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# Living with Water Stress in the Hills of the Koshi Basin, Nepal

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# Living with Water Stress in the Hills of the Koshi Basin, Nepal

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## Introduction

Situated in Nepal's eastern Ganges region, the Koshi basin is one of three snowfed watersheds in the country. Altogether, the Koshi river draines 71,500 km$^2$ in Tibet, Nepal, and north Bihar. Along its course, the river is known for floods, extremely high sediment loads, and capricious behaviour. Its major tributaries drain the east of Nepal, particularly the Koshi basin, which lies east of Gosainsthan (north of Kathmandu) and west of Kangchenjunga.

The Koshi river has drawn the attention of scientific, engineering, and political leaders for decades. During the colonial era, the British rulers of India were concerned about the floods and high sediment load of the river and they aimed to control flooding in the Koshi delta in Bihar. However, they were not particularly concerned about drought or water shortages and showed little interest in such events in the mountainous region of the Koshi catchment. Their only interest in the Nepali hills generally, or the Koshi basin hills in particular, lay in the fact that the region provided young men to fight on behalf of the British Empire. The fact that the hardships of daily life and the impacts of natural hazards – cloudbursts, landslides, flash floods, and droughts – forced able-bodied men to leave their homes in search of a livelihood elsewhere received little recognition.

This historical push factor has changed little. Even today, seasonal migration is one of many strategies Nepali hill people use to cope with the impacts of the natural hazards. They also pursue other strategies, such as changing land uses and livelihood diversification. In fact, for centuries Himalayan herders and farmers have adjusted to environmental uncertainties in order to survive. There is little understanding of exactly how hill people have and continue to adapt because they pursue adaptive strategies in isolation so little effort has been made to study them systematically. At the same time, little is known about the impact of the changing climatic context on the meteorology and hydrology of the Koshi basin region.

In Nepali, Koshi means 'river' and its seven tributaries – the Sun Koshi, Indrawati, Dudh, Tama, Likhu, Arun, and Tamor – give it the name Sapta Koshi or 'seven-rivers'. The three largest tributaries, the Sun, Arun, and Tamor, join at Tribeni, where the Sapta Koshi turns south and flows through the Barahkshetra gorge for about 15 km before reaching Chatara in the Terai. Downstream of Chatara, the Trijuga **river** drains the southern Mahabharata range in Nepal, flowing from west to east into the Koshi **river**. After flowing through the lowland Terai region of Nepal enclosed in embankments, the river flows over the Koshi barrage and enters North Bihar of India (Figure 1).

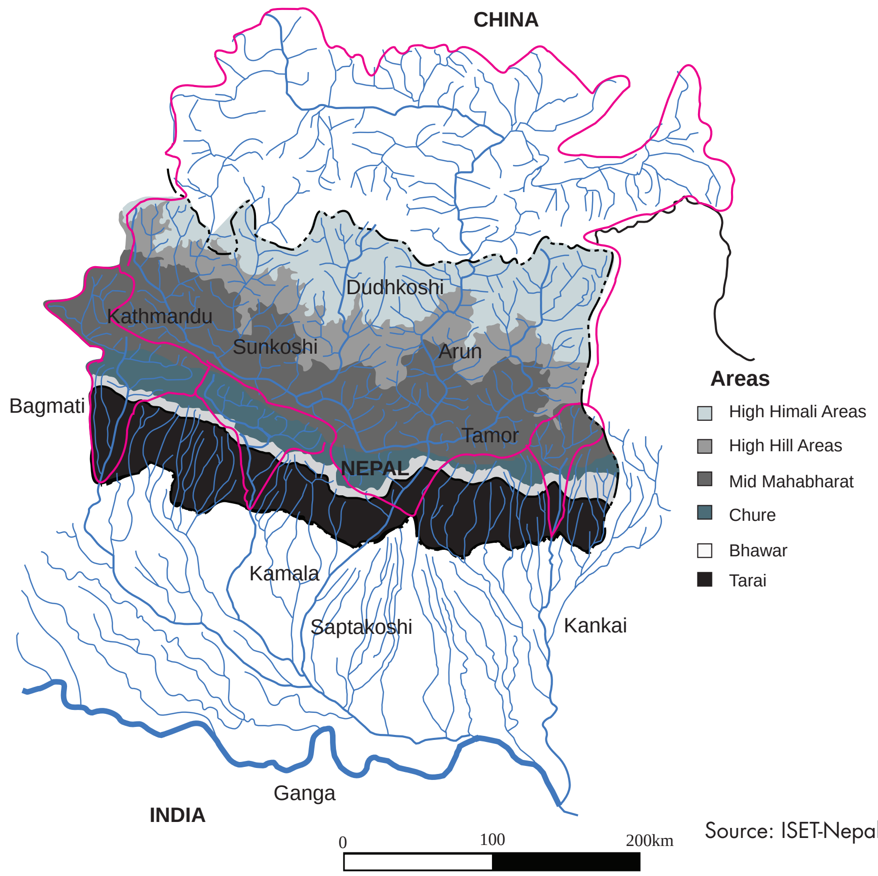
The Koshi basin region encompasses the eastern highland and lowland system of the Ganges river. It bears the impacts of a rapidly changing ecosystem and livelihood processes. A recent study (DST 2008) suggests that in the coming decades, two interacting forces will influence ecosystem services and their role as a foundation for livelihood systems in regions, like the Koshi basin, in developing countries: intensifying processes of technological and economic globalisation, which simultaneously increase pressures on ecosystems and shift patterns of dependency on ecosystems from local to global levels; and environmental degradation at all levels, from local to global, including the impacts of climate change.

These two forces will undermine the capacity of intertwined ecological and social systems to provide the services necessary for achieving human wellbeing. The study of these currently poorly understood forces and their implications for vulnerable populations is essential because only policies informed by ground realities can help lead to appropriate actions.

Climate change is of particular relevance to policymaking because the inexorable rise in the average global temperature is expected to change the hydrological cycle, a consequence that will have multiple impacts on natural resources. These changes will alter the magnitude, timing, and intensity of a region's prevailing precipitation (whether snow or rainfall) and affect evaporation.

In particular, wet seasons in Nepal in general and the Koshi basin in particular are likely to be wetter. Dry seasons are apt to be drier. The extremes will accentuate differences between high and low water flow regimes. The likelihood of descending groundwater levels and drought during the dry season will increase. Similarly, life-threatening flash floods and inundation in the rainy season will be more probable.

Figure 1: **Koshi Basin in Tibet (China), Nepal, and Bihar (India)**




Source: ISET-Nepal

As the globe continues to warm, more water-induced disasters can be expected especially in the Himalayan region, where very little is understood about how global warming will affect the climate and hydrological processes. Global warming is already affecting snow distribution and glacier mass balance in the Himalaya ranges. The consequences of this change for the millions of people who live in the Ganges Basin may be serious.

For Nepal, the normal hydrological system brings an average annual precipitation of 1,600 mm (Alford 1992). About 80% of this falls between June and September, during the monsoon season. Within the monsoon itself, the total amount of rain comes within just 20% of its duration and exhibits considerable macro-, meso-, and micro-scale variations.

The periodicity of and variations in rainfall are especially marked in the Koshi basin. However, this localised and concentrated deluge recharges water sources, including groundwater, and provides water for ecological, environmental, and economic purposes. At the same time, excess water in the monsoon causes landslides and floods, which take lives and damage property. In contrast, during the long dry season, women must travel greater distances to collect water for domestic use, so the added workload limits the time they have to engage in enterprises that are more productive. Crop production also declines and cattle yield less milk because they have less fodder to feed. These vulnerabilities of the population in the Koshi basin region are typical of Nepal.

A summary of the findings of a recent study on the climate change scenario in Nepal (NCVST 2009) makes those vulnerabilities clear.

- Global Circulation Model (GCM) projections indicate that the average temperature increase in Nepal by the 2030s will range from 0.5 to 2.0°C with a multi-model mean of 1.4°C. By the 2090s, the increase will be from 3.0 to 6.3°C, with a multi-model mean of 4.7°C. The differences between the eastern, central, and western regions are expected to be minimal.
- The models suggest that the number of extremely hot days (those as hot as the hottest 5% of days in the period 1970-1999) is likely to increase by up to 55% by the 2060s, and by up to 70% by the 2090s.
- GCM outputs suggest that extremely hot nights (the hottest 5% of nights in the period 1970-1999) are projected to increase by up to 77% by the 2060s and 93% by the 2090s.
- GCMs project a wide range of precipitation changes, especially during the monsoon: precipitation could range from 14% less to 40% more by the 2030s and from 52% less to 135% more by the 2090s.

This study does not specifically explore the above or any other impacts of human-induced climate change; instead, it attempts to understand the strategies that communities in selected locations of the Koshi basin have used to adapt to the stresses imposed by climatic hazards. These stresses are described generally as 'too much water' and 'too little water'.

The study's findings are expected to provide insight into the strategies that people adopt to cope with water excesses and water shortages so that the strategies can be woven into national policies designed to enable people to respond to stresses successfully. Exploring the interrelationship between the approaches of households and those of the national government provides an appropriate way forward to devising approaches useful for policymaking in a future that is becoming ever more uncertain by human-induced climate change. This linkage will be revisited at the end of this report.

## Research approach and methods

The study team conducted research in selected locations in the hills of Koshi basin with the aim of identifying the strategies that populations adopt in order to address the challenges they face. The team's initial step was to prepare an information matrix (Table 1) to link our conceptual framework to the array of tasks to be conducted and the information to be solicited for analysis. The matrix helped clarify the approach by indicating linkages between the answers being sought and the information available.

In addition, the central questions indicated in the matrix linked water stresses with local adaptation strategies. After reviewing the literature and identifying gaps, we conducted field investigations designed to fill those gaps. The fieldwork included interviews and shared learning dialogues with community members. It was explicitly mandated that the study team not influence respondents by using the phrase 'climate change'.

Table 1: **Approach, survey tools, and information matrix**

| Task or Activity | Details |
|---|---|
| Literature review | Existing reports, studies, and evaluations were collected, examined, and analysed in order to identify gaps in knowledge that the team could fill by conducting a well-designed field investigation. |
| Household survey | Households were surveyed to collect quantitative information on adaptation strategies. |
| Focus group discussions | Qualitative information was collected by holding discussions with focus groups that involved gender, caste, and ethnic categories. |
| Key informant survey | Information regarding agriculture, the utilisation of natural resources, constraints facing farmers, changes in weather and rainfall patterns and other observations was collected from key informants who represented gender, caste, and ethnic categories. |
| Case studies | Stories about particular individuals with significance as case studies were recorded in as much detail as possible. The case study and documentary film in Panchkhal aimed to understand and show the dynamics and impacts of drought in the midhills. |
| Field visits | Field visits were to Sankhuwasabha, Dhankuta, Sunsari, and Panchkhal in Kavrepalanchowk District. Two visits were made to Sunsari to understand the flood situation, damage to roads, and rescue and relief operations. The objective of including these two sites was to use events in these sites as case studies to understand better the potential impact of climate change. Although not a climate related disaster, the 2008 flood shows what a future major disaster could be like. |

## Fieldwork and data collection

The study team used the following survey tools to examine both the impacts of water stresses and hazards on local livelihoods and the local responses to stresses and hazards.

**Field visits:** Between August 2008 and February 2009, the study team visited four sites for a week each. In a second round of field visits from 18 April to 3 May 2009, we visited all six sites. During the field visits, the following survey tools were used.

