of off-farm income activities, our study in the same basin indicated that 33 percent of men and 13 percent

Table 16. Household and land distribution pattern in the basin districts.

Class of Land Size	No. of Households	Households (%)
<1ha[4]	76,938	75
1 to 2ha	18,137	18
>2ha	6,266	6
Landless[5]	763	1
Total	102,104	100

Source: CBS 1991.

[4]Smallholders are those who generally hold less than one hectare of cultivable land. This does not apply to urban areas. But in rural areas like the Chitwan valley, a household made up of a medium-sized family can make just a simple living and support schooling of children by cultivating one or nearly one hectare of land. Without supplemental irrigation these smallholders are always at risk of crop failure from flood, drought or disease, thus contributing to poverty.

[5]Landless households are understood to be those who may own a house, or run a trade or business, but do not possess land for cultivation. This may result either from flood or land fragmentation. Since landholding is related to farm income, holdings that lack other dependable income sources may contribute to poverty.

of women are involved in off-farm activities that include technical/professional, sales, labor, contractors, pension, own bus/truck/tractor, and the services.

Gross margin of paddy crop including its input cost computed for comparing the effect of variation in source of water supply (table 17) should be the most reliable indicator for understanding income from the main crop in the valley, as the data were collected from a large number of households surveyed.

Table 17. Mean comparison of system performance by type of water source.

Indicators	Mean		Mean		Difference	t-stat
	Off the river	N	Tributary	N		
Monsoonal rice, yield (t/ha)	3.74	20	3.19	17	0.55	2.88*
Gross margin, rice (Rs/ha)	20,123	20	15,181	17	4,942	1.79*
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Input cost (NRs/ha/yr.)	17,121	20	14,498	17	2,623	2.39*

N=No. of observations;
*=Significant at 0.05 confidence level

Nonagricultural Use of Water

Domestic and Municipal Supply

This sector uses both surface water and groundwater sources. A groundwater survey indicated that, at different times, the farmers in the ERIP area had, at different times before the ERIP was started, constructed about 400 shallow tube wells or open wells (ERIP 1998). The District Water Supply Office at Bharatpur, Chitwan developed 17 medium-sized and 20 small water supply schemes in the plains and surrounding hills to provide access to safe drinking water for a population of 143,657, corresponding to 40 percent of the district population. Drinking water facilities in the hills are targeted to most of the poverty-stricken communities. However, the current achievement still falls short of the initial agency target of providing clean water to 65 percent of the district population in Chitwan (personal communication with the agency authority). In the case of Makwanpur, there are 71 schemes out of which 21 lie within the basin. Altogether, 43 percent of the district population in Makwanpur now has access to safe drinking water (personal communication with DWSO authority 2000). After the completion of project work, the O&M of some of the schemes have been handed over to the beneficiaries.

Generally, the water supply schemes in Nepal are constructed assuming an effective production period of less than 20 years. A field survey of Pithuwa and Bhandara water supply schemes in Chitwan showed that high cost of repair and maintenance has been a problem for users. Problems included faulty design and inappropriate diversion siting, as well as unauthorized water extraction by a community of migrants for use in kitchen gardens. Usually, the users demand relaxation of water service fee for periods when no water was supplied.

Because of inadequate monitoring and record keeping of water availability, this demand has become unsuccessful. Furthermore, faulty diversion structures, from which a reliable supply cannot be expected, have forced the users to switch to alternative sources, such as dug wells, at their own cost.

With a very few exceptions, no conflicts are found between drinking water supply and irrigation in the basin. One example of conflict was related to drinking water of the Pithuwa Village Development Committee (VDC) and the irrigation water for neighboring Chainpur VDC. Both use the same source of water, the Kair stream. Both want water supply according to their own convenience. Since drinking water is more critical than irrigation and due to high water demand during the daytime, the conflict was resolved by a mutual written agreement whereby Chainpur would divert water only at night for irrigation, so that the high demand for drinking water of the Pithuwa residents is met during the daytime.

