ICIMOD Working Paper 2016/3

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Springs, Storage Towers, and Water Conservation in the Midhills of Nepal

NEPAL WATER CONSERVATION FOUNDATION

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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. Globalization 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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Authors

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The massive earthquake that struck Nepal on 25 April 2015 caused a major disaster in the villages in the areas where this research was carried out. In Dapcha alone, almost 90% of the houses were destroyed. The people in our study area have our deepest sympathy and we will support them in any way we can. We understand that rebuilding will be a long process, and having sufficient water to meet daily needs will be critical before, during, and after rehabilitation. In the second phase of this project, we have started an investigation to discover whether the springs, wells, and deep borings in the area have been disrupted, whether new sources of water have appeared, and whether any immediate action can be taken to help recharge existing low discharge and dried up springs.

The local communities and leading village voices in our pilot study areas in Daraune Pokhari and Tinpiple provided tremendous help to our team in carrying out the fieldwork by providing valuable information, insights, and local knowledge, and most of all a warm welcome and hospitality to all of us. We especially wish to thank Nawaraj Adhikari, Krishna Bahadur Tamang, Dinesh Adhikari, Hari Adhikari, Keshav Humagain, and Rajina Adhikari of Dapcha, and Bhoj Raj Panta, Badri Prasad Dhungana, Narayan Sapkota, and Saroj Dhital of Tinpiple, as well as the many other members of the community who helped us at both sites.

Foreword

When ICIMOD and NWCF teamed up to pursue an action research programme to help understand the role of springs in the livelihoods and water security of hill hamlets, they were guided by a certain moral prodding. In meetings with scientists, senior political leaders have always asked that our research efforts bring quick and concrete benefits to farmers and the poor, especially in rural areas. Although villages in the midhills of the Himalayas are dependent on springs for drinking water, and increasingly experiencing problems with water availability, little research has been devoted to springs and there have been no development programmes focussed on their conservation. It is only recently, as springs have started drying up, that they have begun to receive some media attention. The research programme was designed to address this important gap, which potentially affects millions of farmers across the Himalayas.

The drying up of springs is a slowly unfolding tragedy. Springs are the lifeblood of Himalayan hill hamlets, and without water entire villages might have to be relocated. While the villages may sometimes appear on a map to be close to major rivers, the vertical distance is actually so great that lifting water is not a technically or financially feasible option for these poor and scattered hamlets. Simply blaming climate change is not the answer either. There are many socioeconomic and institutional drivers involved in the decline of spring flows; climate change is simply worsening the situation. Identifying the factors that do lie under our control should provide a basis for developing approaches to reverse the situation and rejuvenate the springs.

The first phase of the research was initiated in mid-2013 through ICIMOD's Innovation Programme Fund and was an attempt to address serious grassroots concerns. And we were surprised by what we discovered. Despite the lack of winter snow, the midhills of the Himalayas are covered with a dense network of permanent and seasonal springs; the hills are effectively 'leaking water towers' with as many as five to seven springs per square kilometre. But as many as a third of the springs in the study area have dried up during the last decade. The drivers behind this loss include a decline in livestock keeping, and with it the ponds for wallowing buffalo that helped recharge the hill aquifers; filling in of ponds for malaria eradication and use of the resulting flat land as real estate; overextraction as result of replacement of the laborious hand collection of water with easier access via pumping and PVC pipes, without concomitant social or institutional regulations to limit water use; a shift from rain-fed crops to irrigated vegetables; other changes in land use including planting of pine trees which reduces infiltration; and earthquakes, among others.

The findings helped us to formulate one potential approach to spring rejuvenation that could be undertaken by the villagers themselves – rehabilitation of dried up ponds to form a recharge source for the spring aquifers. The first results of these activities indicate that reviving these small ponds can indeed increase the water flow in the springs below them.

The main lesson we have drawn from these activities is that to be effective locally, the science of geohydrology has to be brought to the grassroots level of the villagers, and that a significant effort has to be invested in community mobilization to enable villagers to comprehend the problem, and understand what they themselves can do. Towards this end, we have prepared an issue brief on ponds in English and Nepali to support policy and grassroots understanding. This working paper captures the main features of the first phase of this work and is aimed at the science and research community. We hope that it will contribute to addressing the reversal of this slow disaster in the middle hills of the Himalayas.

David Molden, PhD
Director General
ICIMOD

Dipak Gyawali
Chair, NWCF, and
Former Minister of Water Resources

Introduction

In the villages perched high in the midhills of Nepal, springs are a lifeline – providing water to sustain the needs of households, their farms, and their livestock. Many villages sit far above the streams and rivers, which lie at the bottom of deep gullies and valleys far below, and the cost of carrying or pumping water to the hill settlements from rivers can be prohibitive. In contrast, springs emerge all around the hill slopes close to the villages. The springs are fed by groundwater that accumulates in underground aquifers during the monsoon, effectively turning the hills into water towers.

In the past, springs provided sufficient water to meet the modest requirements of the villages. But since the early 1980s, people have started to face increasing shortages of water. There are many factors involved, including increases in population, land use changes, infrastructure development, and now climate change. The flow from many springs has lessened, permanent springs have become seasonal, and seasonal springs have dried up completely. In some areas the problem has become so acute that people are considering abandoning or moving their villages.

People have started to look for other ways to fulfil their water needs including bringing in piped water from distant sources, digging wells to tap the groundwater, and harvesting rainwater. But efforts to understand and address the major problem of disappearing springs remain few and far between. The problem of overextraction and failure to recharge groundwater appears to be almost completely overlooked. None of the institutions involved in water supply in Nepal appear to be concerned with the problem of groundwater in the hills – whether government, non-government, or development agencies. The springs are poorly understood and insufficiently mapped, and responsibility for them is unclear, lying in a grey area between administration and conservation. The precise relationship between precipitation and recharge, and actual extraction rates, remain unknown across Nepal. Experiments have shown that it is possible to increase the life of springs by increasing recharge during the monsoon through the construction of pits and ponds (Sharma and Banskota 2005; Upadhaya 2009) and improving vegetation cover (Negi and Joshi 1996), but the approach has been little tested and little is known about the precise conditions required.

Springs make a major contribution to survival in the hills across the Himalayas, especially in the long dry season, but there are not many studies in any of the countries affected. In Sikkim, 80% of rural households depend on spring water (Tambe et al. 2012), and in the Nepali midhills the proportion is likely to be similar. Valdiya and Bartarya (1989) reported widespread drying up of springs in western India, and attributed the reduction to deforestation of hill slopes, with a 25–75% decrease in spring flow over 5 to 50 years. However, the idea of deforestation as the main culprit of Himalayan degradation has been challenged scientifically since the mid-1980s, specifically at the Mohonk Conference (Thompson et al. 2006) and more recently with the improvements in forest cover following the adoption of community forestry. Tambe et al. (2012) identified catchment degradation as the main cause of drying up of springs in mountain villages and suggested that climate change is emerging as a new threat. Some springs are considered sacred, and Khatiwada et al. (2006) suggested that the community value system plays an important role in sustaining these traditional water supplies.

In order to address the problem of springs, it is first necessary to understand how springs function. This includes some understanding of the social context, knowledge of the hydrogeological formations in which the water is stored, and the pathways for release (Valdiya and Bartarya 1991). Negi and Joshi (1996) noted that spring discharge in a mountain watershed is controlled by rainfall, land use and vegetation, and the geomorphology of the recharge zone, and a better understanding of all these components is needed. An action research project was designed to investigate these issues, and test some possible solutions, in a typical midhills area of Nepal.

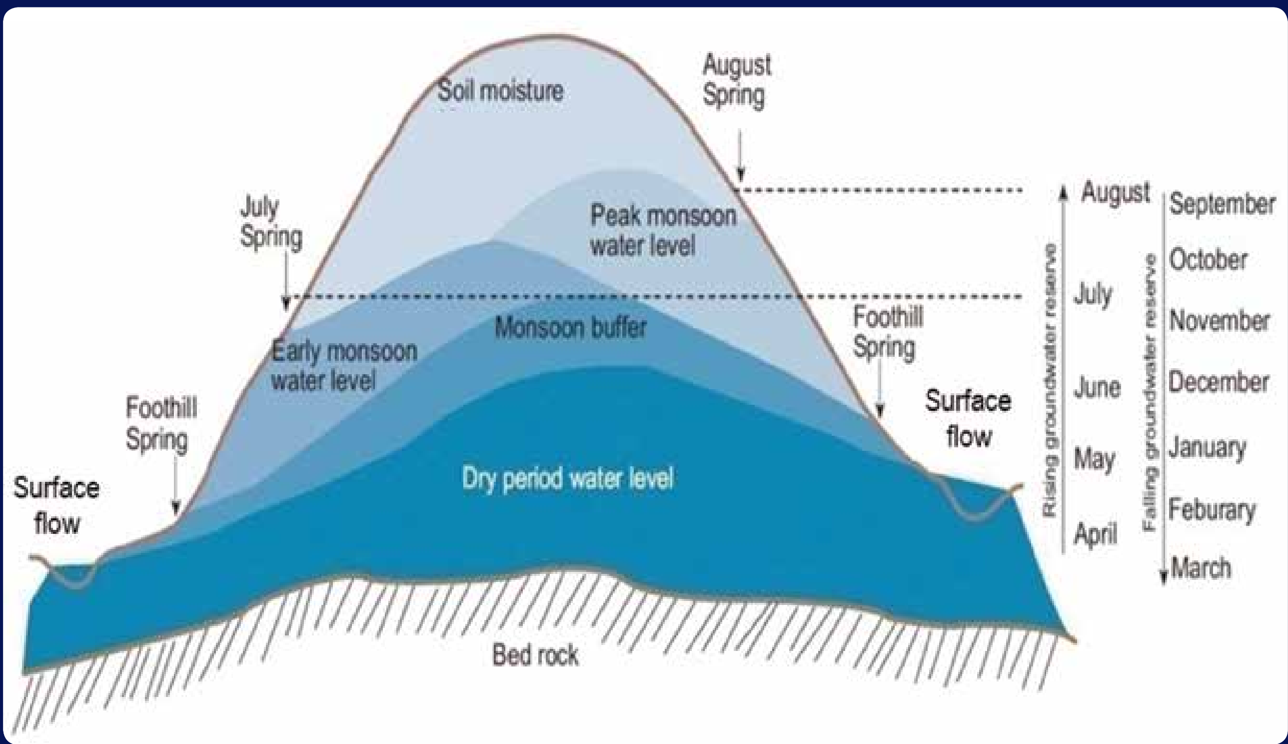
Springs, ponds, and wells in Nepal's midhills

Springs

The natural springs in the midhills of Nepal are found at multiple sites around the hill slope (Figure 1). The ultimate source of the springs is rainwater, which infiltrates the soil and seeps through cracks and fissures in the rocks before accumulating underground above impervious rock layers. Water is stored both in the soil and in the rock fissures, effectively creating a 'water tower'. In other words, the water sources are essentially unconfined aquifers characterized by groundwater flow under gravity. The water emerges where impermeable material blocks the groundwater flow and intersects the sloping ground, or where groundwater flows along a rock fracture and the fracture intersects the hill slope. The resultant springs are found on slopes of all angles and aspects and with different types of land use.

Springs can be relatively short-lived, providing water for a certain period after the monsoon when the groundwater levels are high, or perennial when they are fed from a level below the dry season water table. They can start with high discharge and quickly reduce to very low discharge during the dry season; they can have relatively high discharge or relatively low discharge that is more or less constant throughout the year; or they can dry up completely during the dry season. Some of the typical possibilities are shown diagrammatically in Figure 1. The spring discharge depends upon a number of factors, both natural and manmade, but the main factor is the amount of water in the water tower, which depends on the local recharge. If there is no groundwater recharge or the recharge rate is less than the extraction rate, the spring will eventually dry up. Annual rainfall is highly seasonal; about 80% of the total falls within around 100 days between June and October – the monsoon season – and this is when the main recharge of groundwater takes place. Precipitation in the dry season is often negligible and in some years completely absent. However, although the volume of dry season rain is low, when rain does fall, it can be more effective in recharging the groundwater as it falls when the temperature, and thus evaporation, is low and the ground is more absorbent. Ponds can also be used to trap the surface flow of non-monsoon (and monsoon)

Figure 1: **A generalized water tower and groundwater dynamics in the midhills of Nepal**



Adapted from Upadhya 2009

rainwater and increase infiltration, increasing the amount of groundwater recharge. The additional recharge during the dry season is difficult to quantify and highly variable, but can have a significant positive impact on spring discharge. The detailed relationship between recharge and discharge is still poorly understood and needs further research and micro-watershed modelling.

Types of spring

The Nepali term 'mul' is a generic term that indicates a variety of different forms of spring used for various purposes. We identified four different types of spring in the study area. These are the typical types found across the Nepal Himalayas, although in places the names may change slightly.

Dharo (or dhara): 'Dharo' are free-flowing springs that emerge directly from the ground (Figure 2). In the past, water was usually conducted from the spring along a stone spout or a pipe made from cut bamboo; nowadays, polythene pipe is preferred.

Kuwa: A 'kuwa' is a shallow pit dug to collect water that doesn't flow freely but seeps slowly out of the ground (Figure 3). Water is scooped out from the kuwa, the water level drops and then slowly rises again. Depending on the discharge, the water may deplete very quickly and rise again only slowly. Kuwas range from simple unlined holes in the ground, sometimes under an overhang, to elaborate structures lined with stones and enclosed by stone or brick structures. Enclosing keeps the source clean and reduces evaporation.

Inar or well: When the volume of water in a kuwa goes down, people tend first to widen the pond and then to dig a deeper well called an 'inar', which they line with concrete rings (Figure 4).

Tyanki: In some places, tanks ('tyanki' in Nepali) are built instead of wells to serve a similar purpose to an inar (Figure 5). Sometimes inars are converted to larger capacity tanks to store more water. Tanks are also built to collect large volumes of water from a free flowing spring.

Figure 2: **Polythene pipe conducting water from a dhara**

Figure 3: **Collecting water from a kuwa enclosed by stone**

Figure 4: **A covered inar**

Figure 5: **Tyanki at Thulo Dhara used for collecting and disbursing water from a spring**

Figure 6: **Water conveyed from a distant spring by polythene pipe**

Polythene pipes: This is more a method of conveyance than an actual spring. In many places, water is conveyed from a distant spring to an individual house or group of houses in a settlement using polythene pipes (Figure 6). The distance can be quite long, even several kilometres.

Ponds

Ponds used to be a common feature of the landscape in the midhills, but in recent years they have all but disappeared in many places. Traditionally, households raised buffalo, which constituted an important source of income. Farmers used to dig ponds so that the buffalo could wallow regularly as it is needed for their wellbeing and helps increase milk yields. One beneficial but unintended consequence was that many ponds also served as recharge ponds for local springs. In recent years, the livestock population has declined and buffalo are increasingly being replaced by cows, eliminating the need for ponds for buffalo. Thus many ponds were abandoned and have gradually silted up and disappeared.

Wells

There are many traditional dug wells (inars) in the plains adjoining the midhills. These wells are typically 8 to 10 m deep and usually lined with concrete rings of 1 to 1.5 m diameter. Dug wells are more or less reliable and often provide a large part of household water. There are no dug wells of this type at higher elevations or on the hill slopes; the inars at higher elevations are constructed around seeping springs with low discharge as described above. The water level in the wells fluctuates widely between the wet and dry seasons. In Chhap and Chhahara in Daraune Pokhari, the water depth in the 7 to 8 m deep wells varied from 6 m (20 feet) in the monsoon to only 1.5 to 3 m in the dry season.

It is becoming increasingly common in the midhills to dig deep wells, locally called a ‘boring’, as a community initiative using heavy drilling machines. The drilled wells can be around 150 to 200 m deep.

The action research project

A one-year action research project was undertaken by the International Centre for Integrated Mountain Development (ICIMOD) and the Nepal Water Conservation Foundation (NWCF) to increase understanding of springs in Nepal’s midhills and investigate ways of increasing spring flow. The specific objectives were

- to develop a better understanding of the geohydrology of springs in the midhills of Nepal;
- to understand the linkages to groundwater and water recharge systems in selected small-scale watershed areas;
- to understand the relationships between precipitation, groundwater recharge, and spring discharge;
- to understand the social aspects of local water use and management; and
- to investigate the possibilities for augmenting spring discharge by constructing recharge ponds.