**Data collection:** The team used both secondary sources and participatory rapid assessment (PRA) tools to ascertain the knowledge, attitudes, perceptions, and practices of the various stakeholders in the study areas. These included a number of issues including poverty, on- and off-farm economic activities and incomes, dependence on incomes generated from water resources, constraints posed by water stresses and their impact on livelihoods, and ongoing community development activities.

**Household survey:** Sample households were selected to represent those vulnerable to water shortages, landslides, and floods. The team conducted a questionnaire with the heads of 61 households (47 men and 14 women) in the six villages. The respondents ranged in age from 22 to 70, but the majority were 46 to 61. They represented so-called 'high' caste (Brahmin and Chhetri) households, ethnic (Janajati) families, and so-called 'untouchable' (Dalit) households.

**Focus group discussions (FGD):** Qualitative information was collected during 12 FGDs, two were held in each of the six villages of the two districts. The specific groups invited to participate were farmers, teachers, traders, students, entrepreneurs, women, disadvantaged groups, and political workers.

## Study sites

Given the large size and great diversity of the Koshi basin, the selection of study sites posed a challenge. Since the purpose of the study was to identify responses to too much water and to too little water, rainfall extremes were one obvious criterion. Using annual rainfall records as an indicator, the team first selected the three districts of Sankhuwasabha, Dhankuta, and Kabhrepalanchok, which respectively receive high (more than 5,000 mm), moderate (about 2,000 mm) and low (about 1,000 mm) rainfall (the location of the study districts is shown in Figure 2).

As a contiguous corridor, Sankhuwasabha and Dhankuta encompass Nepal's High Himalaya, High Mountain, and Middle Mountain physiographic regions. These districts have a great diversity of topography, slope, aspect, climate, vegetation, demography, and socio-cultural systems (Table 2).

Figure 2: **Trends in total rainfall amount over the last 30 years in part of the Koshi basin.**


Source: ISET-Nepal

Table 2: **Road physical features of the Sankhuwasabha-Dhankuta corridor**

| Region | Geology | Elevation | Climate | Soil | Rainfall intensity | Moisture regime |
|---|---|---|---|---|---|---|
| Middle mountains | Phyllite, quartzite limestone, and islands of granites | 800 to 2400 m<br>Hills 1500 m with isolated peaks reaching 2700 m | Subtropical, warm temperate (but tropical in lower river valleys and cool temperate on high ridges) | Ustochrepts, Haplustalf, Rbodustalfs, Haplumbrepts, Ustorthents, and Ustifluvents | Medium | Humid; per-humid above 2000 m |
| High mountains | Gneiss, quartzite, and mica schists | 1000 to 4000 m<br>High relief 3000 m from valley floor to ridges | Warm to cool temperate; alpine | Eutrochrepts, Dystrochrepts, Cryumbrepts, Cryorthents, and Ustorthents | Low | Sub-humid to per-humid |
| High Himalaya | Gneiss, schist, limestone and Tethys Sea sediments | 2000 to 5000 m with peaks >8500 m | Alpine to arctic (snow 6-12 months) | Cryumbrepts, Cryorthents and rock | Low | Semi-arid to alpine |

Within the Sankhuwasabha-Dhankuta corridor, the team selected six villages (Table 3) that experience either very high or very low rainfall for detailed field investigations. The selection was based on informal discussions with villagers and government officials and on initial observations of the rainfall system. The four villages in Dhankuta are close to rural roads, but the two in Sankhuwasabha are not.

The team also did preliminary examinations of the impacts of floods and drought in Sunsari and Kabhrepalanchok districts. It studied the inundation in Sunsari caused by the breaching of the Koshi river embankment at Kushaha in 2008 as a case study to examine adaptive strategies to too much water on the plains. Our field study was supported by references to secondary information, which enabled the team to assess the damage and rescue and relief operation and to draw broad lessons.

In Kabhrepalanchok, the team used secondary literature and field visits to examine the impact of drought in Panchkhal valley (Box 1), a small valley east of Kathmandu, which began supplying vegetables to the city in the 1990s. A watershed management programme has been implemented in a portion of the valley for over a decade.

## Data analysis

The team compiled and analysed field data was to examine the linkages between the water situation and livelihoods and to ascertain how communities have been coping with or adapting to the hydrological extremes of too much and too little water. Some of the information was compared with secondary information to check for any discrepancies. It was not possible to crosscheck information in all the cases, due to the high degree of local variation and scarcity of data. For instance, informants testify and oral history documents that both mountain valleys and the Terai experience periodic floods,

Table 3: **Study districts, VDCs, and villages**

| District | VDC | Households | Population | Villages |
|---|---|---|---|---|
| Dhankuta | Bhedetar | 539 | 2,753 | Namje |
| | Danda Bazaar | 621 | 2,977 | Danda Bazaar, Dhoje |
| | Maunabudhuk | 507 | 2,585 | Maunabudhuk |
| | Rajarani | 496 | 2,811 | Rajarani |
| Sankhuwasabha | Madi Rambeni | 1,148 | 6,040 | Madi Okherbote |
| | Tamaphok | 1,425 | 7,069 | Mudhe |

Source: Field Survey

Box 1: **Panchkhal valley**

Panchkhal, a mid hill valley in the Jhiku Khola watershed, ranges in elevation from 750 to 2100 masl. The valley is situated in Kabhrepalanchok District of central Nepal about 40 km east of Kathmandu. The Arniko Highway that connects the capital with Tibet runs through the valley. Panchkhal has a monsoon climate with a dry season from October to May. There are 11,872 people living in Panchkhal VDC, the majority of whom are Bahun, Newar, Dalit, Tamang, and Chhetri (CBS 2001).

The main subsistence activity of the people in Panchkhal is agriculture and animal husbandry. The agricultural history of the valley has some interesting changes from sugarcane production to rice and vegetables. At present, many households engage in vegetable cultivation, as it does not require as much water as sugarcane. They sell the vegetables grown here in Dhulikhel, the nearby tourist city, and in Kathmandu.

Although the valley's soil is fertile, it is becoming increasingly difficult for farmers to cultivate vegetables due to lack of water for irrigation. They are using electric water pumps in excavated trenches as a coping strategy during periods of drought. The impact of the drought became quite serious in the summer of 2009.

Due to its prime location on the route to Tibet, there are plans to develop Panchkhal as a major commercial hub with assistance from the Chinese government. This may further stress water availability in the valley.

landslides are frequent and life threatening in the hills, and droughts are regular and recurrent. However, there is not enough data at the local level to establish trends related to these phenomena.

Similar gaps exist in district-level data: many locations do not have data on topics such as hydrology, river discharge, changes in forest cover, and insect pests in forests. The information available is often inconsistent; for instance, forest cover is reported to have increased remarkably in some places and not at all in others. Although reports on disputes over water resources in the plains is available (Pun 2004), there are almost none on disputes in the hills and mountains, where shortages are most acute and conflicts most likely occur (IDA 2005).

Similarly, with food sufficiency in particular, district-level data does not provide a real picture of this essential household-level characteristic. With improvements in lifestyle and income levels, Nepali villages have started to import more foodstuff than they export, but we do not know the exact nature of these exchanges. This shift in the economy has changed people's dependencies on ecosystem services, but information about the nature of such changes is not available.

The limited coverage of even the available data was a major obstacle. While information on hydrology and water sources does exist, it is available only for those few locations where measurements are taken. It does not give an adequate portrait of the entire watershed. District-level data distorts the true picture because the districts themselves are heterogeneous. For example, data on river flow, forest cover, migration, and passport issuance is available only for the district level. It is impossible to use this data to draw conclusions about water scarcity, food production, or migration trends in the study villages.

The micro-climatic effects of rainfall are particularly hard to assess because a district trend does not represent all the variations to be found in a district's various biophysical settings. Another example of a distortion is reports on the number of infestations of insects and pests. While it is true that a particular insect often thrives at a given elevation, soaring insect populations may not for instance be prevalent in humid river valleys at the same elevation as a forest. Table 4 outlines the geographic level of coverage of the secondary sources of information the team consulted.

Table 4: **Type of information in the literature examined**

| Information coverage | Geographic coverage | | | | | |
|---|---|---|---|---|---|---|
| | National | Regional | District | Ward | Specific Area | Points of Specific Interest |
| Land use | | ■ | | | | |
| Forest | | | ■ | | | |
| Agriculture | | | ■ | | | |
| Livestock | | | ■ | | | |
| Economic | | | ■ | | | |
| Population | | | | ■ | | |
| Political | | ■ | | | | |
| Climate | | ■ | | | | |
| Rainfall trend | | ■ | | | | |
| Temperature trend | | ■ | | | | |
| Parks and reserves | ■ | | | | | |
| Hydrology | | ■ | | | | |
| Rainfall | | | | | | ■ |
| Temperature | | | | | | ■ |
| Insect in forests | | | | | ■ | |
| Management practice | | | | | ■ | |
| Flood disaster | | | | | ■ | |
| Land slides | | | | | ■ | |
| Laws and rules | ■ | | | | | |
| Treaties | ■ | | | | | |

## Context of the Koshi basin

### Geographic characteristics of the Koshi Basin

The catchment area of the Koshi basin ranges in altitude from 65 metres above sea level in the Terai to over 8,000 metres in the high Himalaya. In a direct line, the basin is about 160 kilometres from north to south and covers six geological and climatic belts. Within the Koshi catchment lie eight peaks over 8,000 metres high, including Mount Everest, 36 glaciers, and 296 glacial lakes (Bajracharya et al. 2007). Studies show that 16 of these glacial lakes pose a threat of a glacial lake outburst flood (Mool et al. 2001).

The landscape of the Koshi catchment is the result of the uplift of the Himalaya and the pre-existing river systems (Zollinger 1979). Before the Himalayan range emerged, the Sun Koshi, Arun, and Tamor rivers flowed into the prehistoric Tethys Sea. As the Himalaya were pushed up about 70 million years ago, the rivers rapidly cut narrow valleys as the range lifted. The result is that Nepal's rivers, like the Arun and Tamor, flow in deep gorges between high peaks such as Kanchenjunga (8,586 m) and Sagarmatha (8,848 m). The Arun gorge is about 4,000 m deep and the Tamor is 2,000 m deep.

### Climate and precipitation

The basin's climate ranges from tropical in the Terai and low river valleys to arctic on mountain peaks, and passing through warm temperate, cool temperate and alpine conditions as elevation increases. In narrow valleys with steep slopes, the influence of aspect on microclimate conditions yields a vast diversity of vegetation. As is the case on all mountain ranges, radiation on the north-facing slopes is diffuse compared to that on south-facing slopes; as a result, the humidity on north-facing slopes is relatively higher for a longer time after the monsoon ends than on south-facing slopes. Due to the combination of radiation effects and altitude, two areas in close proximity might have very different moisture regimes that can also vary significantly from year to year.

The differences are starker in the low-rainfall areas of Dhankuta than they are in Sankhuwasabha. For example, tea gardens flourish on northern slopes but their productivity on drier southern slopes is much less. Valleys and deep gullies are characterised by humid and wet micro-climates and perennial water sources.

Rainfall is intense during the monsoon, which lasts from June to September. The orographic effect causes large local variations even within a single valley (Figure 3a, b, c). In the hills, sudden cloudbursts are common and can generate almost 500 millimetres of rainfall in a single day. However, in the rain-shadow regions of the Tibetan plateau, the conditions are dry and desert-like. The Koshi river has seasonal variations in flow and sediment charge. Often these changes are sudden and great; the river can rise 7 to 10 metres in 24 hours. In the smaller tributaries of the Koshi, the impact of flooding is localised, but can become widespread when there is greater volume, extent, and/or duration of rainfall.