Industrial Use

In our industrial survey, we found 71 and 68 industries in the Chitwan and Makwanpur districts, respectively. Most of the industries are relatively more dispersed in Chitwan, whereas they are more clustered in Makwanpur. In Chitwan, groundwater is the sole source of water that is managed and regulated by individual industries. In Makwanpur surface water (Karra stream) is the major source of water, which is supplemented by groundwater during the dry season. The Industrial District is the authority to manage water production and distribution in Makwanpur. The consumption rate of water in the Industrial District has been calculated to be 358,232,149 liters/day. In terms of quantity, it seems that industries have used water that other sectors had used minimally or not used at all. Industrial use of water has not adversely affected the irrigation-water sector or the drinking-water sector. With caution, it can be said that no noticeable water competition prevails in the basin between industrial and other sectors related to quantity, source and allocation of water. Every industry produces some kind of pollution. However, industrial effluents of some of the factories like textiles, leather, soap and cement, and feed industries located in the Hetauda Industrial District (HID) in Makwanpur were reported to have produced high water pollution (NPC and IUCN 1991). Since the east Rapti river flows via Hetauda towards the national park and Chitwan, the effluents of these industries have presumably polluted the river and have posed threats to those using this water downstream.

Environmental Use

Although the Ninth Five-Year Plan (1997–2002) has brought about an Environmental and Resource Conservation Act in Nepal, there is still room to doubt progress in formulating rules and defining accountability of government line agencies in the district to implement this act. This situation can lead district-level agencies to remain ineffective in terms of coordinating and ensuring participation in the management and development of natural resources. However, as encouraged by the act, a large number of local and international NGOs and local youths now appear to have participated in different spheres of environmental development and conservation activities.

Related to environmental water use in the basin, there is a paucity of published government data on the apportionment of total water into different sectoral uses. However, based on the recent water-accounting study, an attempt was made to quantify relative patterns of water uses by various sectors (RTDB/IAAS/IWMI 2000) (figure 8).

Since water keeps moving from one sector to another, any change in its level in one component brings corresponding changes in its amount in other related components. Considering this relationship, all sectors as shown in figure 8 form integral parts of the whole environment of the basin. The figure explains the difference in water use across the sectors as affected by annual variation of water in the basin. It is thus important to understand whether excess use in one component has produced any adverse effects on other, but equally important, sectors of the basin.

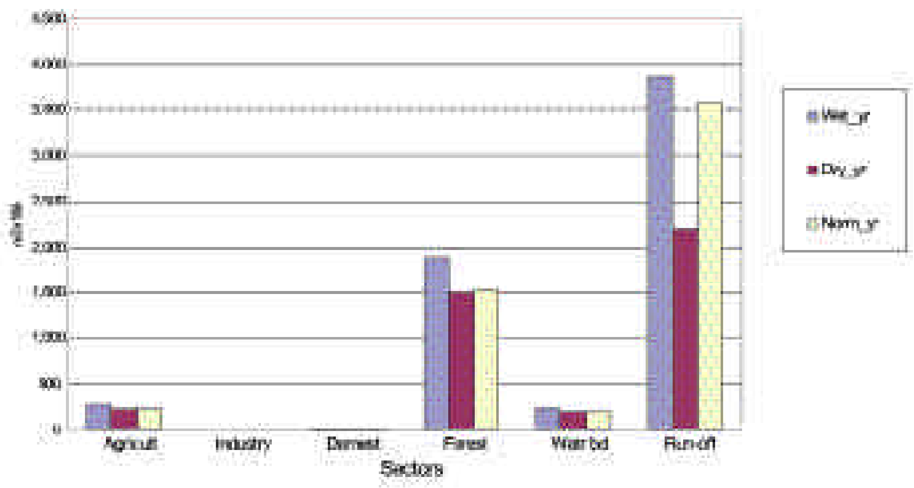
Land and Water Rights: An Overview

Recognized property rights to land and water, and related duties provide definitions as to who may control and use the property. Although patriarchal society, social customs and statutes are the three major factors that largely determine the property rights in Nepal on land and water resources, Pradhan (1989) states that traditionally, property rights had been well defined by social customs or by the community at large, rather than by statutes.

After marriage, women leave their homes to live with their husbands. Parental properties including land are therefore endowed to and shared equally among the male offsprings. However, female offsprings also hold statutory rights on the parental land, provided they remain unmarried and decide to stay single after the age of 35. Parents can also bequeath land to any or all daughters regardless of their marital status, although this practice is not very common. The daughters can acquire all parental property when there are no male siblings in the family. Caste and cultural traditions also affect the pattern of inheritance of property rights.