The research aimed to address some basic questions such as: How are springs distributed around a particular aquifer? What are the flow characteristics? How are they used and managed within a local water management context? What social and environmental stresses are they facing? Can recharge ponds extend dry season life and by how much? How can scientific information reach communities to help them conserve this vital resource?

Two sites were selected in Kavrepalanchok District, east of Kathmandu, for the study. They represent typical hill hamlets in the midhills of Nepal. They are not isolated, rather they have strong rural-urban interlinkages to Dhulikhel and the Kathmandu Valley and are subject to both the stresses and strains and the benefits and opportunities associated with modernity. As such, it was hoped that the results and insights of the study could be used to help frame future research in other areas of the Koshi River basin and midhills.

This paper presents the outcomes of the pilot study including the major findings and important insights gained from both scientific investigation and interaction with the local community. Some policy implications are discussed and recommendations made for future actions needed to enhance the performance of functioning springs and revive those that have dried up.

Methods

The project had three main components: a scientific study using physical mapping, climate records, and discharge measurements of springs; a social survey of users based on group discussions, interviews, and enumeration; and action research into spring enhancement through construction of recharge ponds and monitoring of springs.

The study sites

The selected study sites were Tinpiple and Dapcha in Kavrepalanchok District to the east of Kathmandu (Figure 7). Site selection was based on the following criteria:

- an area known from previous field experience to be experiencing water stress for a variety of reasons including changes related to development;
- related to ICIMOD's current larger study of the Koshi basin as well as a previous study in the adjacent Jikhu Khola sub-basin, providing a rich source of data; and
- relatively easy access from Kathmandu to allow intensive monitoring of the springs and frequent interactions with the local community.

Kavrepalanchok lies within the Koshi River basin, which extends from the Tibetan Plateau through Nepal to Bihar in India, and the rivulets in the area flow into the Roshi Khola, a tributary of the Sun Koshi River.The district lies in the Middle Mountains (midhills) physiographic region of Nepal (inset Figure 7).

The area and population of the study sites are summarized in Table 1 and the detailed geographical features are shown in Figures 8 and 9, including administrative units, transport linkages, and drainage systems.

Table 1: **Area and population of the study sites**

	Tinpiple	Dapcha	Daraune Pokhari
Area (km^2)	13.4	24.8	7.5
Elevation range (m)	840–1,340	1,020–1,800	1,100–1,720
Number of VDCs	1	6	1
Number of wards	7	24	7
Population[a]	7,197	9,469	2,027
Population density (number of people/km^2)	537	381	270

[a] Source: National Population Census 2011 (CBS 2012)

The Tinpiple site covered an area of 13.4 km^2 adjoining the Jikhu Khola comprising seven of the nine wards in Panchkal VDC (village development committee, the local administrative unit) (Figure 8). (The boundaries of the VDCs recently changed after they were merged into Kashikhanda Municipality; this report uses the VDC boundaries and nomenclature current at the time of the study.)

The Dapcha site covered an area of 24.8 km^2 drained by the Dapcha Khola, which runs through Bhakundebesi along the BP Koirala (Banepa–Bardibas) Highway, and comprised all or part of six VDCs (Figure 9). Within Dapcha, detailed studies were carried out in an area of 7.5 km^2 covering seven of the nine wards of Daraune Pokhari VDC (Figure 9).

Springs, ponds, and wells

The study focused on springs, as they are the most important source of domestic water supply in the middle mountains of Nepal in general and in the study areas in particular. Ponds were also investigated as they are thought to be an important means of recharging groundwater, as well as hand dug (and other) wells because they are an important source of water at lower elevations and also rely on groundwater. Data was collected on springs, ponds, and wells; on the socioeconomic factors affecting the springs and drainage network; and on the climate.

Figure 7: **Kavrepalanchok District and location of the study sites**

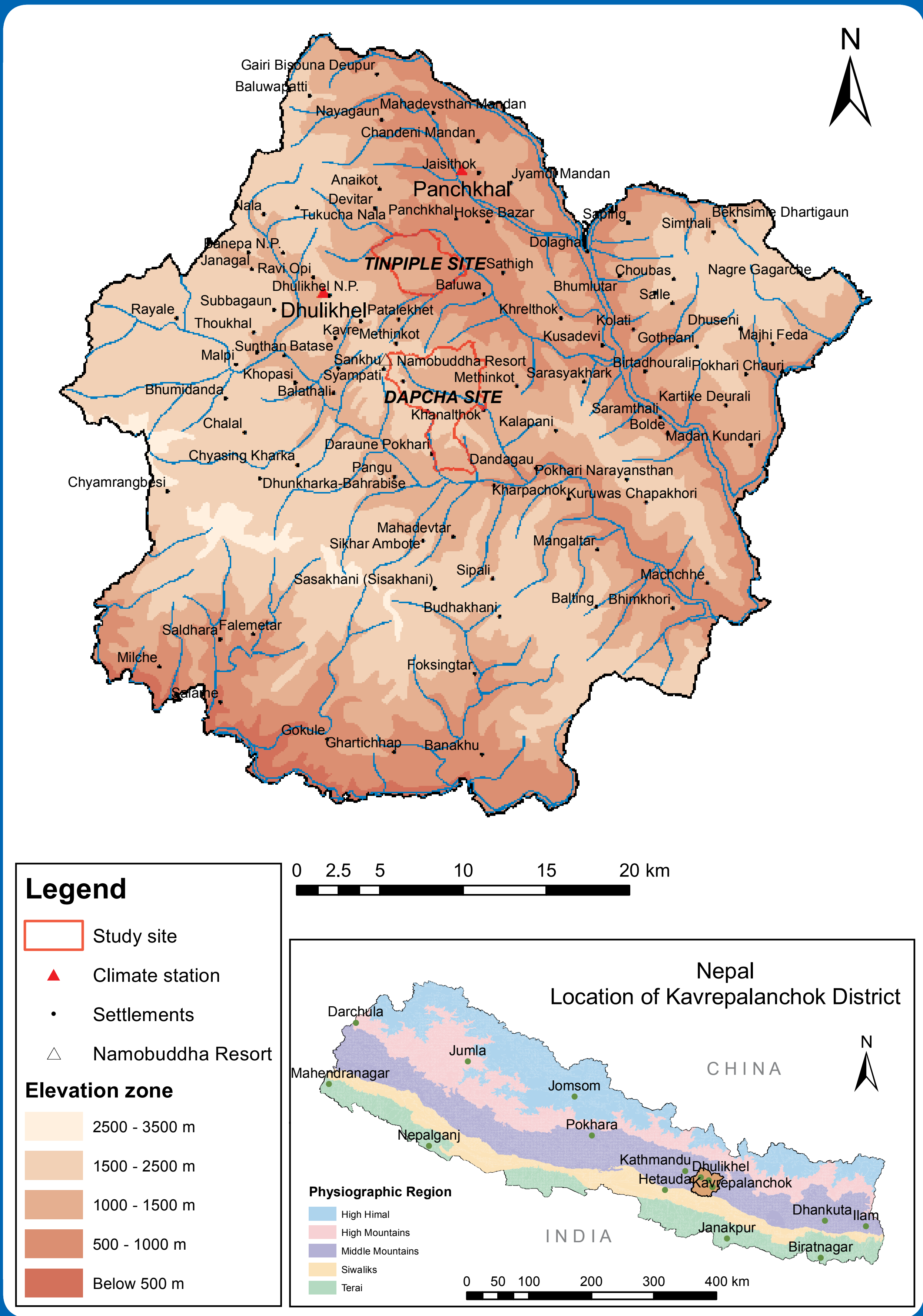
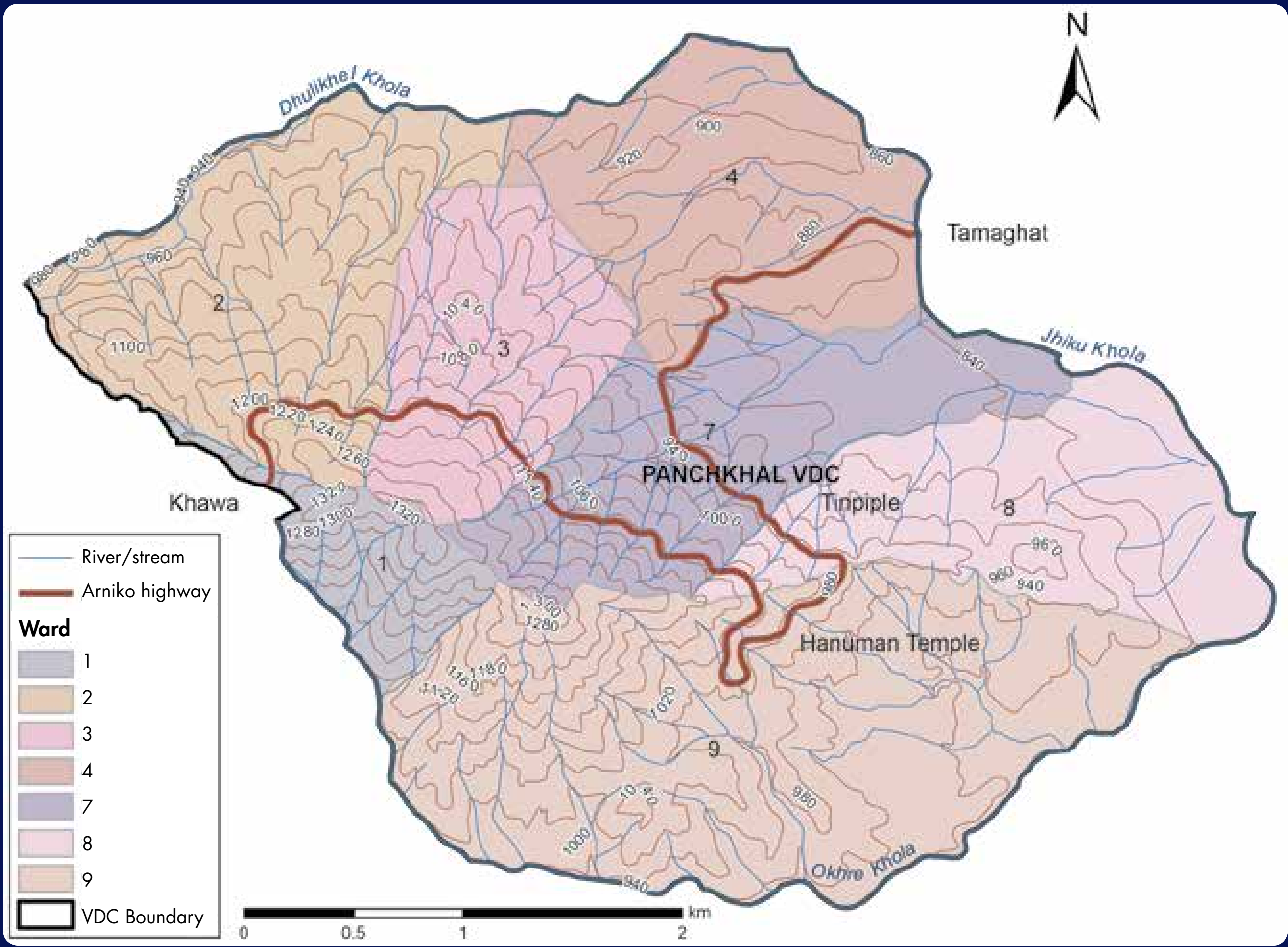


Figure 8: **Tinpiple site**



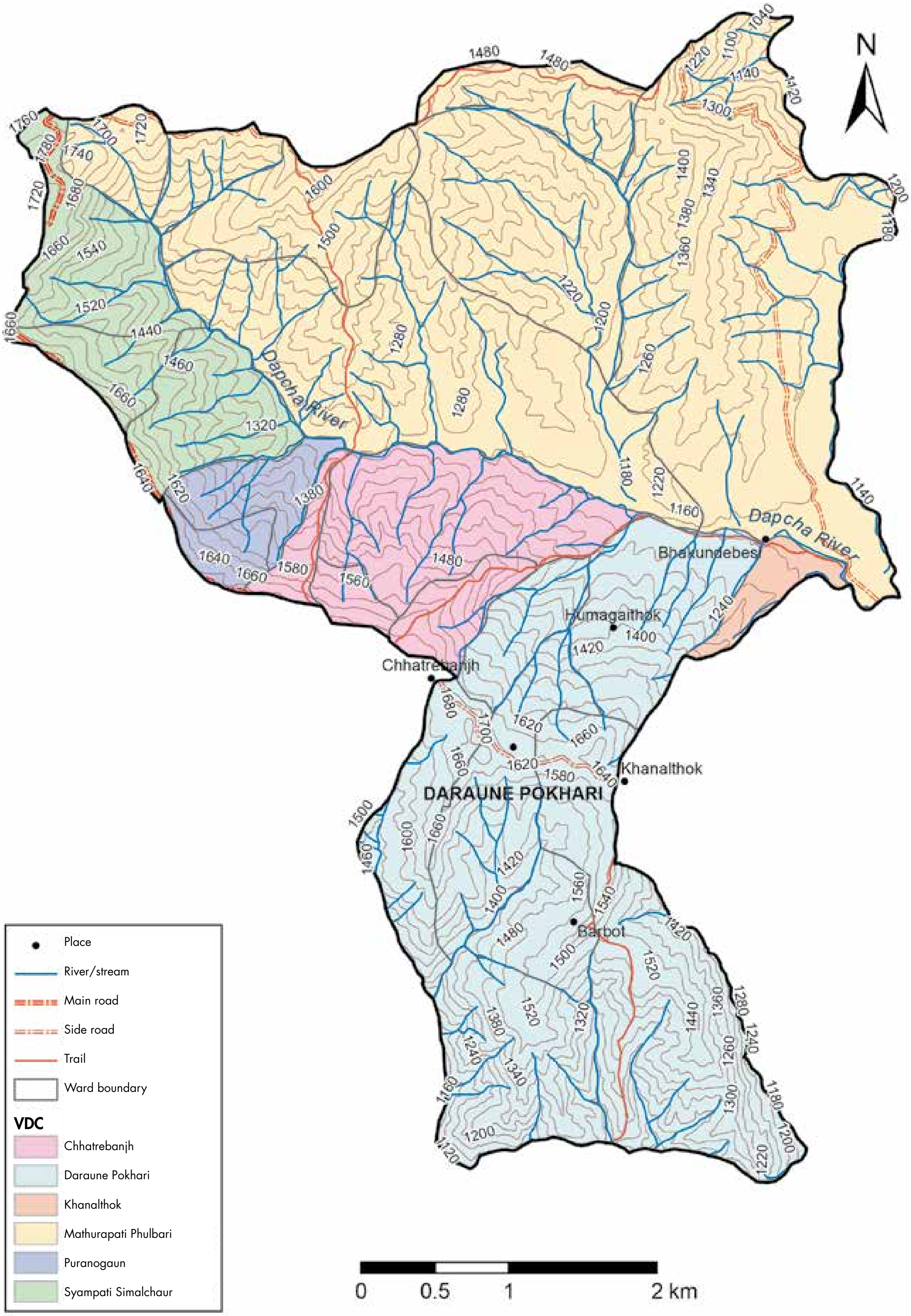
Mapping of water sources

The locations of water sources used by communities in the past and at present were determined in the survey carried out with local residents (see below). Information was collected for the whole of the Tinpiple and Dapcha sites. All identified springs (including those that had dried up) were mapped. Information about the sources was then collected by visual observation and measurement and from community members using a checklist. The information included spring location, discharge and seasonality of discharge, land cover and land use around the site, physical characteristics of the site, number of households using the water source, use of water, perception of quality, and ownership and management system (private, community). Information on ponds was mainly location and depth of any water. The wells were too numerous to map individually, and there was little variation among them in terms of topography and water table. Thus one or two wells were mapped in each locality and taken as representative of the wells in that area. Between a third and a half of all wells were mapped.

The location coordinates of springs, ponds, and wells were recorded using handheld GPS devices in September 2013. The point data was converted to GIS shape files in the form of point features for further analysis.

Digital map layers showing the topography, hydrology, land cover, and administrative units of the study areas were obtained from the Department of Survey, Government of Nepal. Contours, rivers, elevation zones, roads, and land use layers were obtained from the ICIMOD map library. The additional data gained from observations and surveys were superimposed on these map layers, and map layouts were prepared using GIS tools. The maps were superimposed on Google Earth images for visual presentation.