The combination of upstream rainfall and river characteristics governs the behaviour of the Sapta Koshi river on the plains. During the monsoon, the Koshi river transports about 120 million cubic metres of sediment. The annual deposition of this sediment has caused the river to shift its course about 115 kilometres to the west in the last 200 years.

The inhabitants of the six study villages suggest that rainfall has become more erratic and uncertain in the last two decades. The study team examined 30-year rainfall records from 30 meteorological stations within the Koshi basin. It found precipitation is increasing in some stations and decreasing in others (Table 5). Only a few stations show no changes.

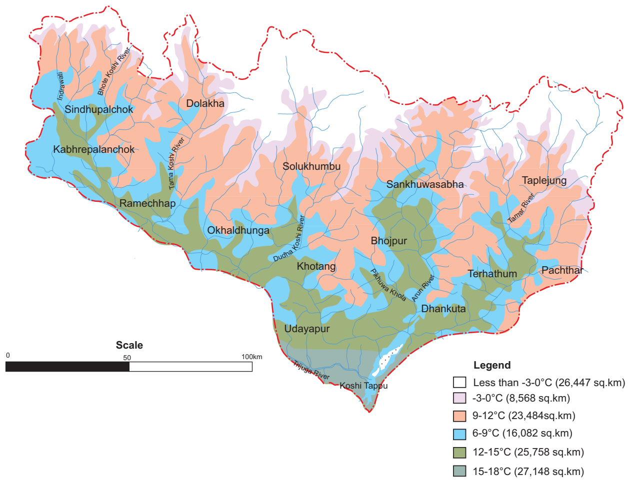
While the trends are in accord with the observations of the locals, a much more detailed and controlled examination of rainfall is necessary before valid conclusions can be drawn. The limited number of rainfall stations would be a challenge in reaching valid conclusions. Accurately defining meteorological and hydrological processes would also have limitations (Dixit and Moench 2006).

Table 5 summarises the precipitation trend for each station observed. Among the stations that have recorded increasing precipitation Num of Sankhuwasabha district received 31% more rainfall than the 30-year normal and Jiri of Dolakha district received 14% more. Tribeni of Dhankuta District has received 10% more precipitation while Terhathum, Dovan, Mane Bhanjyang, and Ramechhap received just slightly more precipitation: 7%, 6%, 4%, and 2% respectively. Rainfall has declined with the other stations, which lie along the valleys of the Tamor and the upper Arun rivers (Table 5 and Figure 2).

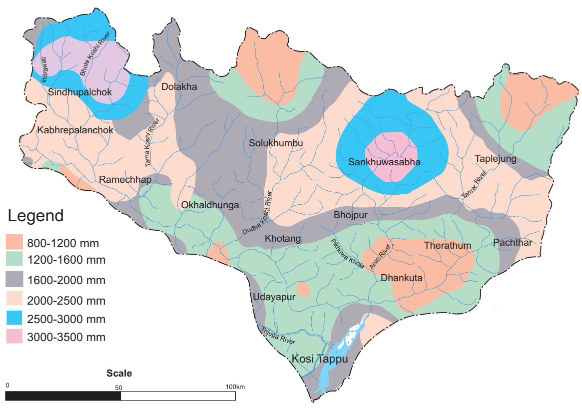
Figure 3: **Rainfall variation in Koshi basin**

Like the rest of Nepal, the Koshi basin experiences macro, meso, and micro variations. The Koshi River can respond rapidly to widespread rain in the catchment with flooding, as happened in 1954 and 1968 when it had its second highest and highest discharges. In 1954, the flood peak was 24,241 $m^3/s$ and in 1968, 25,879 $m^3/s$ (GoI 1981). The high sediment load of the river has mostly natural origins in the large glaciated areas and natural mass movements.

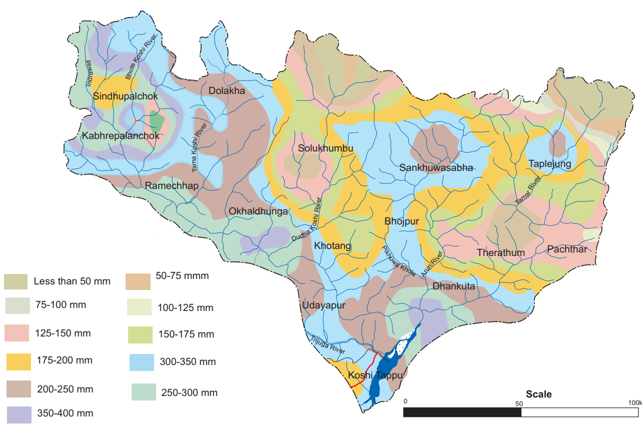
**a) Mean annual rainfall**




**b) Monsoon precipitation**




**c) Highest 24 hour rainfall events**




Adapted from ICIMOD (1996a)

Table 5: **Rainfall trends in selected districts of the Koshi basin**

| Station index | Station | Trend | DHM index | Station | Trend |
|---|---|---|---|---|---|
| 1,115 | Nepalthok | ↔ | 1,106 | Ramechhap | ↔ |
| 1,321 | Tumlingtar | ↔ | 1,226 | Barmajhiya | ↔ |
| 1,405 | Taplejung | ↑ | 1,301 | Num | ↑ |
| 1,308 | Mul Ghat | ↑ | 1,314 | Terhathum | ↑ |
| 1,103 | Jiri | ↑ | 1,207 | Mane Bhanjyang | ↑ |
| 1,309 | Tribeni | ↑ | 1,404 | Lungthung | ↑ |
| 1,307 | Dhankuta | ↑ | 1,303 | Chainpur | ↑ |
| 1,420 | Dovan | ↑ | 1,419 | Phidim | ↑ |
| 1,104 | Melung | ↓ | 1,324 | Bhojpur | ↓ |
| 1,304 | Pakhribas | ↓ | 1,317 | Chepuwa | ↓ |
| 1,203 | Udayapur Garhi | ↓ | 1,016 | Sarmathang | ↓ |
| 1,202 | Chaurikhark | ↓ | 1,316 | Chatara | ↓ |
| 1,219 | Salleri | ↓ | 1,325 | Dingla | ↓ |
| 1,305 | Leguwaghat | ↓ | 1,322 | Machuwaghat | ↓ |
| 1,306 | Munga | ↓ | 1,036 | Panchkhal | ↓ |

Note: (↔) = no significant change, (↑) = increasing, (↓) = decreasing.
Source: DHM (2000)

Madi Mulkharka and Madi Rambeni of Sankhuwasabha and Basantapur of Terhathum receive higher rainfall in comparison to other parts of the country. Local people say that the precipitation trends are changing in both intensity and frequency. Both existing records and local perceptions show that the timing and amount of precipitation has become more erratic and does not indicate a pattern. This broadly concurs with the lessons from NCVST (2009).

Demography: Eighteen of Nepal's districts lie in the Koshi catchment. According to the 2001 census, the basin was home to a population of 5,081,463 (21.94% of Nepal's total) living in 962,695 households. Sunsari had the highest population density (498 persons/sq.km) while Taplejung had the lowest (37 persons/sq.km). The study districts of Sankhuwasabha and Dhankuta had population densities of 46 and 187 persons/sq.km respectively. The average household size of all 18 districts in the Koshi basin is 5.3 members, which is slightly less than the national average of 5.44. The average population density of the basin, at 176 persons/sq.km, is higher than the national average of 157 persons/sq.km.

Energy usage: Firewood is the major source of cooking fuel in the basin as about 73% of households depend on it. The second most common source of cooking fuel is animal dung, which 13% of households use. Fossil fuels are used only by a few; 9% rely on kerosene and 3% on liquid petroleum gas. Biogas usage is rare as just 1% use it. The remaining 1% of the population uses other sources. For illumination, the majority (67%) rely on kerosene and 31% have electricity. A few households (2%) depend on other sources of energy, such as biogas, wood, or candles to light their homes.

Drinking water and sanitation: About 47% of the households in the Koshi basin have access to piped water for drinking, while 35% rely on tube well water. Another 10% use wells and 6% depend on spout water. About 1.5% drink river or stream water and 0.5% rely on other sources, such as water holes. Overall, about 91% use improved sources, which include piped, tube well, and well water.

Sanitation facilities are poorly developed. About 54% of households have no toilets at all. Of those who do have toilets, nearly 32% have pit latrines and 14%, all of whom live in urban areas, have modern flush toilets. The use of flush toilets increases the amount of water used for sanitary purposes and creates sewage that must be treated before being disposed. The use of modern toilets increases water stress levels by creating an additional pressure on existing water sources for water and by requiring new institutions and infrastructures to treat wastewater.

Literacy: The total literacy rate in the Koshi basin is about 60%. As is true elsewhere in the country, the gender gap is marked: 65% of the literate are male and about 65% of women are illiterate. About 10% have not attended any school at all, 43% have received primary education, and 19% have completed lower secondary education. Just 4% have completed higher secondary school and only 2% have completed bachelor's level education or beyond.

**Employment:** A large number of people (71%) within the basin are employed in agriculture. Wholesale and retail trade and business provide employment to about 8% and 7% are employed in manufacturing and recycling. The construction and education sectors each employ 2%. The services – including transport, public service, social security, health, finance, real estate, and others – collectively employ about 10%. Tourism employs less than 1% of the population even though it is regarded as being essential to the economic development of the country. Out of the 67% of the population who are economically active, men are 36% and women are 31%, although there are more women than men.

## The study villages

The area of Sankhuwasabha is almost four times larger than that of Dhankuta, but because of its harsher climate and more difficult terrain, the populations and numbers of households in the two districts are almost the same (Table 6). From 1991 to 2001, the population growth rates in Sankhuwasabha and Dhankuta at 1.26% and 1.29% respectively, were considerably less than the national average of 2.25%. These figures suggest that the rate of out-migration from the hills was high even then, but there is no data to confirm this postulation.

According to the 2001 census, 72% of the population of Dhankuta and 78% of that of Sankhuwasabha are engaged in agriculture. The adult literacy rate in Dhankuta is 59% and in Sankhuwasabha is 48% – almost at par with the national average of 48.6%. Female adult literacy rates are 46% in Dhankuta and 37% in Sankhuwasabha; both figures are higher than the national average of 34.9%. Both districts have a mix of ethnic groups and castes (Table 7), including Rai, Chhetri, Newar, Limbu, Dalit, Tamang, Brahmin, Magar, Yakkha, and Sherpa groups.

The average family size of the households studied was 6.08 – slightly higher than the national average of 5.44. Although sizes ranged from three to 17, about 66% had four to six members and 18% had eight to 10. Only 8% had very large families with 11 to 17 members. In order to accommodate the growth in population, settlements have spread to the less desirable and drier ridge areas like Danda and Mudhe bazaars over the last 50 years. While there were only 10 households in Danda Bazaar 50 years ago, there are now more than 125. In Mudhe Bazaar, the number of households increased from 12 to 200 in the last 25 years.