Water rights are also associated with land rights. In irrigated lands, this means that the right to use water is automatically transferred to the offsprings as landownership is inherited by virtue of statutory law as per the Legal Code of Nepal (1963). This is also the case when land buyers acquire landownership after purchase. A number of traditional water mills, locally

Figure 8. Multi-sectoral water use in the basin.



called *Ghatta,* exist in the upper reaches of some streams. However, water is sent back to the stream after its use by the Ghatta without adversely affecting the canal flow downstream. Because of the prior appropriation rights recognized by the Legal Code, irrigation water users cannot stop water use by the Ghatta. The users of the Ghatta are not required to own land. For purposes of irrigation, the Irrigation and Related Water Resource Act of 1967 recognizes rights of individuals, groups of individuals or the community to divert water from sources like streams, rivers or groundwater in such a way that the extraction does not adversely affect the functioning of government irrigation schemes or hydropower plants. The Water Resource Act of 1992 states that the ownership of all water sources of the kingdom will be vested in the state and people will have use rights so that the resource is utilized for creating national assets and contributes to revenue.

Irrigation being the major domain of beneficial process consumption of water in the basin, it is important to focus more on how property rights in water are practiced. The conventions for property rights in water include both principles by which water is allocated among farmers and the responsibilities that individuals have for maintenance of the system (Martin and Yoder 1988). Depending on the nature of the water source, there can be a series of diversion structures along the course of a given stream or river and irrigation systems with diversions next to each other may have conflicts over water acquisition and distribution. To minimize such conflicts, the Legal Code of Nepal 1963 clearly spells out that the diversion distance between two systems that are located close to one another should be kept at least 100 meters apart. Although local geomorphology controls the drainage behavior of stream flow to a great extent, the intent in the Code is, as far as practicable, to allow the downstream users equal access to water. It is forbidden to construct concrete diversions that can substantially harm the water rights and availability to other systems.

Water rights are also related to tenure. Different kinds of tenure arrangements operate in the basin including owner-operator, sharecropping, mortgage, lease and contract farming. Sharecropping is a quite common practice after owner-operators. All operators possess water rights as they are required to contribute resources in terms of kind, cash or labor for the acquisition, production, distribution and the use of water resources for irrigation. In the absence of male members, women can also represent the household in WUAs or assembly and related decision-making processes as de facto members (Ghimire et al. 2000).

Stakeholder Perceptions of Water Resource Development and Management in the Basin

Perceptions of Water Scarcity

The water accounting study indicates that the east Rapti river is an open basin as it drains a significant amount of the utilizable water flow (47%) out of the basin annually. On the other hand, out of the remaining 53 percent of depleted water only 6 percent is used for beneficial process consumption within the basin. A complementary study using a Key Informant Survey indicates that even in an open basin there exists great variation in the availability of agricultural water and dry-season scarcity because of diverse topography and highly skewed seasonality in the rainfall pattern. Significant spatio-temporal variations in water availability are forcing some areas to look for alternative cropping patterns (see under subhead Crop Production and Cropping Patterns). Although rice has low water-use efficiency, irrespective of water adequacy it is cultivated as the main crop in large tracts of the basin for a variety of reasons. The main reasons are that it is considered as a staple and traditionally superior food crop. It fetches a good price and stores well. Also, rice straw serves as excellent animal fodder throughout the year. That is why everyone, including poor people, grows rice even under rain-fed conditions.

Despite many irrigation infrastructures, lack of dependable water sources and unreliable supply have, in many cases, resulted in failure of maize crops, particularly in dry areas during the spring season. However, due to low evapotranspiration requirements, winter crops, such as wheat, mustard, lentil and potato, grow fairly successfully even with a few light winter showers. As farmers put in substantial collective efforts to manage water for all possible crops in all seasons, they have experienced more water deficit in winter and spring season, particularly in dry areas that have no access to river water.

The drinking water sector appears to be relatively better served irrespective of location and season. Almost every household in the plains owns a low-cost open or dug well or a hand pump. For dry areas with deep water tables, there are community water supply schemes in place. The government agency for drinking water, and NGOs have made more efforts to build community water supply schemes in the hills, especially for poverty-stricken areas. The industrial sector uses a minimal amount of water as evidenced by figure 8 and no noticeable deficit or scarcity of water was observed in any industry during the survey. This sector is also not found to have any water competition with other sectors except in matters related to localized pollution by a few industries.