Figure 9: **Dapcha site with Daraune Pokhari**



Discharge measurements

Discharge was measured from all springs. Different methods were used according to the specific conditions at the water source.

- In free flowing springs (dhara), discharge was measured using a simple bucket and stopwatch method. The time taken to fill a bucket of known volume with water flowing from the spring was noted using a stopwatch, and the discharge rate was calculated in litres per minute by dividing the volume by the time taken.
- In shallow pools (kuwa), discharge was measured by removing a known volume of water, noting the drop in water level, and recording the time taken for the water to rise again to the same level.
- In places where people have diverted spring water via polythene pipes to specially constructed collection tanks, measurements were made by measuring the discharge into the tank from the inlet pipe.

Classifying discharge rates

There was a high variation in discharge both for a particular spring at different times of year, and among different springs. To understand the extent to which a source met local water demand, the spring flow was categorized in terms of supply potential (Table 2). This classification was prepared specifically for the study area and will need some adaptation before it can be applied on a broad scale across Nepal's midhills area. The classes were based on 50 households using a spring and an average household size of six, and defined as follows:

Survival minimum flow – defined as a spring discharge that yields up to 1 litre of water per day per person. This water is sufficient for bare survival, for drinking only, and represents an extremely water stressed situation.

Household low flow – defined as a spring discharge that yields up to 20 litres of water per day per household or a little more than 3 litres per person. This is the minimum quantity required for basic use; it is sufficient for drinking and some restricted cooking, but not for cleaning, washing, or sanitation, and represents a highly water stressed situation.

Rural low flow with cattle – defined as a spring discharge that yields up to 100 litres of water per day per household. This is sufficient for drinking and cooking and to cover the needs of a cow or a pair of goats, with a limited amount available for washing, cleaning, and sanitation. It represents a water stressed situation.

Rural average flow – defined as a spring discharge that yields up to 40 litres of water per day per person. Water is sufficient for drinking, cooking, cleaning, washing, and sanitation, with some available for cattle and a small kitchen garden, and represents water restricted households.

Rural high flow – defined as a spring discharge that yields a total flow higher than the rural average requirement of 40 litres of water per day per person. Water is sufficient for all household uses including cattle and some irrigation; there is no water stress for a typical rural household.

Table 2: **Spring flow classification**

Flow class	Flow type	Discharge		Basis of classification[a]
		l/day	l/min	
1	Survival minimum	<300	<0.208	≤ 6 l/day/household; 1 l/day/capita
2	Household low	300–1,000	0.208–0.694	≤ 20 l/day/household; 3.3 l/day/capita
3	Rural low	1,000–5,000	0.694–3.472	≤ 100 l/day/household; 16.7 l/day/capita
4	Rural average	5,000–12,000	3.472–8.333	≤ 240 l/day/household; 40 l/day/capita
5	Rural high	>12,000	>8.333	> 240 l/day/household; 40 l/day/capita

[a]Average household size of six; average 50 households using source

Long-term monitoring

A number of springs were selected for long-term monitoring of discharge. Selection was based on the initial measurements and information and designed to ensure that a wide range of springs with different physical and use characteristics were monitored. Selection criteria included the number of beneficiary households, initial discharge, seasonality, use, and geology. Only springs currently being used by at least a few households for domestic purposes were considered. The selection ensured that the list included springs used by very few as well as many households; springs at a range of elevations from low to high; and springs with high, medium, and low discharge rates. An attempt was made to include both seasonal and permanent springs as well as those in different geological formations. Some springs were used for specific purposes like drinking, washing, or for animals, or for different combinations of these, and an attempt was also made to capture as many of these uses as possible.

A total of 26 springs were selected for detailed observation, regular inspection, and discharge measurement – ten from Tinpiple and 16 from Daraune Pokhari. Detailed observation for these springs was carried out by expert observation and included slope aspect of the spring, overburden type and thickness, rock types, joint patterns, joint openings, and joint persistence of the surrounding geological formation. The vegetation cover and land use pattern of the surroundings was also recorded, and a note was made of any obvious physical changes brought about by development activities that could have an impact on the natural drainage network. The temperature of the spring water was measured at the same time, as was the surrounding air temperature.

Initial flow measurements of springs were made in September 2013 during the GPS survey of all the springs and ponds. These measurements provided baseline data, but there were some problems in data gathering at the start. Systematic data collection started in December 2013 and continued to the end of the initial project in December 2014. The monthly discharge measurements and daily weather data collection will continue at least up to June 2016.

Problems with measurements

Some problems were encountered in the number of springs and in later measurements.

- The local community helped us to identify the springs, but in some cases there was an initial lack of trust and they did not show us all of them, particularly those used only privately by a few individuals. As trust built up, they showed us these other sources as well.
- In some cases, tanks were built to collect water from the springs and more sources were added to the existing tanks using underground PVC pipes subsequent to our first measurements in September.
- Some sources were locked up by the villagers and became inaccessible.

Socioeconomic data

General data

Ward level information on the population, households, ethnicity, and literacy at the study sites was obtained from the CBS Population Census 2011 (CBS 2012). Data on land use were calculated from the Land Resource Mapping Project (LRMP) land utilization map as digitized by the Survey Department of the Ministry of Land Reform and Management, Government of Nepal.

Social survey

Local views on the water resources, water use, and resource management were gathered in a social survey. The survey also covered changes in land use, changes in agriculture and water consumption patterns, and physical changes brought about by various developmental activities, all of which can influence the natural drainage network. Two approaches were used 1) interviews using focus group discussions (FGD) and key informant interviews, and 2) social mapping using a standard questionnaire.

Eighteen focus group discussions (FGD) were held at various times in October 2013 and January 2014, seven in Tinpiple (one in each ward) and 11 in Dapcha (one per group of three or four wards). Each had ten to 12 participants, all experienced local people known to be knowledgeable about their surroundings. A checklist was used to guide the discussion. In addition, key informant interviews were held during almost all field visits by experts from the initiation of the project in May 2013 to December 2014. Interviews were held with individuals or two to three people together to gain insights into the history and nature of spring water use, and to supplement the information and further clarify issues raised during the group discussions.

Social mapping was carried out between December 2013 and January 2014 at 18 springs selected from among the springs used for the detailed spring monitoring: ten in Tinpiple and eight in Daraune Pokhari. Only permanent springs regularly used by several households were selected and care was taken to include springs from different geographic locations and at different elevations. The survey was carried out using a structured questionnaire focused on socioeconomic aspects of water use and management. Two enumerators stayed at each of the 18 sources for one day from 5:00 am to 5:00 pm in mid December 2013 and asked every person who came to the spring the questions on the questionnaire. The interviews were held on different days from Sunday to Friday (not Saturday). Users were asked why they had come to the spring (e.g., to collect water, take a bath, wash clothes, water animals, or wash animals) as well as questions related to water use and socioeconomic aspects (Annex 1). The total number of people interviewed was 421, with numbers per spring ranging from three to 66.

A spring management checklist was used separately to gather information on the management aspects of the springs.

Climate

Simple rain gauges and maximum-minimum thermometers were installed in or near the high school premises at each of the pilot study sites. Sites were selected in consultation with the local community and school staff so that they could contribute to the science curriculum in the schools while ensuring regular data collection and maintenance of the instruments. The science teachers and headmasters at both schools accepted the safe keeping of the instruments, reading and recording data on a daily basis, and sending the results to the NWCF office via SMS. Rainfall data from Namobuddha Resort near the study site in Daraune Pokhari was also made available for the study.

There were a few initial problems. It took some time for the people to get used to the process of measurement and there was also a problem of security. In Daraune Pokhari, the rain gauge was vandalized and had to be replaced and installed in a secure place. The thermometers also had to be replaced a couple of times at both sites. Systematic and reliable data collection started in December 2013.

Long-term rainfall and temperature data were obtained from the two Department of Hydrology and Meteorology stations closest to the study sites: Dhulikhel in Dhulikhel Municipality and Tamaghat in Panchkhal Municipality (Figure 7). This data had some gaps.

Construction of recharge ponds

A number of ponds were constructed at the study sites to test the hypothesis that recharge ponds located at strategic spots could replenish the groundwater in the aquifers and help increase the discharge of springs located downstream.

A first list of possible sites for pond construction or rehabilitation was made based on the geological conditions, relative locations of ponds and springs, presence of abandoned ponds, and discharge measurements. Following intensive consultations with local stakeholders, three sites were selected in Daraune Pokhari and three in Tinpiple.

Study Findings

Water availability and use

Households in the study areas obtained water from a range of sources: 1) water from springs or deep tubewells supplied by the government or the community as tap water in individual households; 2) privately dug shallow wells; 3) collection from springs; 4) water conveyed by pipe from a distant spring; 5) collection from streams; 6) rainwater harvesting; and 7) buying from commercial tankers that collect water from distant springs or streams.

The preferred source is tap water in individual houses, but this type of supply is rarely available, probably reaching less than 5% of households. The next preference is for water from a deep boring, especially as other sources have started to become depleted. All the wards within the study site in Tinpiple had areas with some access to water from deep borings, but in Dapcha deep boring water was only available in a few places in and around Bhakundebesi. Almost all households in the low lying areas of Tinpiple had private dug wells, but there were very few in Dapcha. Those without access to water from a tap, deep boring, or private well have to depend on springs, or in times of scarcity, streams.

During the monsoon, almost all households collect rainwater from their roofs in large household utensils and buckets in the traditional manner. Such water can fill household needs for a few days avoiding the need to collect from a spring. In Tinpiple, some people had installed more modern systems for harvesting rainwater from roofs using gutters and plastic or metal pipes to direct the rainwater into large durable underground or above ground concrete or ferro-concrete containers called 'ghyampo', which typically hold about 12,000 litres of water. These systems had been constructed as demonstration projects with the help of NGOs such as the Nepal Red Cross Society; some had been built during the PARDYP project (People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas) implemented by ICIMOD between 1996 and 2006 (ICIMOD 2007). The water is kept as a reserve to be used in times of scarcity and can last for up to three months if used frugally. The systems indicate a potentially useful technology for conserving water, but their use is limited at the moment to only about five or six households at the Tinpiple site, mainly because most households cannot afford to build them without some kind of a subsidy.

Traditionally, rainwater is also harvested by capturing runoff to irrigate rice fields. These days some farmers also harvest rainwater by collecting runoff in ponds lined with plastic film (locally called plastic pond) to use for irrigation of vegetables, fish farming, or livestock, a practice also promoted by the PARDYP project (ICIMOD 2007). Some households in Dapcha have built plastic ponds that can hold up to 70,000 litres of water.

In practice, people generally collected water from multiple sources because no single source provided sufficient water for all domestic needs, especially washing clothes and bathing. People often went to streams for these. Local people at both sites said that for most households water collected from all available sources was still barely sufficient to meet their household needs, and that the amount available is going down each year.

Sometimes, on special occasions like weddings, people would buy water from tankers. In some places, people had to buy water from tankers to use in home construction. Commercial establishments, mainly larger hotels and restaurants along the highway in the Tinpiple area, must buy from tankers. Smaller establishments managed with the water available from other sources.

Distribution and characteristics of water sources

The locations of the water sources mapped at the two sites are shown in Figures 10 and 11; the number and distribution of sources is summarized in Table 3. Mapping was carried out for the whole of the Dapcha site, including Daraune Pokhari. The study sites had a large number of permanent and seasonal springs; Dapcha had