Table 6: **Number of households, population by gender, and population density**

| District | Population | | | | No. of households | Average household size (no.) | Area (sq. km) | Population density (per/sq.km) |
|---|---|---|---|---|---|---|---|---|
| | Total | Male | Female | Per cent of total Nepal | | | | |
| Taplejung | 134,698 | 66,205 | 68,492 | 0.58 | 24,764 | 5.44 | 3,646 | 37 |
| Sankhuwasabha | 159,203 | 77,853 | 81,350 | 0.69 | 30,766 | 5.17 | 3,480 | 46 |
| Panchthar | 202,056 | 99,042 | 103,014 | 0.87 | 37,260 | 5.42 | 1,241 | 163 |
| Dhankuta | 166,479 | 81,841 | 84,638 | 0.72 | 32,571 | 5.11 | 891 | 187 |
| Terhathum | 113,111 | 54,932 | 58,179 | 0.49 | 20,682 | 5.47 | 679 | 167 |
| Bhojpur | 203,018 | 97,762 | 105,256 | 0.88 | 39,481 | 5.14 | 1,507 | 135 |
| Okhaldhunga | 156,702 | 75,361 | 81,341 | 0.68 | 30,121 | 5.20 | 1,074 | 146 |
| Khotang | 231,385 | 112,821 | 118,564 | 1.0 | 42,866 | 5.40 | 1,591 | 145 |
| Udayapur | 287,689 | 143,756 | 143,933 | 0.24 | 51,603 | 5.58 | 2,063 | 139 |
| Morang | 843,220 | 422,895 | 420,325 | 0.64 | 167,875 | 5.02 | 1,855 | 455 |
| Sunsari | 625,633 | 315,530 | 310,103 | 0.7 | 120,295 | 5.20 | 1,257 | 498 |
| Saptari | 570,282 | 291,409 | 278,873 | 0.46 | 101,141 | 5.64 | 1,363 | 418 |
| Dolakha | 204,229 | 99,963 | 104,266 | 0.88 | 43,165 | 4.73 | 2,191 | 93 |
| Sindhupalchok | 305,857 | 115,012 | 153,845 | 0.32 | 60,452 | 5.06 | 2,542 | 120 |
| Sindhuli | 279,821 | 139,280 | 140,541 | 1.21 | 48,758 | 5.74 | 2,491 | 112 |
| Ramechhap | 212,408 | 100,583 | 111,555 | 0.92 | 40,368 | 5.26 | 1,546 | 137 |
| Kavre | 385,672 | 188,947 | 196,725 | 1.67 | 70,509 | 5.47 | 1,396 | 276 |
| **Basin total** | **5,081,463** | **2,520,462** | **2,561,001** | **0.95** | **962,695** | **5.30** | **30,813** | **165** |
| Nepal | 23,151,423 | 11,563,921 | 11,587,502 | 100 | 4,253,220 | 5.44 | 147,181 | 157 |

Source: CBS (2002)

Table 7: **Caste/ethnic group composition in per cent**

| Sankhuwasabha | | Dhankuta | National |
|---|---|---|---|
| Chhetri | 19.4 | 20.4 | 15.80 |
| Bahun | 6.6 | 6.4 | 12.74 |
| Magar | 3.2 | 9.7 | 7.14 |
| Tamang | 9.5 | 6.0 | 5.64 |
| Newar | 5.1 | 4.7 | 5.48 |
| Rai | 22.4 | 23.0 | 2.79 |
| Yakkha | 4.4 | 3.0 | 0.06 |
| Limbu | 4.8 | 13.7 | 1.47 |
| Gurung | 5.8 | 1.2 | 2.39 |
| Others | 18.9 | 12.0 | |
| | 100.0 | 100.0 | |

Source: CBS (2002)

Table 8: **Land use**

| Land use | Dhankuta | | Sankhuwasabha | |
|---|---|---|---|---|
| | Area (ha) | Per cent | Area (ha) | Per cent |
| Cultivated land | 46,816 | 52.0 | 49,468 | 14.3 |
| Forest | 36,383 | 40.4 | 180,581 | 52.2 |
| Grazing land | 4,067 | 4.5 | 39,256 | 11.4 |
| Other | 2,754 | 3.1 | 76,424 | 22.1 |
| Total | 90,020 | 100 | 345,729 | 100 |

Source: LRMP (1984)

Land use: Agriculture is the dominant economic activity in the study villages and contributes about 52% to the GDP of the study districts (Table 8, calculated by Rural Self Reliance Development Programme for the Eastern Economic Region including the Koshi basin). A greater proportion of land in Dhankuta is cultivated (52%) than in Sankhuwasabha (14%), which has significantly higher proportions of forest, pasture, and shrub land than Dhankuta. The dominant vegetation in the middle mountains is pine forest with mixed hardwood and oak species. In the high mountains, fir, pine, birch, and rhododendron species prevail; the vegetated areas of the high Himal are covered mostly by meadows and tundra-type grassland.

Economy: Dhankuta and Sankhuwasabha together have 1.41% of Nepal's total population and contribute 1.26% of its GDP. Rice, wheat, maize, millet, and barley are the major cereal crops. Oilseed, potato, and sugarcane are traditionally the main cash crops. Ginger, vegetables, and fruits are the main high-value crops. Other cash crops are cardamom in Sankhuwasabha and tea, on a small scale, in Dhankuta.

Landholding: The average landholding sizes in Dhankuta and Sankhuwasabha, 1.02 and 0.87 hectares respectively, are higher than the national average of 0.8 hectares.

Irrigation: Irrigated land is about 47% of the agricultural land in the mountain district of Sankhuwasabha and 28% in the hill district of Dhankuta (Table 9). While farmers in Sunsari rely heavily on traditional tube wells, those in Dhankuta and Sankhuwasabha rely on ponds for the limited irrigation they practice. Only 7% of the total land cultivated is irrigated in the study districts, where rain-fed agriculture prevails. Only about 28% of the land in Dhankuta even has water available for irrigation.

Crops: Early rice and maize is grown widely in the study area, but the reliability of these crops is increasingly irregular due to the scant supply of pre-monsoon rainfall. This has called into question the sustainability of this choice of crop. Many farmers also grow cash crops and vegetables but only on a very small area, due to water shortages during their growing seasons. Cereals, leguminous crops, and oilseeds are the three predominant crops by area (Tables 10 and 11).

## Current livelihoods and vulnerability

All the respondents interviewed have multiple sources of income. Altogether 83% said that agriculture is one source; 49% said it is the primary source; 18% said it is the secondary source; and 16% that it is a tertiary source of income. Farmers produce cereals, vegetables, and fruit. Teaching is a major source of income for about 14% of those interviewed, while 11% rely on business and other secondary sources. Studies and industry each engage 3% of the respondents.

The two-thirds of the population who rely on agriculture as their primary or secondary source of income are affected directly by water stresses. Although farmers are less able to find alternative sources of income than are people who earn a living from trade, business, or teaching, 16% of farmers have alternative sources. A family's response to water or other stress is determined, among other things, by its sources of income and its access to various services and institutions.

Livestock is an important source of income in our survey areas. Only a one family reported that livestock is its main source of income. For 28% it is a secondary source of income, and, for 23%, a tertiary. About 75% of those who earn income from livestock do so from raising goats and buffaloes for meat, while nearly 54% earn from dairy and poultry farming.

There are a significant number of wage earners. About 20% earn wages within the district, 5% earn outside the district, and another 21% have a wage earner outside of Nepal (Tables 12 and 13). About 15% rely in part on a pension – 10% from the British or Indian army and 5% from the Government of Nepal.

Small business and trade, including the running of local teashops and general stores, provides income to about 47% of households. Three families (5%) report that trade and business is their major source of income. Some families are engaged in services, teaching, or cottage industries. A few families sell firewood as their source of livelihood.

## Patterns of change

According to CBS (2001), the area under rice cultivation in Nepal's high mountains has been increasing since 2001 and its yield has been increasing in regions across the country. The area under maize production has been stable since 2001. While yields of maize in the high mountains have increased, they have decreased in Dhankuta.

Table 9: **Irrigation sources**

| District | Irrigated land of total agriculture land (%) | Land irrigated by sources (%) | | | | |
|---|---|---|---|---|---|---|
| | | Tube well | Perennial | Seasonal | Pond/well | Other |
| Dhankuta | 28 | 0.7 | 45 | 49 | 0.7 | 2.8 |
| Sankhuwasabha | 47 | 0.3 | 15 | 74 | 2.6 | 6.5 |

Table 10: **Major cereal crops grown in the two districts studied in the Koshi basin**

| District | Early paddy | | Main paddy | | Spring/winter maize | | Wheat | | Summer maize | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. of holdings | Area (ha) | No. of holdings | Area (ha) | No. of holdings | Area (ha) | No. of holdings | Area (ha) | No. of holdings | Area (ha) |
| Dhankuta | 3,284 | 1,175 | 11,732 | 6,191 | 4,605 | 1,754 | 5,384 | 1,389 | 26,376 | 13,956 |
| Sankhuwasabha | 4,280 | 1,678 | 18,592 | 12,221 | 1,372 | 378 | 8,230 | 1,458 | 25,037 | 9,138 |

Table 11: **Other crops including cash crops**

| District | Cereal grains | | Leguminous grains | | Tubers and bulb crops | | Cash crops | | Oil seeds | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. of holdings | Area (ha) | No. of holdings | Area (ha) | No. of holdings | Area (ha) | No. of holdings | Area (ha) | No. of holdings | Area (ha) |
| Dhankuta | 27,409 | 31,216 | 11,241 | 2,422 | 9,362 | 1,337 | 440 | 38 | 7,568 | 1,498 |
| Sankhuwasabha | 27,896 | 30,808 | 4,793 | 501 | 8,742 | 962 | 297 | 44 | 4,148 | 567 |

Table 12: **Income source ranking**

**Respondents ranking income (in per cent)**

| Agriculture | | | Livestock | | | Wages | | | Pension | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I | II | III | I | II | III | I | II | III | I | II | III |
| 49.2 | 18 | 16.4 | 1.6 | 27.9 | 23 | 6.6 | 9.8 | 13.1 | 6.6 | 4.9 | 1.6 |
| | Total | 86.9 | | Total | 26.2 | | Total | 37.7 | | Total | 13.1 |

Table 13: **Income from farms and wages**

**Respondents income earning sources (in per cent)**

| Agriculture | | Livestock | | | Wages | | | Pension | |
|---|---|---|---|---|---|---|---|---|---|
| Cereal | Veg/fruit | Meat | Milk | Poultry | Inside district | Outside district | Foreign | Govt | Brit/Ind Army |
| 82 | 82 | 75.4 | 54.1 | 54.1 | 19.7 | 4.9 | 21.3 | 4.9 | 9.8 |

In the high mountains, the populations of cattle and buffalo have remained stable since 1996 whereas the number of goats has increased. In Dhankuta, the trend is the opposite: since 2002, the number of goats has dropped while the numbers of cattle and buffalo have increased slightly.

### The broader context

The six study villages represent three major agro-climatic regions, social and ethnic diversity, and economies and levels of development characteristic of the Koshi basin and other regions of Nepal. The problems these villages have in managing water are similar to those reported by other residents across the Koshi basin and in other parts of Nepal.

Thus, this study and the issues it identifies have nation-wide relevance. For example, the cause of the 2008 flooding in Sunsari District, the breach of the Koshi embankment, was the result of institutional failure, not the changing climate. However, other districts of the Terai – where flood disasters are common and significantly add to population's vulnerability – can learn from its lessons (Box 2). A recent study that analysed Nepal's vulnerability to climate change came to similar conclusions (NCVST 2009).

Climate variability has also been noted in the Narayani basin from Mustang in the north to Bhairahawa in the south. A recent study suggests that the pattern of rainfall has changed in the last decade. For instance, half of Syangja District receives more rainfall than it did in the past (DST 2009). The similarity between the Syangja findings and those of this study speak to the need for the government to take action to reduce the impacts of water stresses and extreme events, as also expressed in NCVST (2009).