Perceptions of Issues on Water Quality

The basin receives water intercepted and conserved by the surrounding hills and mountains, whose ecosystem is dominated by forests (>60% basin area). Irrigators have considered such water as clear, and a boon for crop production due to its fertile nature. They also tap flash floods to feed into canals. Although flood events have become more destructive in the east Rapti river, one biologist at the Mahendra Trust for Nature Conservation, Sauraha, Chitwan emphasized the need for floods that sweep away old vegetation including grasses and allow growth of new vegetation necessary for wildlife. Government line agencies for water supply in both basin districts have considered water from the hills and mountains to be safe for drinking.

However, water-polluting industries such as textiles and leather, despite their wastewater treatment plants, were found to have polluted the river water upstream. Although the toxic effects were reported to be more of a confined and localized phenomenon, it seems logical to foresee that industrial effluents (toxic substances and heavy metals) might have affected the aquatic creatures downstream. So long as there is no monitoring of water pollution levels in the river it will be hard to know the magnitude of their effects on different flora and fauna. However, considering the high price of chemical fertilizers, the wastewater sludge if managed properly, could be an attractive supplement to the animal manure currently in use (MoFA et al. 1996).

Perception of Water-Related Conflicts and Conflict Resolution

In Nepal, people hold legitimate rights to develop, manage and use water for productive purposes. Those who invest in a water resource can stake a claim to it. For irrigation, the users' collective decisions and actions define incentives in proportion to the level of contribution to irrigation development. Individuals in a group reach a set of agreements, forming working rules that define what is required, forbidden or permitted, and monitor closely what has been done. The rules are season- and location-specific as the canal flow changes temporally and spatially. Conflicts arise if rules are somehow altered or violated, which in turn may limit or expand one's claim. Intersystem conflicts are mainly attributed to the use of common sources, whereas intra-system conflicts mainly come from methods of water distribution, often during dry season or low-flow periods. External factors like high floods, associated with catchment degradation due to encroachment upstream, damage diversion structures, resulting in high repair and maintenance costs. While none of the users want to lose their claim on water, conflicts arise due to those who have sometimes not participated in, or paid cash or contributed the required labor for repair works. Floods that change stream courses have been a potential cause of conflicts. In some cases, intervention by an external agency has displaced the old structures and obstructed water distribution patterns among users. Although settled by the users themselves, more conflicts do occur due to competition for water in water-deficit areas.

Depending upon the nature and severity of conflict, a range of mechanisms is used to resolve conflicts. These include both formal and informal mechanisms. Many cases are resolved by simple informal negotiations or arbitration, while some have gone as far as hearings by the Supreme Court. Although informal mechanisms are most common, users approach legal and quasi-legal institutions when informal mechanisms fail to resolve conflicts adequately (Shukla et al. 1996). Different water rotation schedules, monitoring, and graduated sanction systems are used to minimize conflicts within the system.

No major conflicts are found between sectors in terms of quantity of water used in the basin, except between hotels in the National Park, Sauraha, Chitwan and between irrigation systems with diversions upstream of the Park. Hotel authorities claim that these systems divert substantial amounts of river water, hindering rafting and boating for tourists during the dry season. The irrigators' grievance is that they find their temporary diversions dismantled by hotel workers at night. Both parties fight for their own interests. The concern of the farmers is for their survival, as they have no alternate sources of irrigation in the area, whereas it is a matter of making business more profitable for the hotel people in the park. Obviously, the conflict is due to the absence of appropriate institutions to resolve such multi-sectoral water uses. It seems that existing use patterns of river water by the National Park and irrigators downstream, and the disposal of industrial effluents in the river upstream need to be assessed for appropriate mechanisms agreeable to all water use sectors in the region.

Perceptions of Current Institutional Arrangements for Water Allocation

Farmers themselves manage all irrigation systems except the Narayani Lift and Khageri irrigation systems, which are jointly managed by the government and users associations. Most of the irrigation systems acquire water from a series of head-works along the same streams. An arrangement for water allocation between these systems is based primarily on mutual consensus among upstream and downstream users when water becomes limiting, especially during the dry seasons. The tradition is that the downstream users approach the upstream users through functionaries to make an informal request for sharing water. Also, there are irrigation systems among which a formal legal right of access to water is also found. In some others, water is allocated proportionately into a number of shares depending upon the labor contribution and farm-size to be irrigated. Contributions in terms of kind, cash, or labor are made to maintain the common intake and keep the canal structures functioning. All users must own or lease land for cultivation. Those individuals who demand more water for irrigating additional land areas are required to make proportionate contributions.