Figure 10: **Water sources in Tinpiple**

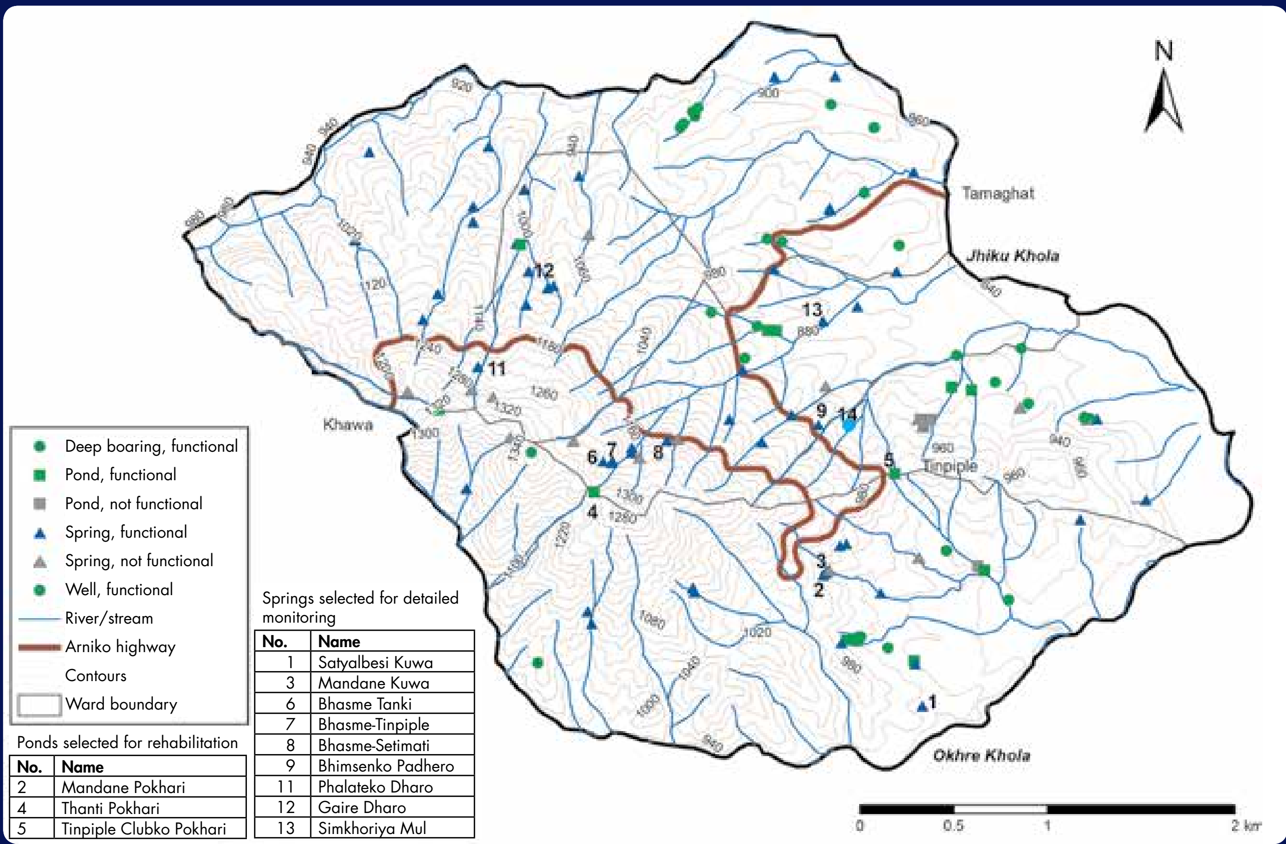


Table 3: **Number and distribution of mapped water sources**

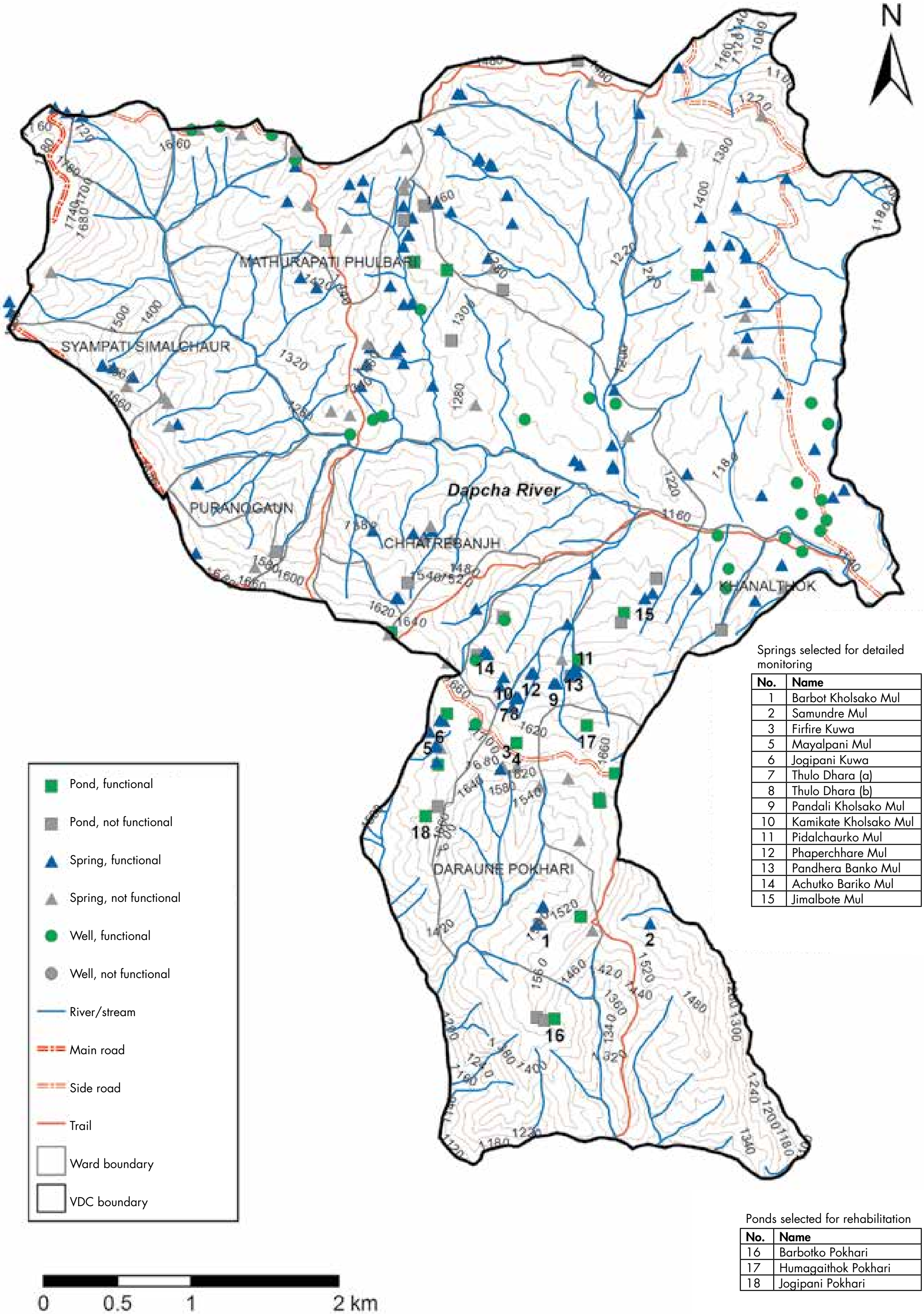
Sources	Tinpiple (area 13.4 km²)		Dapcha (all) (area 24.8 km²)		Daraune Pokhari (area 7.5 km²)	
	No.	No./km²	No.	No./km²	No.	No./km²
Spring sites	70	5.2	174	7.0	42	5.6
Functional	60	4.5	121	4.9	29	3.9
Dried up	10 (14%)	<1	51 (29%)	2.0	13 (45%)	1.7
Pond sites	14	1	43	1.7	16	2.1
Functional	10	0.8	24	1.0	8	1.0
Dried up	4	0.3	19	0.8	8	1.0
Hand dug wells[a]	30	–	29	–	3	–
Deep boring wells	4	0.3	2	0.1	–	–

[a] Sample of those located, see methods

more spring sites per square kilometre (seven) than Tinpiple (five), but 29% of the springs in Dapcha had dried up, compared to 14% of those in Tinpiple, thus the density of functioning springs at the two sites was similar (Table 2). This indicates that underground storage is decreasing at both study sites, but at a faster rate in Dapcha where the elevation is higher.

Ponds used to be common at both sites, as is evident from the many names of dried up ponds mentioned by local residents. Both sites had remnants of dried up ponds that had previously been maintained for buffalo to wallow in and for irrigating small patches of kitchen gardens. The number of pond sites per square kilometre was considerably higher in Dapcha than in Tinpiple, but again many more had dried up so that the density of functional ponds was similar in the two areas (around one per km²). In Dapcha, observations indicated a clear relationship between the existence of ponds and spring discharge.

Figure 11: **Water sources in Dapcha**



Springs selected for detailed monitoring

No.	Name
1	Barbot Kholsako Mul
2	Samundre Mul
3	Firfire Kuwa
5	Mayalpani Mul
6	Jogipani Kuwa
7	Thulo Dhara (a)
8	Thulo Dhara (b)
9	Pandali Kholsako Mul
10	Kamikate Kholsako Mul
11	Pidalchaurko Mul
12	Phaperchhare Mul
13	Pandhera Banko Mul
14	Achutko Bariko Mul
15	Jimalbote Mul

Ponds selected for rehabilitation

No.	Name
16	Barbotko Pokhari
17	Humagaithok Pokhari
18	Jogipani Pokhari

In contrast to ponds and springs, the density of hand dug wells was much higher in Tinpiple than in Dapcha. In the lower areas around the Jikhu Khola River in Tinpiple and Bhakundebesi in Dapcha almost all households have traditional hand dug wells (inar), but not at higher elevations or on the hill slopes. Tinpiple also had twice as many deep boring wells as Dapcha in an area half the size. Both the deep wells in Dapcha were in the lower elevation Bhakundebesi area.

Annual flow characteristics

Spring discharge in the midhills of Nepal tends to be seasonal, reflecting the rainfall pattern. The discharge normally lags a little behind the rainfall and reaches a maximum sometime after the monsoon peak. The monthly discharge from the springs selected for detailed year-long monitoring at the two sites is shown in Figures 12 and 13. The minimum and maximum discharge values and details of the spring locations and elevation are provided in Annex 2. The discharge in most of the springs started to increase in July and peaked in September.

The springs in Tinpiple were overall low flow, but they showed a marked increase in discharge in August/September and a generally gradual decrease thereafter with low discharge from April to July. This variation is likely to reflect recharge of the aquifer during the monsoon between June and September.

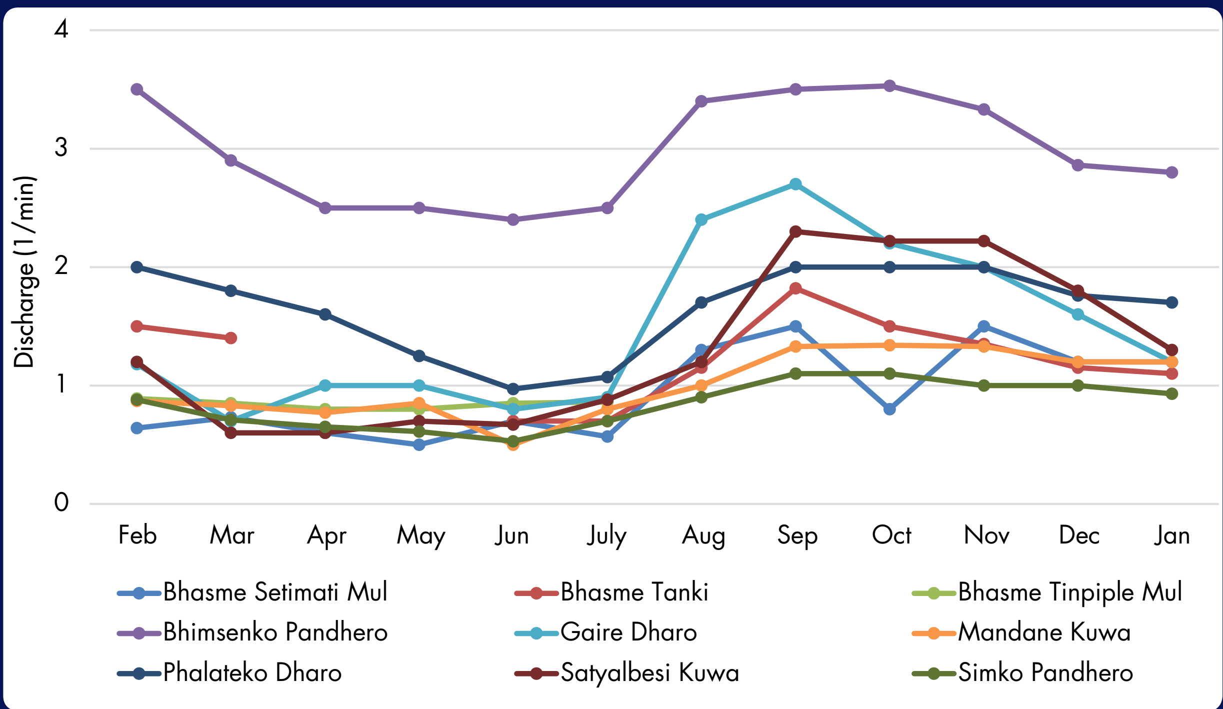
Four of the springs in Daraune Pokhari had a high flow and one a medium flow, while the remainder were low flow. In general, they showed a more constant flow over the year than the springs in Tinpiple, with a small decrease in flow in April to June, which had recovered by August/September.

In both areas, peak discharge occurred from September to October, about a month after the peak monsoon rainfall, while flow was at a minimum in June at the end of the dry season.

Climate

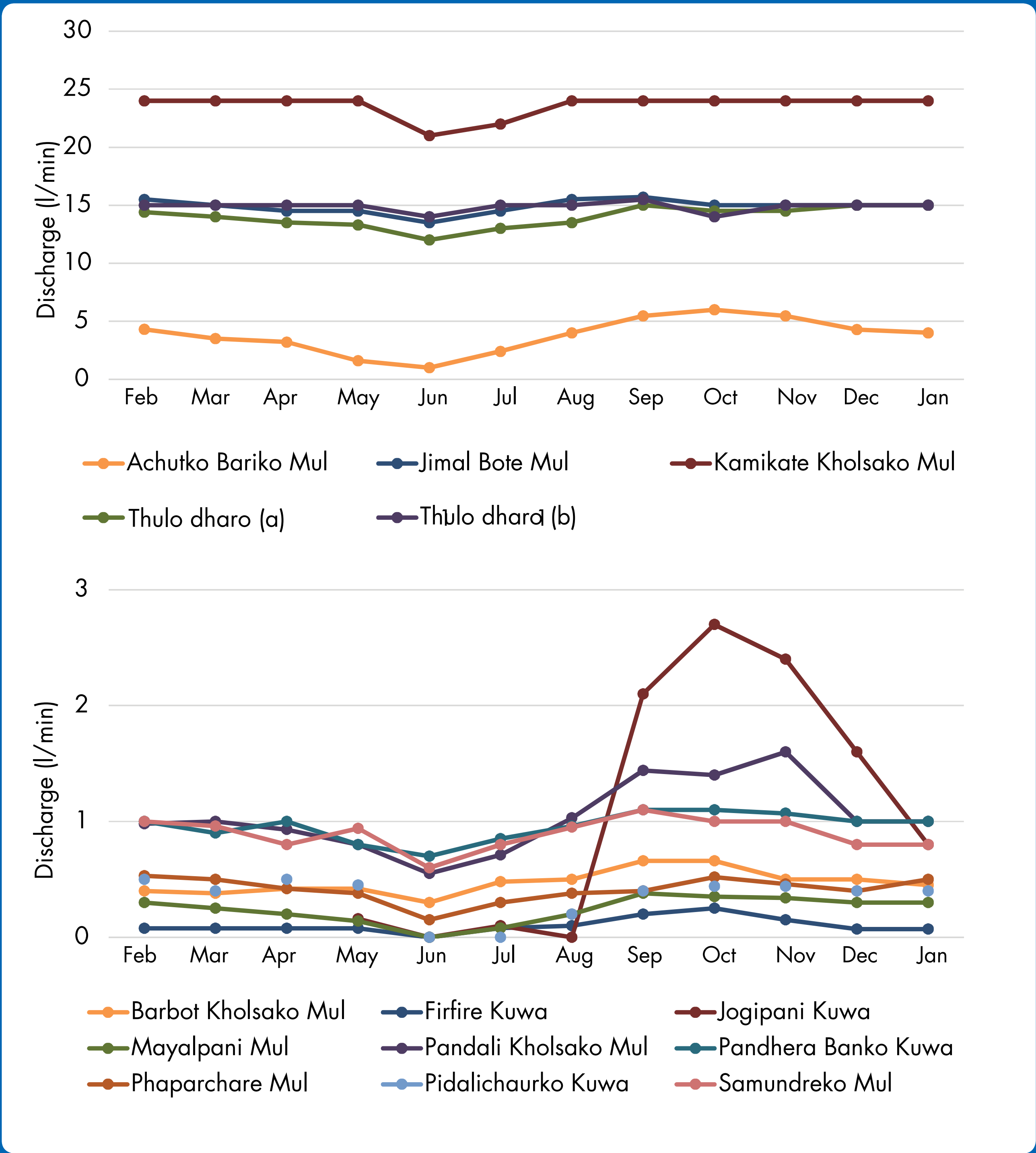
Details of the average monthly rainfall and temperature data at the pilot study sites and nearby climate stations are given in Annex 3.

Figure 12: **Discharge of selected springs in Tinpiple (February 2014 to January 2015)**



Note: Bhasme Tinpiple Mul (data available until July only); Baise Daharo (insufficient data for graph)

Figure 13: **Discharge of selected springs in Daraune Pokhari (February 2014 to January 2015)**



Temperature

Figure 14 shows the average maximum and minimum monthly temperatures (2004–2013) for the two stations maintained by the Department of Hydrology and Meteorology (DHM). Overall temperatures were lowest in Dhulikhel (1,552 masl), and highest in Panchkhal (865 masl) and Tinpiple, with the lowest temperatures in January and highest in June at all stations. The minimum temperatures in Panchkhal in winter (January to March) were lower than in Daraune Pokhari, which is at a much higher elevation, possibly as a result of the fog that prevails in the mornings in Panchkhal in winter. Single-year data from the pilot study sites are not yet sufficient to enable general

Figure14: **Average maximum and minimum monthly temperatures for Panchkhal (865 masl) and Dhulikhel (1,552 masl) for the period 2004 to 2013**

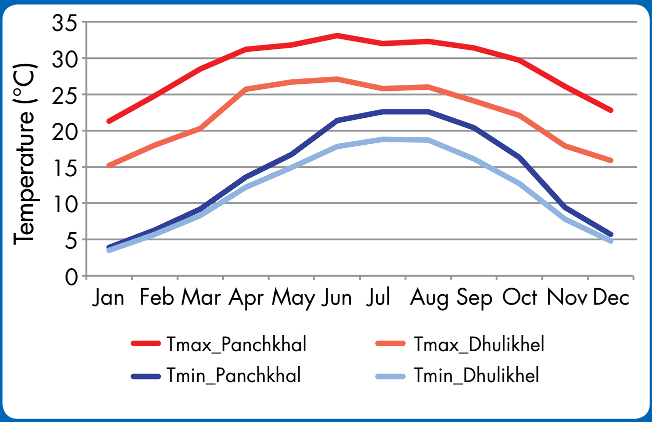
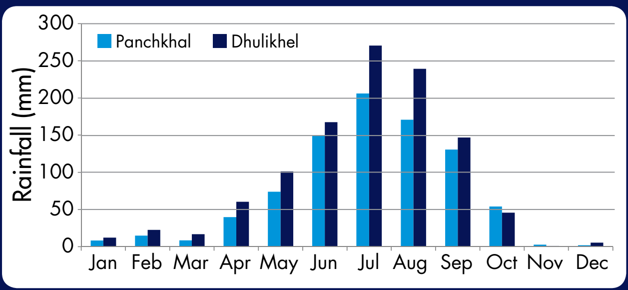
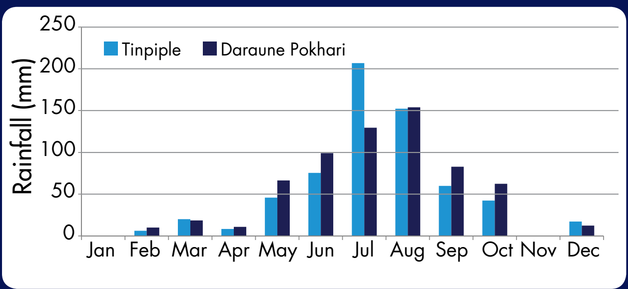


Figure 15: **Average annual precipitation in the study area**



a) Ten-year average data for 2004–2013 from DHM stations



b) Single-year data from January to December 2014 from study site stations

conclusions to be drawn, but the first results indicate the extent of variation and the importance of research into micro-climatic conditions in mountain areas.