## Impacts of and responses to water stress and hazards

### Historical experiences and responses to water stresses and hazards

In all six study sites, the villagers said that climate has been variable for decades, recalling several droughts and floods that had severe impacts (Box 3). Generally, villagers mentioned that in more recent years, the number of days without rainfall has increased and that situation of drought has become more regular than in the past, but systematic records at the village level is not available. In a recent study, villagers of Koshi basin region also mentioned increasing instances of erratic rainfall, drying of springs, and that drought period is increasing (NCVST 2009).

Following each crop-destroying disaster, the people of all six villages borrowed from local moneylenders so they could seek temporary work as migrant wage labourers in locales more fortunate than their own. Being able to borrow money from local moneylenders does provide a safety net during hard times, but one with a very high price tag. Today migrants still borrow in order to migrate, but they no longer have to rely on the local lenders or pay exorbitant rates of interest. Those households that do not depend on farming are less affected immediately by droughts, hailstorms, and downpours.

Perception of vulnerability and risk: People used to feel that they were at the mercy of nature and that farming was a gamble. When disasters or blights destroyed crops, people had to find other ways to survive, often drawing upon social networks. Many took menial jobs outside the village. In fact, migration from the hills began as early as the late 19th century and has continued since then.

Many people of the hills saw moving home as a desirable way of coping with the risks associated with unreliable harvests. When opportunities to settle the Terai plains arose after malaria in the region was eradicated in the 1950s, people migrated south to settle permanently in the Terai. This southward trend still prevails, and the decision is still closely associated with the uncertainties and difficulties associated with farming in the hills. In fact, one study suggests that almost half of all male hill migrants to the western Terai cited the decline in agriculture as the main reason for their moving (NWCF 2008).

Besides permanent migration from the hills to the Terai, respondents described historical and ongoing circular migration. During the agricultural slack season from November to February, seasonal migrants moved to wherever they found wage labour, often urban centres and construction areas. If they succeeded in landing a relatively permanent job, they visited their families and villages once every two to three years; if not, they returned within a few months. Unlike permanent hill migrants who stay in Nepal, some circular migrants went abroad. In recent years, circular migration from the hills is on the rise.

Box 2: **The breach of the Koshi embankment on August 18, 2008**

On August 18, 2008, a flood control embankment along the Koshi river in the Nepal Terai was breached. The failure occurred when flow in the river was below the long-term average flow for the month of August. Over the following weeks, a disaster slowly unfolded as the Koshi river began flowing along one of its old courses east of its present one.

In one year, the Koshi river transfers an estimated 120 million $m^3$ of sediment derived from landslides and mass wasting to the Ganges. Much of the sediment is deposited in a huge fan where the river exits from the mountains to the plains. This exceptionally high load of sediment is brought down to Chatara in the Terai and is dumped on the riverbed as the river slope levels off.

Over time, as its main channel has aggraded, the Koshi had naturally shifted its course. In the preceding 220 years, the river had oscillated over a stretch of 115 kilometres. In 1959, this natural process was interrupted when the river was jacketed between two embankments following an agreement between the governments of Nepal and India that had taken place in 1954.

Following completion of the Koshi barrage in 1964, the river gradient changed and sediment deposition in the river section upstream of the barrage increased rapidly. Over time, this raised the bed level of the river above the surrounding land, a factor that contributed to the breach of August 18, 2008. When that occurred, the main river discharge began flowing along a course that had been blocked by the eastern embankment.

Instead of permanently protecting the surrounding area from floods, the embankments had changed the morphology of the river, raising the jacketed channel above the level of the surrounding land. This is one of several factors that led to the breach. Other factors included poor maintenance and institutional corruption and dysfunction in the aftermath of the Nepal-India treaty on the river. The resulting flood caused widespread inundation and concomitant adverse effects on social and economic systems depending on the river.

Once the embankments were completed in 1959, the area to the east of the river was largely protected from major flooding and in the subsequent four decades roads, irrigation channels, railways and other features were constructed. These developments blocked the natural drainage and divided the region into a series of enclosed basins.

When the Koshi embankment breached, the waters no longer flowed in one or a few clearly defined channels, but instead spread out across a width of 30-40 km seeking the path of least resistance and filling the enclosed basins, low-lying lands and ponds. Vast flooded area low points were scoured and transformed into new main channels for the river. Sand and sediment were deposited across fields and in irrigation channels, drainage ditches, and other structures. In addition, approximately 50,000 people in Nepal and more than three million in India were displaced and many lives were lost.

Breaches are an inherent risk of any flood-control embankment but even more so in a river such as the Koshi where the riverbed aggrades rapidly because of the high sediment load. Topographic maps indicate that the riverbed within the embankment is now about 4 m higher than the adjoining land. In other words, the elevation of the bed has increased approximately 1 m per decade since the embankments were put in place.

The August breach was the eighth major one since the embankment was constructed. No matter how well embankments are maintained, whether the breach occurs during a high flow or, as in this case, a normal one, breaches are inevitable. Furthermore, when such breaches occur it is next to impossible to return the river permanently to a bed that is, in many cases, well above the adjacent land without substantial input of resources and technology.

An embankment can provide relatively high levels of flood protection immediately following construction but its ability to protect declines at rates that depend primarily on sedimentation and, to a lesser extent, on how well it is constructed and maintained. Unless some way of addressing the massive amount of sediment deposition can be

Cont...

found, the river channel will breach and new channels will be established across lands that have been settled for decades. According to Dixit (2009), the breach of the embankment and the flood disaster was the outcome of

- inappropriate technology in a sediment charged river,
- reliance on a structural solution (embankments) that promoted a false sense of security,
- she lack of a warning mechanism and no preparedness,
- poor management of infrastructure (embankments),
- poor capacity to respond to the humanitarian crisis,
- institutional dysfunction and governance deficit,
- the trans-boundary dimension of the river and Nepal-India Treaty, and
- the political transition in Nepal.

What are the costs of this breach? The true costs may never be known. The most evident costs include the loss of land, assets, and livelihoods. They also include losses associated with current and future agricultural production and in local ecosystems. In addition, the social cost associated with disruption of over three million people in one of the most politically unstable areas of India must be recognised.

Some families may never be able to live on their land now that it has been submerged by the Koshi. Bihar is one of the poorest and least developed regions of India and is a focal point for insurgent activities. The loss of lives, livelihoods and, in many ways, hope for the future among its population may well exacerbate existing frustration and conflict, generating costs that spread across much of South Asian society, not just India. A systematic cost-benefit analysis that includes the potential for massive disruptions such as the one of August 2008 might assist in identifying strategies with lower levels of inherent risk.

Adapted from Moench (2008)

**Box 3: Historical water stresses and hazards in one village**

In Maunabudhuk in 1956, the monsoon rains came only in August, after maize and other crops had died. The village experienced more droughts in 1961 and 1977. In 1969, the opposite extreme devastated the village: it rained continually for three successive days. The resultant flooding swept away crops and severely damaged trails. In 1978, an earthquake was followed by a heavy downpour that inflicted widespread damage to cropland and natural springs.

The people of Maunabudhuk also remember many hailstorm events. In 1969, a particularly heavy hailstorm annihilated the maize crop and damaged others. Another storm in 1974 damaged the entire rice crop during the harvest season; only those lucky enough to have planted early varieties or to have harvested a little early were spared. In 2004, there was another major hailstorm.

## Current experiences and perceptions of water stresses and hazards

The study did not reveal any findings in particular about people's current vulnerability to water, as opposed to other stresses. As described above, people have always regarded life in the mountains and hills as a challenge and water is just one of many complications.

Although all six study villages experience persistent water scarcity in the post-monsoon season, the exact nature of the problems is specific to each location. Danda Bazaar and Maunabudhuk have been hit hardest by drinking water and irrigation problems. For example, in Danda Bazaar, the number of houses has risen from 12 to 300. Many of these new residences are along ridges, where, due to the geography, there is less water in the first place.

Another reason given by farmers for water shortages is the loss of traditional ponds due to neglect, encroachment, or changes in land use. A few mentioned that some natural springs had been damaged by recent road construction, which, they noted, increases the general trend of changing land use because it opens up the possibility of settling in new areas. Twenty-five respondents (40%) reported that water sources are being damaged by road and other construction works that obstruct natural springs on slopes. Traditional ponds have deteriorated as canal irrigation has grown more popular. The loss of ponds was mentioned by nine respondents in Danda Bazaar and by between four and eight respondents in the three other VDCs in Dhankuta. No one in Sankhuwasabha mentioned that the loss of ponds was a problem.

Perceptions of water shortages: Although about a third of the respondents have not yet felt any effect on any of their water needs, 24% said that the shortage of water has severely affected their drinking water needs. People living in the foothills of Dhankuta and in high-rainfall areas in Sankhuwasabha are among those not at all or only slightly affected by water shortages.

Most people in Dhankuta District, and everyone in Danda Bazaar and Maunabudhuk, believe that there is less water available than there used to be. Although they all linked the shortage to less rainfall, they understand that other factors have a role, like the growing population.

Perceptions about the effects of water shortage on livelihoods vary by gender. Men tend to be more alarmist; women are more optimistic (Table 14). Half the women surveyed classified the problem as 'somewhat affecting' and only 14% said it was 'very serious'. Meanwhile, 28% of men said it was 'very serious' and only 26% said 'somewhat affecting'. For men, the main concern was poor irrigation; for women, it was sanitation. Responses to the impact of water stresses on agriculture vary considerably: some define the problem as 'severe'; others say 'moderate' or 'no problem'. The variations may correspond with where they live with respect to water sources, the type of soil and topography of their land, and the crops they grow.

Table 14: **Gender and perception of the degree of effect**

| Sector | Degree of effect (per cent of respondents rounded) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Not so big | | Some | | Moderate | | Big | | Severe | |
| | Men | Women | Men | Women | Men | Women | Men | Women | Men | Women |
| Drinking water | 32 | 29 | 26 | 50 | 4 | 7 | 6 | 0 | 28 | 14 |
| Irrigation | 23 | 36 | 17 | 14 | 17 | 21 | 15 | 21 | 15 | 0 |
| Agriculture | 28 | 43 | 30 | 21 | 9 | 29 | 13 | 21 | 11 | 7 |
| Sanitation | | | | | | | 11 | | 89 | 100 |
| Livestock | 32 | 10 | 26 | 5 | 4 | 7 | 9 | 14 | 19 | 64 |
| Construction | 28 | 0 | 21 | 36 | 0 | 7 | 11 | 21 | 19 | 7 |

Beliefs and social customs: Beliefs and traditional customs in the social and institutional context need to be explored for insights into the opportunities and barriers they offer for individuals or communities adapting to stresses posed by climate change. For example, the people of Tamaphok village attribute the recent land creep they have experienced to the fact that the new generation has almost stopped worshiping the god in a shrine located at the top of the hill. People say that in his anger, the god destabilised the slope. This issue would appear irrational to some but creative ways need to be devised to create synergy between faith-based understanding and rational scientific methods.

Customs like giving water to passers-by have eroded completely, especially where markets are dominant and teashops are available. The teachers at a school in Danda Bazaar report that they can get drinking water at a teashop — but only if they order tea. Students bring their own drinking water from home. While water sharing is on the decline, social networking is not.

Although agricultural labourers are in short supply, farmers continue planting tea saplings, working in a tea garden, and marketing cardamom with the parma system of exchanging labour.[1] In another mark of solidarity, men and women are

[1] Parma is a system of sharing labour for cultivation and repairs between households in the hills of Nepal.

paid the same wage rate. An exception to these examples of community cooperation is the fact that the victims of the Tamaphok land creep were given no help when they were forced to move.