In the case of intra-system water allocation, boundary rules are used to define who the users are and who are not. Each farmer within the rule is allocated water, based on his or her labor contribution to O&M of the system. Stringent rules are implemented during water-deficit periods to ensure equity in allocation. Systems switch from continuous to rotational patterns of water distribution as canal supplies decrease. In most systems, opportunistic user behaviors such as shirking and water pilferage are controlled by rules for graduated sanctions.

One embankment (18-km long) and a number of spurs were built along the river course for flood protection in the downstream area. But no storage facility that can control or distribute the flow from the river to other places or sectors has been developed. No explicit allocation of uncontrolled river water is found among various sectors. As mentioned earlier, conflicts between tourism and irrigation sectors indicated that although the national government assigns high priority to tourism and national parks, exclusion of irrigation water use from the river appears impossible unless options are developed acceptable to both sectors. This raises the issue of little or no water allocation between sectors or protection of riparian property rights for water use.

The HID, located in the upstream area, supplies water to all industries except one. Using an intake channel, they extract water from both Karra stream and a well. Hetauda Textiles has its own well and only a minor part of the consumption is supplied by the HID. Water allocation and supply within industries are demand-based and does not seem to be a problem since revenue is collected from the use of power. At present, the wastewater from all industries is discharged practically untreated and eventually ends up in the river. Although textile factories drain wastewater at night, river water is still very polluted where it is used for various domestic purposes. This raises an issue of water quality in the river due to poor wastewater management.

Institutional Structure

Kinds and Levels of Institutions Involved

The Ministry of Water Resources (MoWR), Water Resources Development Council (WRDC) and National Planning Commission (NPC) are at the national policy level. The District Water Resources Committee (DWRC), District Irrigation Office, Irrigation and River Control Committee (IRCC), District Water Supply Office, and District Branches of National Irrigation Water User Federation (NIWUF) are at the district level; Municipalities, Village Development Committees (VDCs), resource users, both individuals and WUAs, industries as well as the Buffer Zone Development Council, National Park, and tourism are at the local level. Together, these are the principal actors related to development, management and utilization of the water resources in the basin districts.

Role of the Government Agencies

MoWR, WRDC, NPC and DWRC are the main agencies for overall interagency water resources coordination. The DWRC, as seen today, provides legitimate status to water users by registering users groups, based on a recommendation by the VDC on whether the acquisition and use of water from a given source would create disputes with other user groups in the area. Such a licensing process gives the user groups water use rights. The National Code of Conduct (1963) has also legally recognized customary water-use rights. More recently, the Irrigation and River Control Committees (IRCCs) have been formed with the responsibility of taking preventive measures and protecting irrigation infrastructure against landslides and floods. The IRCCs of related districts can hold joint meetings if the problem is large and the river is designated as part of more than one district. The IRCCs also have to maintain coordination between irrigation- and agriculture-sector programs of the District Agricultural Development Office. The Chief District Officer is the chairperson of both the DWRC and the IRCC, while the Local Development Officer, a government nominee, and the Chief of the District Irrigation Office serve each as member secretary in the DWRC and IRCC, respectively.

The Water Resource Act of 1993 has set sectoral priorities for water use, in which drinking and domestic use receive top priority followed by irrigation, hydropower, industrial, navigational, recreational and other uses. Conflicts are resolved based on the importance and priorities stated above when multi-sectoral claimants are involved in water use for different purposes. However, conflicts between new versus old users for any specific purpose are resolved based, primarily, on customary rights. Within the irrigation sector, water users usually seek conflict resolution first by informal negotiations and arbitration. The VDC intervenes only when the contenders seek solution from a government-authorized agency at the village level. There have been a few cases in which the side that lost the case in the VDC has filed a petition with the Chief District Office and the District Courts to seek a favorable verdict. In some other instances, the Supreme Court has also intervened in the cases when the losing side appealed after being defeated in the Appellate Court.

As guided by the Irrigation Master Plan of 1988 and the revised water resource policy of 1997, the Department of Irrigation has so far been directing its investment mainly a) to turn over of its small irrigation projects to WUAs, b) to assist FMIS with irrigation management, and c) to irrigation management programs and some rehabilitation work on its large Terai projects. However, the newly emerged National Water Resource Strategy Formulation (WRSF 2000) of HMGN recommends that related policy and implementing government agencies be prepared for their new roles. According to WRSF recommendations, the government should move, among other things, towards necessary basin-wide interventions including flow-regulating reservoirs, interbasin transfers and demand-side management for sustainable development of water resources. It should consider river basins as a fundamental planning unit and adopt water balance simulation models through basin-wide database development and analysis, for appropriate decision making for the proper utilization of water resources in the future (WRSF 2000).