Rainfall

The average monthly precipitation at the stations is shown in graphic form in Figure 15. The average annual precipitation (2004–2013) was 860 mm in Panchkhal and 1,088 mm in Dhulikhel in line with the Nepal average. The higher rainfall at the higher elevation station is in line with the observations of others (e.g., Nepal 2012) that in the middle mountains rainfall tends to be higher at higher elevations. Around 76% of rainfall fell during the monsoon season (June to September) at both stations. The total annual precipitation recorded at the study sites of 634 mm (Tinpiple), 646 mm (Daraune Pokhari), and 449 mm (Namobuddha) was considerably lower than the average recorded at the DHM sites. Further measurements are needed to show whether this is because 2014 was a low rainfall year or due to methodological differences. It is less likely to reflect local microclimate variation as the Tinpiple station was very close to Panchkal.

Springs and Society

Physical factors determine how springs come into existence, where and when they occur, and how they behave under different natural settings. However, the social dimensions are equally important as they determine the management and use and affect their functioning and sustainability. Human activities like infrastructure development and industry directly affect the performance – and in many cases the existence – of springs. The information gathered from the pilot study sites was used to look into these aspects and provide additional insights into the nature of springs and ponds and their function in society in the midhills of Nepal.

Water from springs is used for various purposes, mainly domestic use (drinking, washing, cleaning, sanitation), livestock (watering and washing), and irrigation. Thus, issues arise related to allocation of water for different purposes from different types of springs at different times of the year, as well as conflicts in times of scarcity. There are also issues of differentiated access due to social standing, time required to collect water and who bears this burden (children, women, men), and arrangements for maintaining and protecting sources. The following analysis throws some light on these issues and provides some insight into past problems and potential ways of managing springs better in the future.

Socioeconomic analysis

Table 4 shows the population and ethnicity at the study sites and the sources of income of the households included in the social survey (the people visiting selected springs).

Literacy levels and ethnicity

The majority of those who came to collect water were either illiterate or poorly literate with lower levels of literacy in Tinpiple than in Dapcha. This may be due in part to the relatively easier geographic access to educational opportunities in Tinpiple, which lies at a lower elevation. Tinpiple also has a majority of higher caste Brahmin/ Chhetris, 51% of the population compared to 28% in Dapcha (Table 4). Different ethnic groups sometimes predominated in areas served by different water sources. There were a significant number of Tamangs (a Janajati group) around Barbot in Dapcha, Newars around Thulo Dhara in Dapcha, and Dalits around Mandane, Bhasmeko Tanki, and Gaire Dhara in Tinpiple.

Different ethnic groups continue to experience different opportunities, and ethnic differences may also play a role in the difference in literacy levels and education. However, many factors can play a role including, for example, age distribution, outmigration, in-migration, and location of government and private schools. More research is needed to understand the differences at the study sites.

Table 4: **Ethnicity and source of income**

	Tinpiple	Daraune Pokhari
Population[a] (male:female)	7,197 (48:52)	2,027 (44:56)
Ethnicity (%)		
Brahmin/Chhetri	51	28
Newar	11	38
Janajati	8	25
Dalit	30	9
Major source of income[b] (% participants)		
Agriculture	97	97
Livestock	86	90
Remittance	15	5
Business	16	17
Government service	18	5
Private job	23	31
Agriculture labour	1	6
Non-agricultural labour	14	4
Other (driver, painter, cook, senior citizen allowance)	1	1

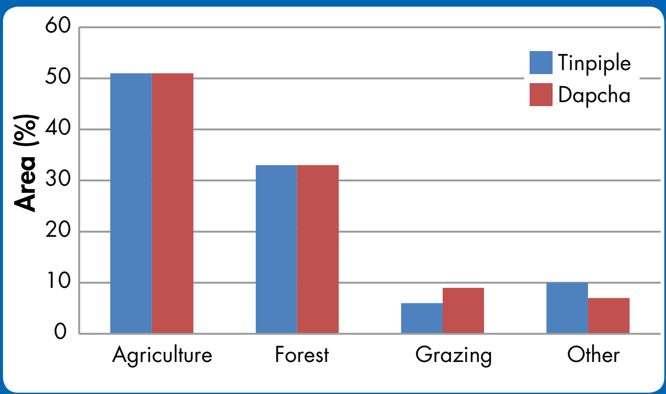
[a] Source: National Population Census 2011 (CBS 2012)
[b] Source: Social survey; respondents can have multiple occupations

Major sources of income

The great majority of people at both sites depend on agriculture for their livelihoods (Table 4). Panchkhal VDC, which includes Tinpiple, is a pocket area of vegetable farming with relatively easy access to markets in Dhulikhel and the Kathmandu Valley and has more cash crop farming. In Dapcha, which includes Daraune Pokhari, most farmers still grow subsistence crops, although a few people have started farming tomatoes as a cash crop, which is becoming more and more lucrative (called 'tunnelling' from the polythene tunnels used).

Most people have multiple sources of income (Table 4); the majority of those engaged in agriculture also rear livestock, families may have small businesses, and often some family members work in government service or private jobs, or have travelled abroad for work and send home remittances.

Figure 16: **Land use in Tinpiple and Dapcha**



Data source: Land Resource Mapping Project (LRMP) land utilization map as digitized by the Survey Department of the Government of Nepal

Land resources and land use

The land use patterns at the two study sites are almost identical (Figure 16). Slightly more than 50% of the total land area is cultivated, 33% is forested, 6–9% is used for grazing, and 7–10% is settlements, infrastructure, water bodies, wasteland, or another type of land use.

Around 80 to 85% of the cultivated land at both sites is rainfed upland ('bari' land) while the remainder is irrigated ('khet' land). The traditional cropping pattern on khet land is rice-based, with rice cultivated by holding back monsoon rain and diverting it to bunded fields; the traditional cropping pattern on bari land is maize-based. Vegetables are grown as a second crop on both types of land in winter where water is available. In recent times, production and marketing of vegetables for the Kathmandu market has become a growing and lucrative business, and the traditional maize-based cropping pattern on rainfed land is gradually being replaced by vegetables, potatoes, fruit, and other high-value crops. Millet, a major crop in the past, has almost disappeared. Those who are able to access water from springs grow vegetables such as tomatoes in polytunnels. Tinpiple is more advanced in commercial vegetable farming, but the trend is apparent in both areas. There are no formal irrigation systems. In earlier times there was a formal irrigation system in the Panchkhal valley near Tinpiple in which water was distributed through canals called 'raj kulo' (royal canal), but these now exist only in name. The system first degraded organizationally and then the structures deteriorated physically.

Most of the forests are community forests and in good condition and well managed. Community forests are usually formally registered with the government, although some in the project area are managed by informal committees that have yet to be registered. The number of user households ranges from 15 to more than 200 depending on the size of the forest and its condition. There are also a few religious forests like the Brahmapuje in Tinpiple and Pashupati Tower, Kotkalikaban, Kuldeutako ban, and Shivalayaguthi in Dapcha. Some forests are managed by religious committees ('guthi'). Some of these committees are effective and manage their forests well, for example the Kotkalikaban, while others like Pashupati Tower are neglected and have started to degrade.

The major species of tree are sal (*Shorea robusta*), pine (*Pinus* spp.), chilaune (*Schima wallichii*), utis (*Alnus nepalensis*), paiyun (*Prunus cerasoides*), and lapsi (*Choerospondia saxillaris*). Sal and chilaune are found at lower elevations and pine, utis, and chilaune at higher elevations. Until the late 1980s, pine was the most common tree species used for afforestation. As pine trees survive on almost any type of land and grow quite fast, the afforested areas quickly turned into good stands of green and dense forests, and the government promoted pine tree plantation in afforestation programmes all over the country. Later, the negative environmental consequences of pine forests were recognized: lack of undergrowth leaves soil unprotected, pine needles on the ground promote rainwater runoff and reduce the infiltration capacity thus reducing groundwater recharge, the soil acidifies, pine needles cannot be used for making good quality compost, and the trees can't be used for fodder. Some people even reported that the ponds started to dry up after the plantation of pine trees because they used more water than they retained in the soil.

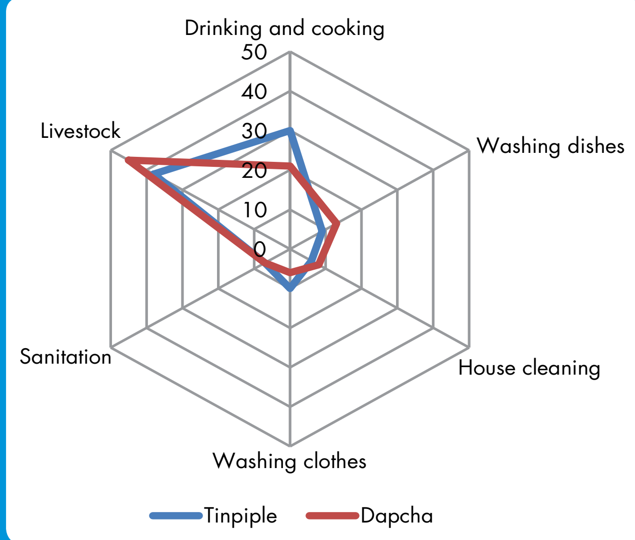
In view of the problems with pine, both the local people and the government are increasingly planting indigenous species like chilaune, champ, utis, bakaino (*Meliacomposite*), paiyun, and lapsi. The indigenous species, usually broadleaved species, tend to adapt well to the local environment, allow ample undergrowth, facilitate water infiltration, provide fodder for cattle, and produce good quality compost. Some species like champ and lapsi also have an economic value. Recently, high-value plants like coffee and amriso (bamboo grass, *Thysanolaena maxima*) have been gaining popularity. Most recently, an exotic tree native to China called paulownia (*Paulownia tomentosa*) has been introduced in the Panchkhal valley and is gaining popularity because of its economic value. It is a fast growing tree with a straight and strong trunk and is said to be as good as teak for making furniture. During the focus group discussions, some participants pointed out the possibility of using pine trees to reclaim degraded land and gradually replacing them with indigenous species once the forest is established. In fact, in many places, the community forest groups have already started to replace the pine trees in this way.

Water use

Purpose

People were asked what proportion of water they used for different purposes. The results are shown in Figure 17 in the form of a spider diagram. Livestock consumed the largest share of domestic water in both areas followed by consumption (drinking and cooking). The remainder is used for washing dishes, washing clothes, cleaning the house, and sanitation. Most of these minor activities take place at the spring itself (kuwa or dharo).

Figure 17: **Domestic water use in the study areas**



Source: Focus group discussions

In the lowlands beyond the study sites, excess water from springs feeds streams and is diverted for irrigation. But the springs at the study sites generally have little surplus, and water is rarely used for irrigation. Sometimes, when there is a surplus, water may be used in small quantities for growing vegetables in kitchen gardens, but large-scale, year-round irrigation is generally not possible. In low lying areas, rice is irrigated by diverting monsoon rainfall through small channels and capturing it in bunded rice fields.

Most of the households in Tinpiple (96%) have a pukka latrine (ceramic base flushed with water into a tank), 1% have pit latrines, and 3% are still without latrines. In Dapcha, only 58% of the households have a pukka latrine, 35% have a pit latrine, and 7% have no latrine. Approximately 1 to 2 litres of water is used per occasion in a pit latrine and 3 litres in a pukka latrine. Thus, about 10 to 15 litres of water per day per household is required for sanitation. In the monsoon, most people use rainwater collected from roofs for sanitation, which is sufficient. In the dry season, there is rarely enough water for the overall domestic supply, which compromises the level of sanitation.

Water requirement

Table 5 shows the estimated total water required for domestic purposes at the two pilot sites based on the level of fulfilment as described in the methods section. A rough estimation of the water available during the high flow

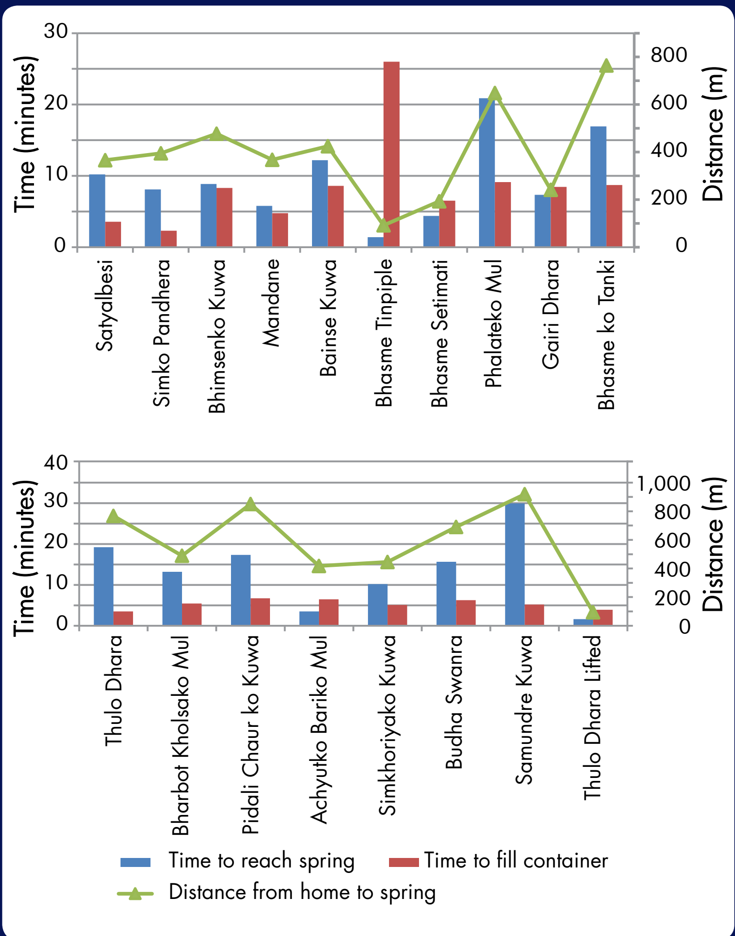
Table 5: **Estimated volume of water required at the study sites**

Requirement	Amount	Volume of water required (m³) [a]			
		Tinpiple[b]		Dapcha[c]	
		per day	per year	per day	per year
Survival minimum	1 l/day/capita (≤ 6 l/day/household)	7	2,627	9	3,456
Household low	≤ 20 l/day/household	32	11,753	44	16,016
Rural low	≤ 100 l/day/household	161	58,765	219	80,081
Rural average	40 l/day/capita (≤ 240 l/day/ household)	288	105,076	379	138,247
Estimated water available from all springs in the peak season (August–September)		181		591	

[a] Based on an average household size of 6; [b]1,616 households, population 7,197; [c]2,194 households, population 9,469
Data source: based on CBS Population Census 2011

season from all the springs mapped indicates that it is sufficient to meet the rural low demand in Tinpiple and more than sufficient to meet the rural average demand in Dapcha. In the dry season the flow in many springs decreases and many springs go dry, markedly reducing water availability.

Figure 18: **Distance from spring and time to collect water in Tinpiple (top) and Daraune Pokhari (bottom)**



Source: Spring social survey

Water collection

Women bear the main responsibility for collecting water in both study areas. Women usually fetch water for domestic use; men are more likely to collect water when sources are far away (as at Samundre Kuwa), and at difficult times (especially during droughts) when altercations might arise. Close to 80% of the respondents who came to fetch water at the springs were women: 70% of them were adults over 20 years; very few were under 13. In the spring survey, respondents said that the division of labour for collecting water was 70% women, 23% men, and 7% children in Tinpiple, and 77% women, 17% men, and 6% children in Daraune Pokhari.

The number of people using the springs varies. Many more people came on Saturdays (the traditional bathing day) and public holidays, mainly to wash clothes and bathe. People only collect water from springs if they have no easier sources available. Power cuts also impacted the use of springs. For example, the main source of water in Tallo Hatiya Bazar in Daraune Pokhari is water pumped up from the lower spring source at Thulo Dhara, which is distributed through community taps. When there is no electricity (load shedding), there is no water in the taps and everyone from Tallo Hatiya walks down to Thulo Dhara.