**Large-scale natural hazards:** None of the six villages studied reported that floods or erosion (landslides and gullies) had affected their livelihoods. Too much water was not an issue for them, though it is for adjoining villages. Those surveyed tend to think that the regular losses associated with erosion are acceptable and do not pose a major threat to livelihoods. In Ram Beni, an entire slope is creeping slowly downward, damaging farms and terraces. Since the mass wasting is a gradual process, people see the damage as simply an inevitable consequence of mountain topography.

Where major landslides have occurred, people have simply moved to stable areas, believing that nothing else could be done. In the last year alone, two families of Tamaphok were forced to resettle. There are no indigenous emergency measures to prepare villagers for landslides or floods and they have received no help from any agency. Villagers feel that roadside slope failures are the problem of the government.

## Specific local responses to water stresses

To cope with the shortage of water for domestic uses, the villagers have taken various initiatives. About 13% have switched to using electric pumps or collecting rainwater. There have been few non-structural responses to water stresses, such as creating a new institution or changing behaviour. The only notable exception is that a water supply system formulated rules to govern irrigation management. This stems from the fact that making non-structural changes, whether in irrigation methods or other areas, requires a level of investment, skills, and community support that the average farmer does not have. In addition, the decision to change has to be a collective rather than a private one. As a result, individuals turn to technological options, such as pumps and new canals, even though they are more expensive than traditional systems such as ponds.

During the winter, disputes over the use of water sources have required careful negotiations and the formulation of new methods of resolution. For example, in 1998 a source shifted from communal to private land. After a period of hostility, the landowner agreed to allow others to access the water in the winter, but not in the summer, when he used it for irrigation.

**Drinking water:** The volume of drinking water available in the immediate vicinity of households has declined, forcing villagers to go themselves or send porters to distant sources or to use polluted water. About half of the villagers in all sites now walk to lower sources when water at local sources dries up during the winter. About 54% of respondents said that more labour is required these days and about 49% reported spending more time filling up their containers because discharges have decreased. Nearly 28% resort to using polluted water and almost 30% make do with an inadequate amount of water.

People in Dhankuta report that there are water sources but that it takes them about one hour round-trip to fetch water as the sources are located at the bottom of hills. They also said that fields remain fallow in the winter because there is too little water for irrigation. Most farmers in Maunabudhuk now have orange plantations, for which they store water in drums to irrigate their trees when rainfall is delayed.

Shortages provoke disputes: 20 families (32%), most residents of Danda Bazaar – where the number of households has increased 12-fold in the last 50 years – have been involved in some sort of conflict. All six villages studied report a rise in the number of conflicts.

**Agriculture:** In most places, however, people report that water stresses have had only a moderate effect on rain-fed agriculture. In Sankhuwasabha, which people claim is getting wetter, people say that wintertime water problems have decreased. Many feel that timing of the monsoon rain has changed, so that its delays have negative consequences for farming. About a third of the respondents report that agriculture has not been affected at all by hazards induced by climate change, another third claim that the effects have been severe, and 24% say that the negative impact has been extreme. To access more water for irrigation, farmers rely on structural changes, which are usually expensive and require a high level of technology and equipment. In the study villages, 8% of respondents use sprinklers and 6.6% collect and store rainwater.

Rain-fed agriculture is affected significantly by water shortages. To manage water shortages in rain-fed areas, farmers use a variety of strategies. About half have changed to crops that require less water, switching from cereals to cardamom or ginger or from rice to maize (Box 4). About 20% now use seeds that require less water or can be sown later, once the

Box 4: **Story of a Dhaka weaver**

Raj Kumari Limbu, who originally hails from Panchthar District, came to live with her uncle in Maunabudhuk village in Dhankuta District when she was very young. She could not attend school beyond the primary level and soon found herself working as a wage labourer on the farms of other villagers because her uncle was so poor. As a young girl, Raj Kumari dreamed of wearing the Dhaka shawls wealthy Nepali women do, but for many years that dream remained unfulfilled. Then, in 1998, Dhankuta District Development Committee, with support from GTZ, organised a number of vocational trainings under a programme called Gaun Nagar Sajhedari (Urban-Rural Partnership). Raj Kumari chose to learn to weave Dhaka and was given a handloom. The training and the loom changed her life. She started weaving Dhaka on her own in 1999, and when her first shawls were finished, there many people keen to buy them because they were affordable and hand-woven.

Encouraged by their enthusiasm and by the good sales, Raj Kumari bought a few more looms and hired a few women to work for her. When local demand increased, she expanded again. Since she paid on time and well, she had no shortage of eager workers. Soon traders in Kathmandu began to order large qualities of Dhaka cloth from her. After three years, she was employing 150 weavers and exporting her Dhaka to America, England, Germany, Brunei, Hong Kong, and Japan through traders in Kathmandu. Had such favourable conditions prevailed, Raj Kumari says, her monthly income would have exceeded one hundred thousand rupees. However, there were looming problems: too little water and too much insecurity.

Like many women of Dhankuta, Raj Kumari has suffered from the effects of water scarcity since childhood. She started fetching water when she was just five and ruefully remembers falling and breaking the ceramic pot she was carrying and getting hurt in the fall. Now, the water shortages have hurt her booming Dhaka business because she had to engage the weavers in fetching water from a source at the bottom of the hill, a one to one-and-a-half-hour trip.

Water was not the only factor hurting her Dhaka production: the frequent strikes and road closures characteristic of the insurgency disrupted the regular supply of raw materials from towns like Biratnagar. The shortage of inputs meant she often failed to meet orders, many of which were cancelled.

Meanwhile without income to pay the loans she had taken to run the business, she had no choice but to lay off all but 25 weavers. However, with her training, those who found themselves without a job are doing well in other districts. Some have even set up their own business in Nuwakot and one has started her own training centre in Bandipur, Tanahu District.

Raj Kumari is pleased that though her own education was limited, she earns enough to send her nephew to engineering college in Kathmandu. She is also pleased with her decision to plant orange trees. They earn her 50-60 thousand NRs per year and require less water than the cereal and vegetables she used to grow.

rains begin. About 13% have abandoned farming altogether – changing their occupation, moving elsewhere, or relying more heavily on a once secondary income source. About 8% have stopped farming temporarily, until, they hope, the situation improves.

Livestock: Water stress has also affected livestock. Although livestock is an integral part of farming in the hills, only one household of the 61 surveyed makes a living exclusively from raising livestock.

Due to the shortage of water, farmers cannot keep the same numbers or type of animals as previously. The more obvious and easier way to cope is to reduce the number of animals. For cultural and economic reasons, this is a hard choice but one that about 30% of the households have adopted.

A second, more difficult option to implement is to change the type of animals. About 20% have stopped raising only water-intensive cows or buffaloes. They now raise combinations of livestock species that require less water. Typical combinations are cows and goats or buffaloes and pigs. The remaining 50% of households have done nothing despite the difficulties they face in providing their livestock with sufficient water. Many families reduce their water consumption for livestock by making less khole, a type of animal feed.

Quantifying benefits and losses: When the study team asked respondents to quantify the benefits of change, 62% found it difficult to do so. Twenty per cent of respondents claimed that the changes had saved them time and money and helped to improve the education of their children. Another 13% said that the changes had improved their health. About 2% of respondents said the land had become more stable. (We made no attempt to assess if it had actually stabilised). A few also believe that planting tea or utis trees in a tea or cardamom garden reduces erosion.

The study found that people could not identify the economic losses they have incurred due to water stresses although water shortages could reduce income from farm and livestock sources and shifting from one crop or animal to another could incur losses. About 78% have made no assessment. Those who could identify their losses mentioned reduced economic returns from farms and livestock, degradation of soil quality (perhaps because fewer livestock produce less manure), loss of interest in continuing to farm, and loss of work opportunities. In this response there were discrepancies as families reported their top three income sources. Some suggested that agriculture as the main income source is vulnerable to water stress. Those with diverse sources of income appeared less vulnerable.

Sanitation: To carry out sanitation activities effectively, a certain minimal amount of water is necessary. Water shortages hamper sanitation services and, eventually, as the system degrades, so does the health of the communities. Intertwined with poor hygiene practices unsanitary conditions could lead to an epidemic of water-borne diseases.

About 27% of respondents report that they cannot bathe as often as they would like and 42% do not even have enough water to wash their hands and feet. Washing clothes is problematic for 37% and washing dishes, for 26%. About 44% of the respondents said that they do not have sufficient water to wash properly after using the toilet.

In terms of the per cent of households, Danda Bazaar has the most serious difficulty in carrying out normal sanitation activities. Maunabudhuk and Rajarani, also in Dhankuta District, are in second and third positions. Villages in Sankhuwasabha reported having only minor difficulties. In all six villages, about 14% assert that the incidence of disease has increased and 47% find the stench of poorly kept toilets a problem.

Hygiene and sanitation is perhaps the most affected sector and the one where people's options for improving conditions are the most limited. About 67% have changed their behaviour, taking fewer baths and cutting back on washing and cleaning. About 46% have reduced water consumption for sanitation activities. A small number of people (about 3.3%) have not made any changes.

Construction: Drought conditions have had an impact on the construction business, although few mentioned this as a problem. Very few people in the study area are involved in building construction, whether for private use or as contractors, but of those who are, about 16% have been impacted severely because they cannot get enough water to mix cement or to be able to accommodate labour crews at construction sites. Another 16% of construction workers suggest that water is so scarce that it is very difficult to continue with their livelihood. Construction in Danda Bazaar, where water is already a constraint, is carried out only during the monsoon season now, when rainwater is collected and stored, or porters are employed to fetch water from nearby sources.

Changing occupations, remittances, and migration: Acute shortages of water force people to make tough choices like giving up farming and/or migrating to areas where water is available or from rural to urban areas. Their responses indicate that as the prospects of making a good income from farming or livestock decline with the decline in water availability, people adopt adaptive strategies.

About a third of the respondents have gradually begun to supplement their income from farming with income from services or trade and about 5% have abandoned farming altogether and settled elsewhere in order to take up trading. Many of those who could, including pensioners, both government and non-government service holders, and traders have already migrated and more are planning to do so. In the last five years, there have also been newcomers to each category of primary income source described in the section above. Two families each have adopted farming and livestock rearing; one family each was added to wage earning, service, and pension. Three families have taken up trade.

Many villagers see development primarily in terms of the availability of roads, electricity, and telephones but even the availability of all three has not convinced the residents of Maunabudhuk to stay put. For them, the shortage of water is the main push factor in their decision to migrate. After each crop-destroying disaster, some people migrate in search of a job as a wage labourer by taking loans from local moneylenders, or, as is increasingly the case these days, from other sources. This practice provides a safety net in hard times, though it comes at a price — debt.

Although such changes do not necessarily indicate any significant shift in adaptive strategies, they do show that people have adopted new ways of earning livelihood, sometimes in response to water shortages. About 42% stated that the changes described above had occurred over the last decade, while 31% said they were more recent, occurring within the last five years. Some said that they made the changes more than ten years ago.

External assistance: Individuals and institutions have helped to make some of the changes identified above possible. About 67% of respondents said that they had help in the form of information and, sometimes, material support. They said that those individuals involved had acted as catalysts for change. About 28% received help from organisations, including one family that installed a sprinkler irrigation system. When asked if the changes made had been beneficial or not, about 44% said 'yes' and 28% said 'no'. Respondents from all six villages agreed that the benefits of change are far-reaching, extending, for example, from economic to education to health benefits.