Institutional Constraints

So far, all the planning and implementation exercises have been carried out on a project basis. No formal institutions exist to manage the water resources from the basin perspective. This has led to an uncoordinated and unbalanced growth of the water sector with the existing institutional structure. Despite the legal provisions, the national government seems weak to translate many of its policies into effective implementation. The concept of long-term basin water resources policy and regulations is not clearly spelled out for integrated development and management of the water resources that includes the involvement of all stakeholders.

While informal WUAs are required to register their associations mainly for external assistance, formalization of WUAs has not been tailored to provide support services. There is also a need to empower the WUAs so that viable local institutions are recognized and organizations assume legal authority, for example to sue a person for damages, for compensation or for resolving a conflict. In this line, unstable government policy, poor administration, inability to enforce rules as in the case of managing industrial effluents and contradictory Acts for sharing water with the multiple water users have been constraints. In the case of the irrigation sector, the users have not been able to realize the expected benefits as envisaged by the new working policy on the development and management of participatory irrigation.

Conclusions

A large number of organizations and levels are involved in the water sector in the basin. Although the resources are part of two districts, at present, none of the agencies are responsible for the basin-level work. However, concurrence of both districts and related offices is crucial for any policy, program and implementation, and stakeholder inclusion for development activities of the basin water resources. Therefore, it seems logical to seek a mechanism, for example a Basin Water Office or an authority that could facilitate coordination across sectors, districts and levels.

While it is an “open basin,” perceptions differ as spatio-temporal variation of water availability is a common phenomenon that significantly affects the agricultural productivity, as illustrated by comparing performances of river-fed and tributary-fed irrigation systems. FMIS have strong local institutions in place but for various reasons, infrastructural performance for effective water delivery is far below designed capacity. Learning from the past agency interventions, many of which ended up with perverse incentives, future assistance should focus on implementing a fully participatory approach (farmers as principal actors). It should work towards a policy of developing scarce zones so that more attention is paid to improve access to water resources in dry areas. Equally important is to increase outreach research for water productivity.

Forests act as a major source of rural livelihoods in the country and in the basin. There is an increasing trend towards private forests at the cost of national forests. The Decentralization Act, new forestry legislation (1983) and the 25-Year Forestry Master Plan (1986) provided legal foundation for handover of government forests to user groups. Despite the willingness of the users, community forestry programs in these districts have not progressed as expected. In principle, reinforcing community forestry would lead to forest conservation that, in turn, would help sustain water sources for drinking water, irrigation as well as to reduce downstream flooding.

Protection of wild life and environmental conservation of the National Park, a World Heritage Site in the downstream area, require safe and adequate water to be maintained in the river around the year. Low dry-season runoff combined with the conflicting interests between irrigators and tourism in the Park has affected both. While both stake claims over use of the river, an identification of water users and provision of alternative sources of irrigation water through subsidized shallow tube wells appear imperative to reduce farmers' dependence on river water. Although against the country's 20-year Agricultural Perspective Plan, the government has stopped subsidizing shallow tube wells from 2000 onwards. From our extensive field observations, we now know that farmers have privately made many dug-wells and shallow tube wells as a means to deal with dry spells. The water accounting study of the basin identifies great prospects for exploiting shallow aquifers for irrigation without adversely affecting the nonrenewable aquifers. The question then turns to learn why shallow tube wells/dug-wells are proliferating at private individual scale and why the government efforts have failed.

While increasing population will put more pressure on river water in the foreseeable future, it appears inevitable to review, establish and implement appropriate policy and programs related to issues on water rights and somehow develop mechanisms for allocating reasonable shares of flow to various sectors. In terms of pollution, Makwanpur and Chitwan are among the industrial hot-spot districts. Keeping in view the adverse impact on river ecosystems, as well as on the National Park and people downstream, monitoring and low-cost pollution control programs must be promoted. The government should establish pollution-control standards, provide industries with necessary support for technical assistance, training and subsidies, and encourage farmers to use treated sludge as manure. Through legal provisions, the government should demonstrate its capacity to convince and force industries to show their willingness to get involved in pollution prevention and control mechanisms. This would lead to far-reaching implications for conserving biodiversity, environmentally sustainable development and aiding the disadvantaged who make a living from traditional fishing, such as the Bote and Kumale communities.

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