The minimum requirement was reported to be about 100 litres per day for an average household without livestock, and about 200 litres per day with livestock. The consumption of water also depends on availability. In the monsoon season when availability is higher, people tend to use more water, sometimes almost double the volume used in the dry season. Collecting water from the springs can be a very labourious task. Water is traditionally collected in a metal or earthenware container called a 'gagri', which typically holds about 15 litres. Nowadays people also use plastic buckets, jerry cans, and other containers. The containers are usually cleaned inside by hand at the water source to remove any slime or dirt that has accumulated before filling with fresh water. A typical household collects eight to 16 gagris of water per day, requiring six to ten trips to the spring. If the source is nearby, one person may be able to do this, but if the source is far away, it isn't possible. In such cases, several members of the household, including children, must participate.

The time taken to fetch water depends on the distance from the spring, the time taken to queue, and the rate of discharge. Figure 18 shows the average distance from a spring, time to reach it, and time to fill a container (including queueing time) for the selected springs at the two sites, as remembered by the respondents in the survey. The time taken by individuals to queue and then fill a gagri varied from less than 5 to 45 minutes, and the time taken to travel to the source also varied from less than 5 to 45 minutes. Thus, the total time for a round trip to reach the source, fill the container, and return home can range from 10 to 90 minutes. There is some correlation between the distance to a spring and the time it takes to reach it, although this was less clear at Tinpiple. The time taken to travel is also affected by the state of the path (slope, vegetation, smoothness) and the physical condition of the people collecting. The average time it took to fill a container was generally less in Daraune Pokhari, while in Tinpiple there was greater variation. The average time taken to fill a container was far longer at Bhasme Tinpiple than at any other spring. The water from the Bhasme Tinpiple source is piped to an outlet close to the highway which is easily accessible for many households, and the time taken reflects the high number of users and resultant long queues rather than low flow.

Institutions and governance

A number of formal and informal committees manage resources at the local level. Some of these committees, like the community forest user groups, are permanent, while others, like construction committees for specific purposes, are time bound. There are a number of committees directly or indirectly related to the management of water in the study area, primarily the committees dealing with drinking water, irrigation, springs, deep boring, and community forestry. The various committees at the study sites ranged in size from seven to 17.

The formal institutional setup at the community level is very strong in the forestry sector as a result of the highly effective government community forestry programmes, which require that management of a forest is handed over to a formally constituted forest user group. These groups are very active in managing their resources at the village and community levels. We found at least seven active forest users' committees in Tinpiple and 14 in Dapcha.

User groups also exist for drinking water, deep boring, and irrigation. Drinking water is managed by informal groups at the ward or settlement level. In larger schemes, formal groups may look after the distribution of water and maintenance of the system. For this, they collect fees from the households that use water from the scheme. In some places construction committees are formed to construct storage tanks and then cease to function after construction is complete. This can mean that maintenance suffers and problems only come to light during breakdowns. There were three deep boring committees in Tinpiple and one in Dapcha involved in construction, development, and management of deep wells. There were at least three irrigation user committees in Tinpiple and one in Dapcha.

Occasionally springs may have a user committee to oversee usage rules. For example, in Bhasmeko Tanki in Tinpiple, people are required to bring clean containers to fetch drinking water and not waste water and time by cleaning their containers at the spring, especially in the dry season. Watchmen supervise the rule and those found violating it are penalized in increasing steps culminating in denial of rights and services by the users' committee.

The following major reasons for having a management committee were identified during the survey:

- Communities suffering critically from water scarcity have formed management committees to oversee rationing and allocate water on an equitable basis.
- Communities funded by government or other agencies are required to have a management committee.
- Some communities are especially active and have formed water management committees in response to awareness of the depleting volume of water and increasing demand.
- In some cases, committees are formed to explore new possibilities like deep boring.

Problems and coping strategies

The major problems people encountered related to springs and water, their coping strategies, and future plans were almost identical at the two sites. The major responses given in the survey are shown in Table 6.

Changes over the last two decades

Many changes have taken place in the study areas over the past ten to 15 years. Water resources have depleted significantly, leading to increased hardship, and land use and agricultural systems have also undergone noticeable change. At the same time, the water requirement has increased due to increases in population and changes in agricultural patterns such as double cropping (ICIMOD 2002).The major changes mentioned by local people during the survey and discussions are summarized in the following sections.

Changes in water resources and coping strategies

The flows in the main rivers, the Jikhu Khola in Tinpiple and Dapcha Khola in Dapcha, are only a fraction of what they used to be ten to 15 years ago. Local people believe that flow in the Jikhu Khola has decreased by more than 75% over this period; extremely low flows were also observed in earlier studies (ICIMOD 2009a). Dapcha Khola used to flood every year during the monsoon and it was impossible to cross when there was no bridge, but now this never happens. The research team noted that even in the peak monsoon season the river had very little flow and looked more like a sewer than a river. At the same time, many streams that used to be permanent have either become seasonal or have dried up completely, and the discharges of the springs were also thought to have decreased considerably, indicating a relationship between spring discharge and stream flow. Groundwater inflow and spring discharge are the main sources of the streams and rivulets, thus drying up of the springs leads to drying up of the streams, and in turn contributes to reduced flow in the rivers. Other factors may also be involved, including reduced rainfall (drought), increased diversion of river water upstream, and increased extraction of water so that no surplus remains.

The easy availability of PVC pipes and cheap electric motors in recent years has encouraged communities to convey water from distant springs to both villages and individual households, which promotes increased use of water and

Table 6: **Problems with water sources, coping strategies, and alternative plans**

Problems	Coping strategies	Alternative plans
• Not enough water • Takes a long time to fill a container • Have to wait in queue • Frequent fights over water • Have to collect water at an inconvenient time (early morning or night) • Source is dirty as a result of rampant carelessness and lack of regulations • Difficult roads and fear of wild animals • Sometimes low caste people must stay at the back of the queue	• Minimize water usage • Water from springs used only for drinking • Rationing of water especially in the dry season • Use distantly located streams and other sources for washing/cleaning and livestock • Install deep boring • Use tanker • Prevention of continuous leakage of water collection tank	• Provide tap water from deep boring to households without sufficient drinking water • Construct dug well • Improve spring • Construct large reservoir tank with lock system and proper distribution • Construct deep boring (e.g., deep boring constructed by the Bakhreldihi Khanepanitatha Sarsaphai Upbhokta Samiti at Simko Pandhero to provide alternative source of water) • Proper maintenance of spring (kuwa) • Deepen existing source • Get tap water from other sources and deep boring • Construct water tank to store surplus water that would otherwise go to waste, and use as an alternative source for livestock and irrigation

means there is no surplus left to feed the rivers. The consequences of such unregulated tapping of the springs on groundwater is not known precisely, but it is likely that it is a major factor in the depletion of the water sources.

Deep drilled wells (deep borings) have emerged as an important alternative source of domestic water. These wells, drilled using heavy machinery, are typically 150 to 250 metres deep and provide continuous water sufficient for 150 to 200 households. The wells are perceived as an inexhaustible and reliable source of water and thus preferred by most people, but they have an impact on the groundwater table. In places like the low lying valley floors where shallow groundwater is available, people use shallow hand dug wells to supplement domestic water. However, the water table that feeds these wells is going down every year, especially since deep wells have been dug.

Where no alternative sources are available, people have responded to the shortage of water by reducing the number of livestock and changing crops and cropping patterns. Another way of coping is to look for distant sources and to use inferior quality water from streams instead of spring water.

When discharge from a spring decreases, the spring may be transformed in an attempt to conserve and store as much water as possible. For example, when flow is very low, a shallow pit (kuwa) is dug to hold the seeping water, which is collected with the help of jugs, small buckets, gagris, or even bottles. When the water in the kuwa decreases, people widen it and dig deeper to form a well (inar), and sometimes construct a concrete tank in the hope of collecting more water from the spring.

Ultimately, when people cannot get sufficient water, they are forced to migrate to places where water is available, usually to the valley and flat land below or to distant towns and cities. During focus group discussions, people highlighted this as a main cause for migration; however, there are no official records or research to prove it.

Changes in land use, agriculture, and forest

Over the past 15 to 20 years, much of the agricultural land, especially the rainfed bari and 'pakho' land (unirrigable sloping land, mostly used to grow grass and fodder trees), has been abandoned and taken over by shrubs and trees. Thus, although the officially designated forest area has not increased, in effect the area under forest vegetation has. The built-up area, including roads, has also increased significantly.

In agriculture, crops and cropping patterns have changed in response to the shortage of water as well as the increasing demand for certain commodities like fruits and vegetables. Cultivation of millet has practically disappeared, and the area under maize is decreasing. These crops have been replaced by vegetables and fruit trees. Rice is still the preferred crop during the monsoon, but the area planted depends on the timing and extent of the monsoon rains.

The general perception in the study area is that, over the course of two decades, there has been a decline in both the quality and quantity of water available, but for irrigation the main problem is quantity. Coping strategies include reducing the area under irrigation; reducing the area under rice cultivation; cultivating crops that require less water, mainly vegetables during the monsoon season; and using pumps to extract groundwater. Water for irrigation is also extracted from dried up river beds, especially the Jikhu Khola, by digging pits that fill with seepage water which is pumped out (ICIMOD 2009a).

The forest condition has improved markedly in terms of density, crown cover, and ground cover. Much of the barren red soil that dominated the landscape of the Panchkhal area has been revegetated and greenery has been much improved. Pine, which used to be the preferred species for afforestation, is being replaced by indigenous species.

Changes in upstream areas

The land in the upstream areas of the study sites is mainly owned by the government or communities. Although government and community land is generally well protected, especially where it is forested or along a waterway, it can come under pressure for use for public infrastructure such as schools, administrative buildings, and roads. For example, in Ward No. 1 of Panchkhal VDC (Tinpiple), an upstream area is being used to make a bus depot. Residents noted that much of the upstream area had been encroached in this way over the past two decades.

Construction of roads without attempting to protect the upstream area has caused severe damage to water resources in many places. It seems likely that such haphazard development efforts have contributed substantially to the deterioration of water sources and severe shortage of water in the study area.

Climate change and its effects on water resources

Climate change is a difficult issue to assess. In Nepali, the same word, 'mausam', is used for weather, season, and climate, and it is difficult to know which of these phenomena people are referring to in discussions. In the experience of the local people, the temperature and rainfall patterns of the area have changed markedly (mausam paribartan or climate/weather change), and this has had an impact on water resources. Winters are much colder and summers much warmer than before. Frost, which wasn't seen in the Panchkhal valley a few years before, has become a regular feature. On the other hand, the ridge tops in Dapcha no longer experience the brief snowfall that used to be a regular occurrence almost every winter. Mosquitoes, once unheard of in the higher elevations of the Dapcha area, are now common. The increased temperatures have manifested in changed behaviour of plants. For example, in the year before the survey, mango and guava trees had flowered and fruited a full month earlier than usual.

Local people felt that rainfall had decreased and become more unpredictable. The onset of the monsoon is often delayed by a few weeks or more, while occurrences of untimely and torrential rainfall have increased. There has been an increase in other extreme climate events too, including heavy frosts and extended drought. Severe flooding and hailstorms have decreased, but flash floods during heavy rainfall events have become common. These changes have led to a deterioration in the water resources. There is an overall decrease in water availability and increase in uncertainty. Soil erosion on the slopes and silting in the low lying areas continues. But the biggest problem is the reduction in 'useful' precipitation, which is spread over a long period and can infiltrate the soil, accompanied by an increase in 'useless' rainfall, which falls in large quantities over a short time during cloudbursts and runs off causing erosion and damaging fields and pathways, and not contributing to infiltration.

As climate change is a recent phenomenon, people are not sure how to cope with it effectively. Some useful strategies have already emerged, such as changing crops and cropping calendars in response to the changes in temperature and rainfall. One of the most visible strategies is the replacement of grain crops with vegetables and fruit. Although economics is the primary reason for this change, the change in climate has acted as a catalyst. Other responses to the change in water supply are described in earlier sections.

Experimenting with spring revival

Connection between ponds and springs

As water scarcity started to become acute in the late 1980s and early 1990s, interest rose in the problems of springs and the importance of groundwater recharge. Many local people associate the onset of the shortage of water in the pilot study sites with an earthquake in 1988/1989. According to them, many springs disappeared after this event and new ones emerged in other places. This is technically possible, but more research is needed to discover whether the earthquake did in fact lead to a change in the aquifer outlets. It may be possible to test the theory quite soon. This report is based on research carried out up to the end of 2014, but the study continued in 2015. The massive earthquakes on 25 April and 12 May 2015 appeared to have changed the flow of some springs, with some showing increased discharge and some drying up. With the initiation of the second phase of the project, investigation into this has already started and we expect to see some results soon.

Spring recharge schemes using eyebrow pits, slope vegetation, and other methods for trapping monsoon rainfall and increasing infiltration have been successfully tested in some small scale studies (e.g., Sharma and Banskota 2005; ICIMOD 2007). But in the study area, the potential role of ponds in recharging the springs only became evident in recent times (Upadhya 2009; DOLIDAR 2013). The relationship between ponds upstream and springs below at the study site became clearer both to the researchers and the local community during the course of the project. Only recently, with the acute shortage of domestic water, have people started to consider the role of ponds in recharging the groundwater and sustaining the springs.

Figure 19: **a) Location of Daraune Pokhari and Thulo Dhara; b) Daraune Pokhari at the top of a ridge; c) Thulo Dhara, a perennial spring with more or less constant discharge throughout the year**

Source: a) Google Earth

Daraune Pokhari, the pond which gives its name to the second site, provides a good example. Daraune Pokhari is a relatively large pond located close to the top of a ridge (Figure 19). There are several perennial springs downstream of the pond including Kamikate Kholsako Mul, Pandali Kholsako Mul, and Phaparchhare Mul. One of the most prominent is Thulo Dhara, a perennial spring towards the foot of the slope. There are two sources at Thulo Dhara: water from one is conveyed into a storage tank which feeds a community spring (Figure 19c); water from the other is stored in a tank, pumped to another storage tank located above the settlement, and distributed through pipes to houses in Tallo Hatiya Bazar. Daraune Pokhari acts as a reservoir and continuously recharges the groundwater in the 'water tower' as it discharges through the springs.

Following frequent visits to the study areas and interactions between the research team and the local community, people have become more aware of the way in which ponds can capture rainwater, increase groundwater recharge, and increase spring discharge. The respondents at both study sites were enthusiastic about trying to increase spring discharge by constructing new or rehabilitating dried up ponds.

Pond construction

Six sites were selected for pond rehabilitation or construction, three in Daraune Pokhari and three in Tinpiple, with the intention of trying to increase discharge in a specific linked spring (Table 7). The ponds were constructed in partnership with the local communities. Where necessary, materials, tools, skilled labour, and supervision were provided by NWCF; the local communities provided voluntary labour. There was a lot of enthusiasm at all sites, with a high turnout for the construction.

Table 7 provides some details of the ponds including location, elevation, dimension, type of intervention (new construction, rehabilitation, or reconstruction), major work done, and springs potentially enhanced by them.

The impact of the ponds on spring recharge will only become clear after one or two seasons of implementation, but the success in increasing water storage was clearly shown in the first rainy season. The photographs in Figures 20 and 21 show the conditions at the sites before and after the work was carried out.

Challenges

The main problem encountered in the action research process was finding a proper authoritative voice in a highly fractured village polity. Although ad hoc committees were formed, significant community mobilization is needed before such activities can proceed. The presence of legitimate, elected local officials is crucial. However, no local elections have been held in Nepal for some years and there are problems across the country resulting from the lack of elected local officials. There were also some problems arising from the difficult nature of politics. For example, people in Humagainthok divided into two distinct groups belonging to different political parties. In some places people focused more on who had brought the project to the community than on the community benefit, and leaders of other groups lost interest. In those places where community mobilization was effective, we encountered a very high level of participation in the pond activities. The local people were very interested in the work and hoped for good results.