## Factors influencing local adaptation

### Enabling factors

Several factors enable people to deal with water stresses. Moench and Dixit (2007) suggest several factors, including access to roads, information, technology, markets, the services of institutions and technicians, and the availability of tools and equipment.

Access to roads: Easy access to a reliable road (one that is operational throughout the year) influenced some survey respondents to raise buffaloes, rather than cows, to take advantage of the market for milk. Farmers can make their living by growing tea and cardamom, only if there are roads by which to import inputs and export produce.

About half the total population of the six study villages can reach a road within three hours, but a quarter of them do not believe that access to markets is reliable. (We used three hours as a cut-off point because perishable goods, like milk and tomatoes, do not last for longer distances without damage.) Others (75%) agree that transport is unreliable, but say that transport problems can be resolved quickly. Those in remote regions without access to roads are deprived of potential income and essential services, including those of technicians. Today, roads connect most district centres except those in the high mountains, but many villages are still unconnected. The roads bring the problem of dealing with their regular maintenance.

Access to services and opportunities: Most of the population of the study villages has electricity and ready access to communication services, cooperatives, agricultural and livestock services, and other service-providers in local markets. Villagers can also access non-local markets through relatively trustworthy intermediaries. However, health and education services are available only at distances greater than a three-hour walk. Similarly, technical support for agriculture, livestock, and the repair and maintenance of simple machines is available to about a quarter of the population, but technology and equipment are available only outside the study area.

People are able to adapt better if they can migrate outside the village to seek a non-agricultural source of income. However, this opportunity depends on having family support, the capital for the initial investment, access to information, and the liberty to leave home for a long period. The success of any individual migrant depends on how well he can overcome the risks associated with living in a new area. Other factors that promote adaptation include social capital, institutional checks and balances, and the flow of information, goods, and services into and out of an area (Moench and Dixit 2004). As seen in (Box 5), when the overall general security deteriorates, the economic opportunities provided by access to roads and information become less relevant as a means for adapting to water stresses.

Diverse income sources: The diversification of livelihood systems is crucial for people to be able to adapt to new situations and especially to those characterised by extremes in water availability. It is a fact that people with diverse income sources adapt more easily than those with few income sources. The diversity of sources is more important than the level of income. For this reason, poor families are not necessarily the most vulnerable to stresses and hazards. A rich farmer or businessperson can be devastated if a flood or drought destroys his sole source of income.

Box 5: **Story of an entrepreneur: From maize to cardamom to tea**

Sudarshan Dahal, now a farmer of Okharbote Bazaar in Sankhuwasabha District, was a peon in a government office until he retired voluntarily in 1990. With his pension and other retirement benefits, he bought pakho land on which to grow cardamom, a crop popular in the region because it is profitable and well suited to the moist soil conditions. During the insurgency, he was displaced from his village. He returned home in 2006. When Sudarshan returned, his cardamom farm had been blighted by disease and he found it difficult to find seasonal labourers. Water was also scarce due to a succession of winter droughts.

Undeterred, Sudarshan switched from cardamom to tea cultivation as many other farmers have done in the last 10 to 15 years. He planted 150 hectares initially and planned to add 10 hectares annually. The region is an established supplier of expensive orthodox tea. Tea grows well here since it needs less moisture than crops like cereals and cardamom and since it can survive droughts because its roots penetrate deep into the soil.

Since tea cultivation guarantees regular employment, it is easier to find a labour supply than it is for cardamom farming, which only needs seasonal help. With the income Sudarshan has earned (tea sells for Rs.200 per kg in the local market), he has been able to send his two sons and his daughter to Kathmandu for higher education.

Sudarshan is not the only farmer in Okharbote Bazaar who has prospered; the entire village has witnessed a steady rise in its standard of living. Before the 1980s, villagers could not afford to buy black pulses, powdered milk, cooking oil, or rice in the local market. By changing what they farm from maize and millet to cardamom and tea and competing successfully in the tea market, their economic status has improved. They are able to engage in conspicuous spending, particularly in the buying of packaged foods.

When farmers replaced their maize and millet crops with cardamom, food insufficiency increased sharply, but the returns from cardamom enabled villagers to buy the food they needed. In any case, with the supply of water gradually declining, it would soon have been difficult to cultivate cereals anyway. Farmers are happy they made the shift from cereals to cardamom but even happier about the shift to tea. Although the changes were guided more by economic incentives and shortages of seasonal labour than by the availability of water, the decision has helped them weather shortages of water.

Although some villagers have begun to use sprinklers to irrigate vegetables, by changing crops, they did not have to look for alternative methods of irrigation. As a result, villagers have limited access to institutions designed specifically to reduce water disputes. Even in the absence of institutions, however, villagers solve disputes through mutual understanding.

Mobility and access to diverse habitats: Mobility is another factor that helps people to adapt. During the winter, some families move temporarily from upland to lowland areas so that they can more easily access water sources for domestic uses, the needs of livestock, and activities like planting a small vegetable patch. A farmer who raises vegetables needs an alternative source for more water than the 45 litres daily per capita that national water supply schemes provide. If a family has the opportunity, it will move to continue small-scale farming even during the dry winter. In fact, settling temporarily in cattle sheds or in valleys is a traditional way of dealing with stresses, including those that are water-related.

## Constraining factors

Several factors may constrain the ability of people to respond and adapt to water stresses. In many cases, the ability to adapt is limited or made more difficult by inadequate physical infrastructure, unreliable sources of drinking water, over-exploited natural resources, or disrupted surface water systems.

Institutional dysfunction: The services offered by institutions may vary depending on the factors of access, availability, and reliability. For example, in many rural areas, people have physical access to services, such as schools, but for economic, social, and sometimes cultural reasons, these services may not be available. Primary education in government school is free, yet some government schools do charge fees, effectively excluding the children of the very poor.

Reliability is another concern. For example, Nepali farmers in border towns have access to seed and fertiliser markets across the border but the goods they need are not always available at a reasonable price or when needed. In addition, their quality is in question as there is no mechanism for checking the open market for adulteration or bogus goods. Another unreliable service is water: about 39% of those who do have access to a water source claim that it is not reliable and reliable irrigation is available to only 18%.

While state-run outlets make good-quality inputs available, most of these institutions are in disarray and function poorly. The study found that farmers in the study area would rather being cheated by a private entrepreneur in an Indian market than to wait for supplies to arrive in government stores —sometimes too late or at unaffordable prices.

Notion of development: Since roads are a symbol of development and help people to connect to the outside world easily, most villagers desire and most politicians promise a road to their village. The fact that the value of land near a road soars creates an additional incentive.

Unfortunately, roads also bring adverse impacts, including the disruption of local hydrology by damaging water springs. These disadvantages become evident only later, when a new road or road-induced erosion blocks an irrigation canal or damages pipelines and canals. For villagers, however, the immediate benefits of a road outweigh any reduction in the supply of water. Indeed, since a road provides them with the opportunity to seek employment that does not depend on water, the sacrifice may seem worth it.

However, in the long term such disruption debilitates water security overall and makes the community and households more vulnerable to water stress. Improved road access creates an environment conducive to new lifestyles and economic activities but also creates additional demand of water for hygienic and sanitary uses due to use of modern toilets, washing machines, and increased bathing habits.

When the natural ecosystem is subjected to severe stress because the population has increased, the nature of the demand has changed, and rainfall patterns have grown erratic, an improvement in water security is warranted, and it is institutional innovation that can provide the answer. Indeed, institutional innovation is at the core of any successful adaptation strategy (Boxes 6, 7).

Political and social instability: The surveyed villagers believe that political stability is a requisite for development and adaptation. The social context in Nepal is changing due to the decade-long insurgency, long-term migration, and the penetration of communication and media. These social changes need to be understood more deeply. As both the state security forces and rebel soldiers would help themselves to harvests, farmers came to have little incentive to grow more food.

Although the insurgency ended in 2006, political instability has continued with frequent strikes and road closures that leave farmers often unable to take their produce to market. Since they often must throw away the produce, such unpredictability is a major disincentive to growing more food, or increasing productivity.

The long absence of able-bodied men from villages has changed people's perceptions about relationships and living. Of the many forced to flee, few have been able to return to the lives they once lived. When the overall general security deteriorates, the economic opportunities provided by access to roads and information become less relevant as a means for adapting to water stresses. To cope with stresses many people have already migrated or plan to migrate. Although Maunabudhuk has four key elements of development for Nepalis – schools, electricity, roads, and phones – villagers are leaving their homes due to the shortage of water.

Gender and adaptation: Our inquiry into gender categories in the study villages revealed that men and

Box 6: **Institutional innovation**

The process of change in Maunabudhuk is typical. Once the village grew into a marketplace, in-migration soared and the population grew. Its two water sources, Raja and Pachyang, became inadequate for meeting the rising demand. The crisis created by the construction of a college forced its management and the local community to devise a solution: students would spend one day a week filling the campus water tank for use the rest of the week. While this solution works for the school, most families do not have either the money to buy a tank or the time to fill it up.

Box 7: **Harvesting fog and rain in Danda Bazaar**

Access to clean drinking water continues to remain a major challenge in the hills. Settlements in hilltops and ridges are particularly critical. Danda Bazaar is a case in point. The ridge village faces a critical drinking water problem. A fog water harvesting system was built as a pilot to supply a section of the population of the VDC. Completed in 2002, the system initially served 11 households and today serves 16 households, generating about 4,000 litres of water. This was an attempt at technological innovation to meet drinking water needs because atmospheric fog water is clean and abundant in higher elevations. Not all fog water-collecting nets originally installed are currently in use because the water harvested by fewer nets is sufficient.

The system was the first of its kind built in Nepal by Nepal Water for Health (NEWAH). Households along the main market of Danda Bazaar harvest rain in plastic tanks and other types of storage as autonomous initiatives. At the higher secondary school of the VDC, a rainwater-harvesting tank is being constructed with support from Bio Gas Support Programme (BSP). An attempt was made to drill horizontally in the hill slope to access underground water for drinking water but the trial was not successful.

women do not perceive the effects of the water shortage in the same way. Men tend to be less optimistic than women, with more seeing the problem as severe rather than moderate. Half the women interviewed feel they are 'somewhat affected' while only 26% of men feel the same way. Conversely, twice the number of men as women see the problem as a serious one (28% to 14%). This difference requires consideration in making decisions about community- and household-level adaptation.

## Discussion

The aim of this study was to improve our understanding of how villagers in selected locations in Nepal's Koshi basin cope with conditions of either too much or too little water and to demonstrate some of the factors working against such changes. These conditions of water extremes are embedded within larger processes of social, economic, and political change both within and outside of Nepal. Villagers are exposed to many of these processes as they attempt to frame their relationships with government departments, NGOs, local communities, and individual households.

Besides providing specific insights into the selected villages, the study highlights the relationships between climate and the human endeavours it affects, such as agriculture, drinking water, and livelihoods. This relationship has to be understood historically in specific local contexts and with respect to future projections of global climate change. Universalised diagnostic indicators of change – an increasingly erratic climate, rising temperatures, receding snowlines, and uncertain rainfall – need to be related to local specificities, human values, and perceptions (Hulme 2007), which, as our study demonstrates, vary considerably.

The definition of dry and wet region is just one of many examples of how global and local understandings contradict each other. The team used district-level data to select Dhankuta and Sankhuwasabha as being representative of dry and wet districts respectively, but this definition needs to be more nuanced to for the great micro-level variability characteristic of the monsoon system.