Table 7: **Pond construction sites and potentially enhanced springs**

Tinpiple			
Pond name	**Mandane Pokhari**	**Thanti Pokhari**	**Tinpiple Clubko Pokhari**
Location	Ward 9 27°37′25.46″N; 85°36′37.45″E 996 masl	Ward 1/7/9 27°37′41.45″N; 85°35′54.84″E 1,269 masl	Ward 8/9 27°37′45.23″N; 85°36′53.42″E 965 masl
Dimensions	133 m² x 2 m deep	35 m² x 1m deep	96 m² x 2 m deep
Work done	New construction: Small check dam construction with stone masonry; deepening and widening of the pond area; runoff diversion channel; outlet protection	Rehabilitation: Increase in area and depth; consolidation of downstream walls with stone masonry; inlet protection	Rehabilitation: Fencing with mesh wire; cleaning; cracking of the plastered bottom to let water infiltrate
Potentially enhanced springs	Mandane Kuwas (three)	Bhasme springs including Bhasme Tanki, Bhasme Setimati, Bhasme Tinpiple	Support to Simko Inar
Daraune Pokhari			
Pond name	**Barbotko Pokhari**	**Humagaithok Pokhari**	**Jogipani Pokhari**
Location	Ward 5 27°32′4.05″N; 85°37′33.28″E 1,576 masl	Ward 8 27°33′8.71″N; 85°37′42.25″E 1,364 masl	Ward 9 27°32′48.41″N; 85°37′0.27″E 1,671 masl
Dimensions	380 m² x 1.5 m deep	380 m² x 1.5 m deep	220 m² x 1.5 m deep
Work done	Rehabilitation: Increase in area and depth	Rehabilitation: Increase in area and depth	Rehabilitation: Increase in area and depth; consolidation of downstream walls with stone masonry; inlet protection; safe outlet
Potentially enhanced springs	Barbot Kholsako Kuwa	Natepani spring and Jimalbote spring	Joigipani Kuwa, Mayalpani spring

Figure 20: **Ponds in Tinpiple before and after rehabilitation and construction work**

Mandane Pokhari

Thanti Pokhari

Capacity building

Capacity building was an integral part of all project activities. It included overall sensitization and awareness raising in the community through multiple interactions; working with the community in identifying water sources; training community members to measure climate data and discharge, and to record and transmit the values; working with the community to identify sites for pond (re)construction and involving them in the construction itself; and training in pond maintenance. Key members of the communities were invited to participate in a three-day workshop in Kathmandu organized from 19 to 21 January in 2014 to familiarize them with water science and to introduce them to relevant work in Kathmandu and Dapcha. Five people from each of the two sites, including local leaders, science teachers in charge of measuring the climate data, and a woman, participated in the Kathmandu workshop. The participants were introduced to basic theory on springs, recharge ponds, and rainwater harvesting, supplemented by field trips to ICIMOD's Knowledge Park at Godavari; the Lutheran World Federation (LWF) farmer's field experimental site at Chhampi; the rainwater harvesting facility run by Narendra Dongol, a water harvesting expert, at Swayambhu; and the rainwater harvesting, groundwater recharge, and water purification systems of the Namobuddha Resort in Kavre. The project also worked with Namobuddha FM Radio, a popular community radio station in the study area, to disseminate information on the activities and findings of the project, broadcast interactions with experts in water science and other related disciplines, and broadcast daily weather data measured at the study sites. A representative from the radio station also participated in the capacity building workshop in Kathmandu. As a part of the second phase of the project, Namobuddha FM has started broadcasting regular programmes related to the springs and ponds and local water management in the area.

Figure 21: **Ponds in Daraune Pokhari before and after rehabilitation and construction work**

Barbotko Chaurko Pokhari

Humagaithok Pokhari

Jogipani Pokhari

Project Learning

Sources of water

The people in the project area rely almost entirely on the local underground aquifers for their water supply. These aquifers supply the array of springs that emerge around the hills, which are the ultimate source of most household water, as well as dug wells. In the past, people went directly to the springs to collect water, now increasingly water is pumped along PVC pipes and delivered to taps in the local villages. Especially at lower altitudes, people tap the aquifers by digging shallow wells; more recently deep boring wells have been constructed to serve whole communities with piped water. On occasion, people also collect water directly from the rivers and streams that flow through the area.

Rainfall, most of it falling in the monsoon period, recharges the underground aquifers, effectively turning the hills into water towers. The cycle of recharging and emptying of the water tower repeats year after year. As long as the balance between recharge and outflow is maintained, the water tower is sustainable. However, the sources are becoming depleted, which is shown most clearly in the large number of dried up springs, and lack of sufficient water is one of the major constraints to maintaining or improving livelihoods.

Why are the springs drying up?

Both the Tinpiple and Dapcha sites are located in a small rain shadow area and receive much less rain than nearby Dhulikhel. Local people believe that the amount of rainfall has decreased over the years, and that this is contributing to the drying up of springs in the area. However, previous studies have indicated that people's perceptions of water shortages may reflect changes in consumption patterns rather than actual changes in availability (ICIMOD 2002). Studies of rainfall in the region indicate that precipitation has not changed overall, although there may be short-term variations (Shrestha et al. 2000). There is no evidence that rainfall has declined significantly, except for an extreme event in 1992 when the winter rains failed completely across Nepal. Further study would be needed to discover whether there has in fact been a reduction in local rainfall in recent years, but this is difficult as there are limitations to the long-term data available. In the future, the rainfall data collected by the school science teachers and Namobuddha Resort will help answer questions of local variation more decisively. Whether or not total rainfall has changed, there does seems to be a change in rainfall patterns, with an overall change in timing, and an increased number of events of short, high intensity rainfall, which runs off very quickly and can lead to disastrous effects like flooding and landslides.

What is clear is that consumption, and thus extraction, have increased considerably over the years. There are various reasons for this. First, the population is increasing, which means increased water requirements. Modern lifestyles also require more water, for example improved sanitation with flush toilets in place of open defecation, improved personal hygiene, and increased washing of clothes. The trend towards commercial agriculture is also affecting water sources. Water use has increased as cash crops (tomato) are grown in fields formerly used to grow dry land maize and millet. Using pumps and PVC pipes to extract water from springs to grow vegetables in polytunnels has put extra stress on the springs.

Ease of access has also increased household use of water. The traditional approach of collecting water from a nearby spring is laborious and time consuming, and by its nature limits the amount of water people use. Today, however, PVC pipes and electric motors have made it easy to pump water directly from the springs, and people only visit the water sources if they have no other option. Market forces have reinforced this trend, the Thulo Dhara lift in Daraune Pokhari has tapped more than four spring sources to raise water and supply it to the households in the higher elevation bazaar area. There is no awareness that water is limited; with water coming from a tap, the direct personal link to the source no longer exists, and there is no realization that spring discharge has lessened and no idea of social control based on conservation ethics. The traditional rituals and customs that limited water use and provided mechanisms for managing and conserving water sources have been lost. In places, various formal and informal committees have been established to manage drinking water schemes of different sorts. However, the lack of elected local bodies means that these management schemes face problems of legitimacy, and a lack of authority for coordination and regulation.

The problems of increased extraction are compounded by a lack of awareness of the mechanisms that support recharge of the springs. Although it wasn't measured directly, the project findings indicate that some of the mechanisms supporting recharge have been disturbed. Land use is known to have a considerable influence on the recharge of aquifers (Sharma 2005; ICIMOD 2007, 2009b). In the study area, traditional water harvesting and collecting schemes such as the ponds maintained for buffalo and as a source for irrigating kitchen gardens have been abandoned and allowed to silt up following changes in agricultural practices. It is likely that these ponds used to provide a recharge source during the dry season. At the same time, using electric pumps to extract water from the springs may have changed the hydraulics of water seepage among interlinked springs, and, on a broader scale, installation of high capacity deep boring wells to extract groundwater for commercial use is likely to have an impact on the hydraulic system and shallow groundwater levels across an extended area. Haphazard construction of infrastructure such as roads may also have impacted infiltration.

Local responses to the shortage of water

The water problems were more acute in the lower elevation area of Tinpiple, and people had resorted to different practices to obtain water. Where possible, households had dug shallow wells, but competitive deepening and the proliferation of deep boring wells meant that many were going dry. There were fewer deep boring wells in Dapcha, but more are planned. Following the project interactions and capacity building workshop, some leaders are beginning to realize that this competitive drilling will not be sustainable and that there is a need to complement wells and borings with a programme to recharge the groundwater.

Most households collected rainwater from roofs during the monsoon, but very few had installed systems for collecting the water into large containers and/or plastic lined ponds to provide water into the dry season. Encouraging installation of rainwater harvesting on a much larger scale could help to alleviate household water stress and reduce some of the pressure on springs.

Meeting future water needs

In principle, the annual rainfall in the monsoon dominated areas of the Himalayas is more than sufficient to meet the requirement for water. But it is highly seasonal, and the greater part of the monsoon water simply runs off into the rivers, not only lost to the users, but also leading to floods downstream. If sufficient monsoon precipitation could be collected and stored locally, it could provide enough water to meet all agricultural and household needs throughout the year (Vaidya 2015). Recharge of groundwater aquifers is an important part of this. This means both maximizing infiltration of rainfall during the monsoon through appropriate land management practices that slow runoff and increase porosity (forests with undergrowth, conservation tillage, eyebrow pits, and many more, see for example Shrestha et al. 2012), and harvesting and storing monsoon rainfall both for direct use (storing in containers and lined reservoirs) and to facilitate continued infiltration and recharge during the dry season (storage in ponds).

Reviving the ponds

The water that feeds the springs is contained both in the soil and in aquifers. Understanding and predicting storage in a particular location, and the correlation between rainfall and spring flow, is an uncertain science, and although advanced scientific studies using tracer analysis and geological drilling might help elucidate the flow patterns, it is very expensive and only relevant in a specific location. For practical purposes, 'learning by doing' offers a better approach in the midhills. In other words, build recharge ponds and see whether spring flow is enhanced. Even if the flow is not markedly improved, the soil will benefit from having greater moisture, which will improve the conditions for agroforestry.

As the study progressed, the relationship between ponds upstream and springs below became clearer both to the researchers and to the local community. Many instances of springs that had dried up after ponds disappeared were recollected during the interactions. This encouraged the idea of using pond construction and/or rehabilitation to recharge the water towers in an attempt to sustain or revive springs for community use. This innovative approach was taken up at both sites and local support for the idea was clearly shown in the high turnout of labour to dig the ponds and requests for construction of similar ponds in other places within the study areas and neighbouring VDCs. Enabling the community to carry out these experiments – grassroots science – has the added benefit of increasing both ownership, essential for successful maintenance, and understanding, essential for extending the approach. The real success of the approach will only become apparent after a few seasons, but it is a very promising start.

Conclusions and Recommendations

In the villages of the midhills of Nepal, springs are a lifeline – providing water to sustain the needs of households, their farms, and their livestock. However, people are facing increasingly extreme shortages of water, and many once reliable springs are now dry. Although lack of rainfall is often blamed for the shortage of water, it seems that the problem is more the result of increased water consumption, increased extraction, and reduced recharge resulting from land use and other changes. Increasing water use efficiency to reduce consumption, and controlling extraction to match the potential available, are important, but the focus of the pilot study presented here was on restoring and increasing recharge, specifically through the rehabilitation and construction of ponds in spring recharge areas.

The villagers in the area were unaware of the link between recharge and spring flow, and had not considered that they themselves might be able to improve the water supply situation through simple (re)construction of ponds. The small project had a marked impact in raising awareness and potentially empowering the villagers to take some control over their water situation. However, local political divides, social discrimination, commercial interests in exploiting water supplies, and lack of a functioning local administration, as well as a tendency to expect and rely upon outside support, hinder the ability of local groups to take full control and ownership of such schemes. Previous experience with time-bound projects, and the feeling of abandonment when projects come to an end without proper planning for local continuation, have also led to a situation of mistrust. Thus it is important to build awareness among the villagers, to involve them closely in planning and implementing activities, and to provide long-term engagement and support which empowers local people to regain a level of control over and improve the water supply situation.

Recommendations

The pilot study enabled us to glean some important insights and take some initial steps towards deeper understanding of the nature of the springs and ponds in the midhills of Nepal. Although it will be some time before the efforts aimed at spring recharge can be properly evaluated, the initial results are promising. It would be useful to expand the project over the coming years both to intensify spring rehabilitation and to increase understanding of the processes involved, and encourage much wider uptake of approaches aimed at water storage and spring rejuvenation in the Himalayas. Active local participation is the key to success in this type of initiative, thus efforts should focus on communication and knowledge sharing to raise awareness of the problems and the ways in which local people can themselves actively improve the water supply situation. The idea that strategically located recharge ponds can help extend the life of a spring and rejuvenate dried up springs has been reinforced by the direct and indirect evidence in the field, but to have a sizeable impact, many such recharge ponds must be constructed in one area. Supporting land management activities may also be needed, as well as better management of the existing supplies and increased awareness of the limited nature of aquifer-based supplies and the problems posed by overextraction.

To be effective, future activities should be carried out in close cooperation with other institutions involved in similar work in the study area and beyond, such as the Advanced Center for Water Resources Development and Management (ACWADAM), International Water Management Institute (IWMI), Helvetas, Lutheran World Federation (LWF), and Namobuddha Resort. It might also prove useful to gather more information on local activities carried out in other areas in the Himalayas focused on spring recharge and local water storage solutions. Some of the specific activities recommended are summarized below.

- It would be useful to extend the activities on pond construction and recharge for at least five years to enable proper testing of the impact. More ponds should be rehabilitated and constructed both in the area covered by the present project and in neighbouring areas. Additional approaches should also be tested, for example afforestation and vegetation above and around the springs, and digging of eyebrow pits on suitable slopes.

Young professionals should be trained as trainers in recharge pond construction, and capacity building activities for the communities in the local and neighbouring area should be intensified so that the approach can be scaled up through community action. Almost all the midhills regions in the Himalayas are facing problems with drying up of water sources and insufficient water supply. Thus, the possibilities for scaling up the programme on a large scale should be explored.

- More detailed geohydrological studies including the use of tracers might prove useful to trace the movement of underground water and strengthen theoretical understanding of the characteristics of the springs and ponds in the midhills.
- The climate stations should be upgraded to technically recommended standards with proper fencing and adequate equipment so that the relationship between rainfall, recharge, and spring discharge can be better studied. It would be useful to install at least one continuous recording station to capture intense rainfall events.
- A communications plan should be prepared to ensure that the findings of the research are shared both with the local community and with a wider audience. Activities could include collaboration with local community FM radio stations and dissemination via mass media, workshops, seminars, publications, and others.
- Further activities that could prove useful include developing a springs database, both for the project area and for use across Nepal, updating and expanding the pond construction handbook to cover different ecological regions, as well as related techniques to support recharge and increase storage, and lobbying to include pond construction and local water storage solutions in development interventions and as government policy.

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Annex 1: **Questionnaires and checklists**

Checklist for focus group discussions

1. General

Area:	
VDC:	
Ward Nos.	
Village/settlement	
No. of households	
Average family size	
Total population	
Male/female ratio	

2. Water Resources by Type

2.1 Rivers

2.1.1 What are the major rivers and streams in the area?

River/stream name	Water availability (seasonal, permanent)
1.	
2.	
3.	
4.	
5.	

2.1.2 For what purpose is the river water used?
Drinking:
Livestock:
Irrigation:
Others:

2.1.3 Have the flows of rivers changed over the past 10 to 15 years?
(Increased, decreased, or remained the same)

2.2 Springs (mul, dhara, and kuwa)

2.2.1 How many springs exist in the area and how are they distributed geographically?

Location*	Permanent	Seasonal	Completely dry
*Location can be up or down or east, west, north, south, etc. depending on the cluster			

2.2.2 What is the duration (months) for which water is available from muls?
Permanent:
Seasonal:

2.2.3 What volume of water do the springs discharge?
Permanent: Maximum………………, Minimum………………, Average………………
Seasonal: Maximum………………, Minimum………………, Average………………

2.2.4 For what purpose is the spring water used?

2.2.5 What changes have you noticed in the past 10 to 15 years in terms of water availability from springs?

2.2.6 If water availability has decreased, how do you cope with it?
Drinking:
Washing, cleaning:
Irrigation:
Livestock:
Others:

2.3 Ponds

2.3.1 How many ponds exist in the area and how are they distributed geographically?

Location*	Permanent	Seasonal	Completely dry
*Location can be up or down or east, west, north, south, etc. depending on the cluster			

2.3.2 For what purposes are the ponds used (religious, recreational, watering animals, fishery, washing, cleaning, groundwater recharge)?
2.3.3 Which of the ponds mentioned above have performed well in terms of water availability and what is the reason for this?
2.3.4 Please give the location of those ponds that may be contributing to recharge the springs downstream.
2.3.5 How have ponds changed in the past 10 to 15 years in terms of numbers, water depth, quality, etc.?
2.3.6 Do you think there is a connection between ponds and springs? Please give examples.
2.3.7 Do you plan to build ponds for the purpose of recharging springs in your locality?
2.3.8 Where are suitable areas located for this purpose?