Defining the monsoon pattern of four months of rain as 'the wet season' and eight months without rainfall as 'the dry season' broadly captures the extreme contexts of too much and too little water, but it is impossible to generalise about how people respond to and cope with too much and too little water. In fact, too much water was not a problem in either the 'wet' or the 'dry' districts. Instead, shortages of water were the major problem in both. Although there is no scientific confirmation of their hunch, almost all villagers agreed that water availability in the dry season has declined. Given the geography of ridges, it is not surprising that people on them reported facing the longest periods of water shortages.

In addition to such over-generalised definitions, the set of contradictory data is another limitation. Some data sets suggest that annual precipitation has increased while others indicate a decline in the last five years. The discrepancy highlights uncertainty in the behaviour of the climate and, in doing so, concurs with recent model results, which also hint at a more uncertain future (NCVST 2009). The contradiction has four possible explanations: first, the existing database does not adequately capture climate diversity in the mountains; second, the changes in climate have no specific trends; third, local variations are stark; and fourth, rainfall events are more intense as a few short, concentrated events that bring the same amount of water as several ongoing events.

Changes in patterns of rainfall affect drinking water first. The impact is pervasive and affects every member of every family, but especially women. The majority of the people in the study villages do not have enough water for domestic uses. To cope, more family members, or even hired labourers, are engaged in fetching water. If for some reason they cannot fetch clean drinking water, families learn to make do with little water or resort to using polluted water, especially during the dry season. When having to make do with what little is available, villagers forgo practices like washing their hands and feet before eating or cut down on bathing. In Danda Bazaar, people collect rainwater for meeting specific needs, like dishwashing.

The shortage of water has a drastic effect on domestic activities: water is rationed and some activities are not done. The first activity sacrificed is cleaning toilets. The result is unpleasant odours and, according to some, an increased incidence of disease. The second activity to suffer is bathing, though people do bathe at faraway sources or in streams. People also forego the traditional practice of washing one's hands and feet upon returning home. Although they curtail washing dishes and clothes, it is still carried out, even if water has to be carried long distances. People collect and reuse the 'used' water for other purposes, including feeding livestock.

The study suggests that Danda Bazaar has the greatest difficulty in carrying out normal sanitation activities, followed by Maunabudhuk and Rajarani. Villages in Sankhuwasabha reported only minor problems. It is however, important to make a distinction between the water problems associated with the monsoon and those characteristic of dry periods. Those who said they have to go to distant sources for drinking water are mainly referring to the situation in the winter, although some families have to go to faraway sources during the rainy season as well.

As described in the report, families face many difficulties with the shortage of water. They cannot make *khole*, a soup of maize flour and hay fed twice a day to milking animals, and, without *khole*, milk production declines. Farmers have turned to feeding moistened cut hay mixed with maize flour, instead. Farmers cannot bathe their buffalo daily, an activity important to cool milking buffalo. The ponds once used for bathing buffalo fell into disuse when piped water was introduced, despite the fact ponds made it easy for farmers to bath their buffaloes at home or at community or individual taps. These days, simply providing drinking water to animals is difficult as farmers are forced to carry water up from sources at lower elevations. Cleaning cattle sheds has become close to impossible, so they remain dirty. Those in the dairy business have found it difficult to get enough water to wash milk cans, which has increased the number of instances of milk souring. Maunabudhuk has suffered most from the effects of water shortages on livestock and, in general, villages in Dhankuta have suffered more than villages in Sankhuwasabha. Many families in Panchkhal have also suffered – some farmers have resorted to selling one or two buffalo, while others have used part of their proceeds from selling milk to buy water to keep their buffaloes healthy.

Unlike their response to domestic problems, farmers have not focused their response to irrigation problems on non-structural changes such as making new institutions or changing behaviour. For the most part, these changes would rely on investments, skills, community support, and decision-making processes, which are beyond their capacity to obtain. Instead, they deal with the hurdles to irrigation posed by water shortages structurally with more expensive, technology-dependent solutions. Farmers are using pumps, participating in the construction of new canals, and building ponds to collect or fetch the water they need to irrigate their fields.

Farmers have adopted two main responses with respect to livestock: reducing the number of animals or changing their type. The first is the more desirable and despite its negative economic and cultural repercussions, 30% have taken this step. Others have opted for having a mixture of cows and goats or buffaloes and pigs because culling cows and buffaloes reduces the demand for water.

However, it is difficult to attribute all these changes as actions to cope with water shortages. For example, people switched from raising many cows to a few buffaloes primarily to take advantage of the emerging milk market, not to use less water. Planting cardamom instead of cereal was an economically motivated change, which only incidentally helped farmers cope with less water. Although both tea and cardamom require less water than cereal crops and provide better economic returns, factors other than water were involved in the shift – cardamom cultivation requires less labour for a more limited period, leaving farmers more free time to pursue other productive activities.

The benefits of the changes, like the decisions to make them, stem from a combination of factors, which relate not only to water. Perhaps the best lesson to take away from our study is that farmers continually change their livelihood strategies in order to make the best living possible from the changing opportunities available.

The study suggests that the people living in the middle mountain and Terai regions of Nepal's Koshi basin are already experiencing the stresses of climate-related hazards, including erratic monsoon rainfall, floods, and extended periods without rainfall. They are coping with the impacts, but have not yet developed effective adaptive strategies. The case studies suggest that people have positive attitudes toward adaptation. Clearly, they recognise that diversification of crops and agricultural practices holds much potential in their struggle to adapt to changes in the frequency, intensity, and duration of rainfall and their ramifications, whether flooding or extended drought.

However, behavioural changes do not happen automatically and depend on factors such as access to information, knowledge, and markets. Being able to change also depends on the appropriate husbanding of water and the availability of drought-tolerant seeds and other supports tailored to the needs of specific sites. It is clear from our findings that different sections of society will require different approaches to adapting to adverse climate impacts.

In the hills, changes have occurred much more slowly than in Sunsari District, where the breaching of the Koshi embankment profoundly shocked a population that had assumed it was safe from flooding. Although it was a manmade disaster, the flood suggested what we can expect once we have reached a climate change-induced tipping point. In Sunsari, too, the diversification of and access to alternative sources of livelihood emerged as an important strategy that can help people to adapt to stress, irrespective of whether its source is climate change or some other ongoing process of change.

It is evident that many people want to leave farming to seek other opportunities. Respondents suggest that state agencies must focus on getting the framework right rather than on pinpointing details. Under a facilitative, flexible structure, they argue, disruptions can be dealt with locally. In many cases, the stress posed by the decade-long insurgency and the current state of insecurity was perceived to be more serious than drought, though the latter has also generated serious and long-lasting concerns.

Concerted efforts are needed to document the ongoing local changes and practices of adaptation in order to consider them in the conclusions of high climate science and generate new understanding. Generating new knowledge requires an iterative effort that pays heed to context-specific experiences. Such efforts need to be linked with policies and implementation so that the nuances of the learning are not lost. At the same time, the process needs to invest in building local skills, knowledge, and capacities to engage at the local, national, and global levels. Spanning the gap between the local and the global is a critical step in responding to all ongoing changes, including those induced by the changing climate.

## Conclusions

The key insights from the study are as follows:

- Sources situated at higher elevations are more sensitive to lack of rainfall because less water stays in the higher groundwater systems as it drains out in lower springs.
- Decentralised water systems, such as rainwater or fog water harvesting, offer incremental solutions to addressing emerging water stress but require larger policy shifts to scale-up and thereby have a significant impact. This approach also demands innovative approach to adopt the technology and behaviour.
- Prevention of the degradation of existing ponds and rehabilitation of damaged ones is ecologically and hydrologically desirable, as they maintain soil moisture and recharge spring sources.
- The access to and flow of information, goods, and services into and out of an area is a necessary condition to respond effectively to stresses.
- Social capital and the presence of multiple institutions help to support adaptation.
- Diversification and access to alternative sources of livelihood emerged as a central strategy to help people adapt to stress, whether induced by climate change or other ongoing change processes.
- The variety of income sources, not the level of income, seems to be an important condition for adaptation.

## Way forward

The above discussion takes us back to the beginning of this study – where we mentioned the ongoing change processes in the Koshi basin, the constraints they impose on people, what people are doing about it, and what these responses tell us about the appropriate role of the government in supporting adaptation. What emerges from the discussion is that people adapt to constraints by avoiding hardship; in this endeavour, diversifying their livelihood is a major strategy.

The question then arises of how adaptation is or could be planned or facilitated by agencies of the state, government, or donors. The answer to this question is necessary to understand the way forward in the Koshi Basin in particular and to respond in general to the impact of climate change across the country. It is clear that the link between planned and autonomous adaptation needs to be defined because adaptation in the six villages studied is largely autonomous. Planned responses rarely come into play.

Autonomous adaptation involves actions that individuals, communities, businesses, and other organisations undertake on their own in response to the opportunities and constraints they face as conditions change. It can be responses to human-induced climate change. Autonomous actions can be individual or collective responses that occur almost entirely in the poorly recorded informal sector. They may involve changes in practices and technological choices, diversification of livelihood systems, access to financial resources like micro-insurance or micro-credit, migration, reconfigurations of labour allocation or resource rights, and collective action to access services, resources, or markets. Social capital and access to skills and knowledge can be particularly important in enabling these responses.

The difference between planned and autonomous adaptation can be conceptualised by using the analogy of an iceberg: the submerged invisible part representing autonomous adaptation is substantially larger than the visible tip above the water level, which is akin to planned adaptation (NCVST 2009).

Planned adaptation includes programmes and projects that governments, NGOs, and international donors implement to address specific climate impacts and vulnerability assessments. Planned adaptations are usually made in response to predicted impacts on ecosystems and hydrological systems. They aim to minimise human vulnerability by focusing on sectoral interventions, such as those related to water management and flood control. A government may initiate these responses with or without donor support. Most planning decisions have long-term planning horizons and are path-dependent, whereas autonomous or indigenous adaptation is short-term and occurs spontaneously as households respond immediately to the social, political, and institutional stresses associated with the changing climate.

The market, both formal and informal, is an important facilitator of autonomous response. The massive rural out-migration seen in Nepal during the last decade is one such example of an opportunity for adaptation provided by the market. However, this 'solution' carries with it a fear: what will be the impact on the Koshi hills and Nepal as a whole if the external demand for Nepali migrant labour goes in to a slump as it did in the 2008 recession.

Regarding adaptation to climate change, there are many unknowns – each of which raises more questions than answers about what, how, and who. The issues highlighted above do not suggest a neat or a silver-bullet solution. Instead, we will need many solutions to the myriad of problems associated with too much and too little water, especially as it is widely projected that both extremes — drought and floods — will be worsened by human-induced climate change. One possibility is that problems due to climate change be mainstreamed into sectors such as education and finance that have traditionally not considered them.

As a way forward, it is worth reiterating the lessons of NCVST (2009), which suggest that there is a pressing need to create new compacts between government and development agencies and between local innovators and community-based civic bodies. It is also essential that these two partnerships bond with each other. NCVST (2009) goes on to suggest that this partnership needs to include actors from across the spectrum, from hard physical scientists to soft social scientists, from researchers to implementers, from central actors to those in far-flung hinterlands. The voices of justice-seeking civic movements and innovative (especially local) markets must be dovetailed into the programmes of national governments and international agencies.

This approach provides a framework within which we need to design pilot projects carefully to fathom the scale of and scope of operation for adapting to the impacts of human-induced climate change.

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The International Centre for Integrated Mountain Development, ICIMOD, is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush-Himalayas – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalisation and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues. We support regional transboundary programmes through partnership with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.

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