2.4 Inars and drilled wells (deep boring):

2.4.1 Are you using inars and deep borings for water?
2.4.2 If yes, how many are in use and how are they distributed geographically?

Location*	Permanent	Seasonal	Remarks
*Location can be up or down or east, west, north, south, etc. depending on the cluster			

2.4.3 Are inars and/or deep borings reliable sources of water? Which is better?
2.4.4 How does the depth of water fluctuate between dry and wet seasons?
2.4.5 What is the quality of water from these sources?
2.4.6 Do you get sufficient water for all your needs? If not, how do you prioritize them?
2.4.7 Have the number of inars and bored wells increased or decreased in the past 10 to 15 years? What about the water table?

2.5 Rain water harvesting:

2.5.1 Do you harvest rainwater in your locality? When was the first rainwater harvesting scheme introduced?
2.5.2 How many households use this practice now?
2.5.3 How has the number of households using this practice increased over the past 15 years?
2.5.4 What kind of water harvesting system is commonly used (collection in drums and buckets, open storage tank, closed storage tank, plastic pond, groundwater recharge, etc.)?
2.5.5 What is the average capacity of the household level rainwater collection system?
2.5.6 What are the preferred uses of water from this source?
2.5.7 For how many months is the harvested water sufficient?
2.5.8 What is the level of acceptance for a rainwater harvesting system? Do you think this is a sustainable source of water for household use?

3. Sources of water for various uses

3.1 For domestic use

3.1.1 What are the major sources of water for domestic use?

System	Number	Beneficiary Households
Tap water (government)		
Tap water (private)		
Spring water (mul, dhara, kuwa)		
Inar (dug well) and bored well		
River/stream		
Tanker		
Rainwater harvesting		

3.1.2 Is the quantity of water sufficient for all your domestic needs (including drinking, cleaning, washing, sanitation)?
3.1.3 What is the quality?
3.1.4 What changes in quantity and quality of water from different sources have you noticed in the past 15 years?
3.1.5 If there has been a decline, how do you cope with it?

3.2 Sanitation

Type	Volume of water used	Source of water	Number of households
Pit latrine			
Pukka latrine			
No latrine			

3.2.1 Is sufficient water available for all your sanitation needs? If not how do you cope with it?

3.3 Irrigation

3.3.1 Major sources for irrigation:

Source	Type (permanent, seasonal)	Irrigated area	Beneficiary households	Trend (increasing/ decreasing)
River/stream				
Spring (mul, kuwa, dhara)				
Ponds				
Canal/channel/raj kulo				
Rainwater harvest				
Inar/deep boring				
Other				

3.3.2 Methods of irrigation:

Method	Trend (increasing/ decreasing)	Source	Remarks
Flooding			
Polythene pipes			
Sprinklers/drip			
Others			

3.3.3 Is the quantity of water sufficient for all your agricultural needs (including irrigation and livestock)?
3.3.4 What is the quality?
3.3.5 How are the irrigation systems managed (in terms of institution, rules, regulations)?
3.3.6 What changes in quantity and quality of water for agricultural use have you noticed in the past 15 years?
3.3.7 If there has been a decline in quality and quantity, how do you cope with it?

3.4 Other users

3.4.1 Who are the other users of water in this area (e.g., hotels, industry)?
3.4.2 What are the sources used for this and what is the situation regarding sufficiency, quality, etc.?

4 Land use and land related activities

4.1 Land use

Land use	Estimated area (%)	Notes and remarks
Agriculture		
Forest		
Grazing		
Others		

4.2 Agricultural practices

4.2.1 What are the proportions of khet and bari lands?
4.2.2 What are the major crops and cropping patterns?
in khet land:
in bari land:
4.2.3 What changes have taken place in the past 10 to 15 years in:
land use?
crops?
cropping patterns?
production and yields?
use of pesticides and chemical fertilizers?

4.3 Forests

Forest name	Type*	Condition	User/ beneficiary households
*government, private, community, leasehold, religious, national park/reserve, others			

4.3.1 What are the natural forest species?
4.3.2 What are the species used in afforestation?
4.3.3 How have forests changed over the past 15 years in terms of:
Area under forests?
Forest condition?
Species of trees and other vegetation?
4.3.4 What are the water resources available within the forests?
Rivers/streams:
Springs (mul, kuwa, dhara):
Ponds:
4.3.5 How are the water resources in the forests utilized?
4.3.6 What is the quality of water?

5. Water collection and allocation for domestic use (Preferably to be asked to women)

5.1 Who fetches water for household use (men, women, children)?
5.2 How much water does one person collect per day?
5.3 How many times does one have to collect water per day?
5.4 How much water does one household use per day?
5.5 How much time does it take to fetch water for household use?
5.6 How is water allocated for household use?
Drinking: %
Dish washing %
Washing clothes %
House cleaning %
Toilet %
Others (specify) %

6. Institutional and governance aspects

6.1 Which institutions are involved in managing water resources?:
Springs:
Ponds:
Wells:
Deep boring:
Irrigation canals:
6.2 How are conflicts resolved?:

7. Upstream areas

7.1 In what condition are the upstream areas of water resources that are used by the community?
7.2 Have there been any major changes over the past 15 years in terms of infrastructure, housing, land use?
7.3 Are there any plans for development and land use changes in the upstream areas in the near future?

8. Climate change

8.1 Over the past 15 years, have there been any major changes (in terms of amount and timing) in:
Temperature and rainfall?
Extreme events e.g. floods, droughts, hail storms?
8.2 How did they impact on the water sources in the area?
8.3 How did people cope with impacts?

Spring Social Survey Questionnaire

SPRING Name and ID:	RESPONDENT CODE:
Date of interview (English):	Time of interview: Start: /Finish:
Name of the interviewer:	Name of the supervisor who checked the questionnaire:

Part 1. Respondent information

1.1 Name of the respondent (who has come to collect water):	1.2 Age (years):
1.3 Sex (Male = 1; Female = 2):	1.4 Caste:
1.5 Level of education (non literate = 0, just literate = 1, primary school = 2, lower secondary= 3; secondary = 4, higher secondary= 5; graduate and above =6):	1.6 Marital status (unmarried = 1, married = 2, spouse deceased = 3, divorced or separated = 4, any other = 5):
1.7 Village and VDC name where respondent lives:	1.8 Ward No. where respondent lives:
1.9 For whom are you collecting water? (own household =1; employers hh =2; relative's hh =3; anybody else's hh =4)	1.10 Total number of household members for whom this water is meant: Adult male (above 16 years): Adult female(above 16 years): Male child (below 16 years): Female child (below 16 years):
1.11 Name of household head for whom the water is being collected:	1.12 Phone no. of HH head or respondent:
1.13 Sources of income for the entire household for whom water is collected (crop cultivation = 1; livestock = 2; remittances = 3; business = 4; government service = 5; private service = 6; agricultural labour = 7; non agricultural labour = 8; any other (specify) = 8 [you can choose more than one option]	
1.14 Of the above sources you mentioned, which one is the MOST important:	
1.15 Level of income (monthly): < Rs. 1,000 = 1; Rs. 1,000–5000 = 2; Rs. 5,000–10,000 = 3; Rs.10,000–Rs.20,000 = 4; Rs.20,000–50,000 = 5; >Rs. 50,000 =6	

2. Spring-specific questions:

Monthly water collection data

Month	Chait, Baishakh, Jeth,	Asar, Saun, Bhadau, Asoj	Kartik, Mangsir	Pus, Magh, Fagun
2.1 Number of times in a day when water is collected?				
2.2 Number of days in the week when water is collected (0-7)?				
2.3 Number of gagris/jerry cans/containers collected per day?				
2.4For how many years have you been collecting water from this source?		2.5 How far (meters) is your home from this spring?		
2.6 How long (in minutes) does it take to reach this from home?		2.7 How long (in minutes) it takes to fill up your gagri/jerry can/container?		
2.8 Capacity of one gagri/jerry can/container (in litres)		2.9 For what purposes do you use this water? (1= drinking; 2= washing clothes; 3= other domestic use such as washing utensils; 4= for livestock; 5= for irrigation; 6= for religious purposes; 7= any other): You can write more than one		

2.10 Do you have to stand in a queue tocollect water? (yes, always=1, no, never=2; sometimes=3)	2.11 Are you allowed to collect as much water as you want in a day? (Yes, always=1/No, never=2; Sometimes=3)
2.12 If you answer, no, never (=2) or sometimes (=3) to Q. 2.11, then how many gagris can you collect at a time in the rainy season?	2.13 If you answer, no, never (=2) or sometimes (=3) to Q. 2.11, then how many gagris can you collect at a time in the dry season??
2.14 Any other rule for water collection? (0= no rule; 1= open only for a specified time in a day; 2= only nearby people are allowed to take water; 3= number of gagris allowed depends on family size; 4= special provisions made for religious/family events like births, deaths and marriages; 5= any other rule, please explain)	
2.15 Perception ofquantity of water from the spring source? (1= always sufficient; 2= usually sufficient; 3= sometimes sufficient; 4= rarely sufficient; 5= never sufficient)	2.16 Has the volume of water in this spring changed over the past 10 years? (1 = increased; 2 = decreased; 3 = no change)
2.17 If volume (quantity) of water has changed (increased or decreased), why?	
2.18 Perception on quality ofthe spring source? (1= very good; 2= good; 3= fair; 4= poor; 5= very poor)	2.19 Has the quality of water in this spring changed over the past 10 years? (1 = improved; 2 = declined; 3 = no change)
2.20 If quality of water in this spring has changed (improved or declined), then why?	
2.21 Problems faced while collecting water: 1= not enough water; 2= takes long time to fetch water; 3= have to stand in queue; 4= there are frequent fights over water; 5= have to collect water at inconvenient times (early morning or night); 6= source is dirty; 7= any other (please specify): **You can write more than one reason**	
2.22 Any suggestions on how to improve water supply from this source?	
2.23In the past 10 years have you changed the source from which you collect water? (1=yes; 2=no)	2.24 If the answer to 2.23 is "Yes" why? (1=insufficient water in previous source; 2=more water in the new source; 3=tap water available at or near home; 4=construction of inar at or near home; 5=others (specify)) you can write more than one reason

3. Other available sources of water: ranked according to importance

Choose ALL available water sources used for household needs and agricultural needs: **(MENTION ALL)	Purposes for which water is used and water source ranked according to its importance											
	Drinking water		Domestic water (other than drinking water)		Water for livestock		Water for irrigation		Type of irrigated land (tick)		Water for other purposes	
Note: Rank, 1= most important	Tick	Rank	Tick	Rank	Tick	Rank	Tick	Rank	Bari	Khet	Tick	Rank
3.1 Dharas (springs)												
3.2 Kuwas (springs)												
3.3 Kholas (rivers)												
3.4 Kulos (canals)												
3.5 Inars (dugwells)												
3.6 Deep tubewells												
3.7 Ponds (pokahri)												
3.8 Piped water supply (from springs)												
3.9 Piped water supply (from sources other than springs)												
3.10 Rainwater harvesting												
3.11 Rainwater for irrigation												
3.12 No water source												
3.13 Other (specify)												

3.14 After obtaining water from ALL of your different water sources, how well are your household's water needs met? (1=always meets our needs 2=usually… 3=occasionally… 4=rarely… 5=never…)	
3.15 On a scale of 1–6, how dependent are you on this specific spring? (1=very low dependence… 6=very high dependence)	3.16 On a scale of 1–6, how concerned are you about the possible drying up of this spring? (SCALE 1=not concerned… 6=very concerned)
3.17 Overall, do you think there is a water crisis/problem in your locality? (Y / N)	
3.18 Any other comments	

Annex 2: **Physical characteristics and annual discharge measurements from selected springs**

Tinpiple

Spring	Location	Elevation (masl)	No. of HHs	Discharge (l/min)		Flow category
				Min	Max	
Satyalbesi Kuwa	27°37'04.92E, 85°36'59.34N	911	10	0.6	2.3	2 to 3
Mandane Kuwa	27°37'27.24E, 85°36'40.32N	955	20	0.5	1.34	2 to 3
Bhimsenko Pandhero	27°37'53.40E, 85°36'38.32N	923	20	2.4	3.53	3 to 4
Simko Pandhero	27°37'11.40E, 85°36'39.18N	878	8	0.53	1.1	2 to 3
Bainse Dhara	27°37'54.18E, 85°36'21.12N	1,004	25	2.14	2.14	3
Gaire Dhara	27°38'16.08E, 85°35'46.07N	1,050	NA	0.7	2.7	3
Bhasme –Setimati Mul	27°37'50.46E, 85°36'09.52N	1,079	30	0.5	1.5	2 to 3
Bhasme Tanki	27°37'47.16E, 85°36'58.44N	1,175	80	0.7	1.82	3
Bhasme Tinpiple Mul	27°37'49.09E, 85°36'04.38N	1,155		0.8	0.89	3
Phalateko Dharo	27°37'02.6N, 85°35'32.1N	1,202		0.97	2	3

Daraune Pokhari

Spring	Location	Elevation (masl)	No. of HHs	Discharge (l/min)		Flow category
				min	max	
Barbot Kholsako Mul	27°32'2.43E, 85°37'23.88N	1,520	90	0.3	0.66	2
Firfire Kuwa	27°32'37.02E, 85°37'17.62N	1,608	15	0.07	0.25	1 to 2
Jogipani Kuwa	27°32'46.49E, 85°36'59.26N	1,667	20	0.1	2.7	1 to 3
Mayalpani Mul	27°32'41.26E, 85°36'57.38N	1,639	20	0.08	0.38	1 to 2
Pidalichaurko Kuwa	27°32'57.24E, 85°37'30.69N	1,505	4	0.2	0.5	1 to 2
Thulo Dhara (a)	27°32'52.40E, 85°37'17.04N	1,570	300	12	15	5
Thulo Dhara (b)	27°32'52.53E, 85°37'17.70N	1,556		14	15.5	5
Kamikate Kholsako Mul	27°32'54.67E, 85°37'13.17N	1,553	25	21	24	5
Pandhera Banko Kuwa	27°32'58.97E, 85°37'31.57N	1,467	9	0.7	1.1	3
Jimal Bote Mul	27°33'15.60E, 85°37'50.56N	1,297	20	13.5	15.7	5
Pandali Kholsako Mul	27°32'55.41E, 85°37'27.10N	1,507	6	0.55	1.6	3
Phaparchare Mul	27°32'57.82E, 85°37'21.30N	1,493	10	0.15	0.53	2
Simkhoriako Mul	27°33'9.77E, 85°37'13.62N	1,428	20			
Achutko Bariko Mul	27°33'2.61E, 85°37'10.42N	1,545		1	6	3 to 4
Samundreko Mul	27°32'3.04E, 85°37'51.15N	1,442		0.6	1.1	2 to 3
BudhaswanraMul	27°32'30.78E, 85°37'29.19N	1,506		0.4	1.14	2 to 3

Station/Type	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ten year average data for 2004–2013														
Panchkhal/ DHM (865 masl)	Rainfall (mm)	8.2	14.8	8.5	39.7	73.9	149.0	206.0	170.8	130.5	54.0	2.6	2.0	859.9
	Tmax	21.3	24.8	28.5	31.2	31.8	33.1	32.0	32.3	31.4	29.7	26.1	22.8	28.7
	Tmin	3.9	6.3	9.2	13.6	16.7	21.4	22.6	22.6	20.4	16.3	9.4	5.7	14.0
	Tdaily	12.6	15.5	18.8	22.4	24.2	27.2	27.3	27.4	25.9	23.0	17.8	14.2	21.4
Dhulikhel/ DHM (1552 masl)	Rainfall (mm)	12.1	22.5	16.7	60.3	101.2	167.5	270.5	239.2	146.7	45.6	0.7	5.4	1088.3
	TMax	15.2	18.0	20.3	25.7	26.7	27.1	25.8	26.0	24.1	22.1	17.9	15.9	22.1
	Tmin	3.5	5.7	8.3	12.2	14.9	17.8	18.8	18.7	16.1	12.7	7.8	4.8	11.8
	Tdaily	9.4	11.8	14.3	19.0	20.8	22.4	22.3	22.3	20.1	17.4	12.9	10.3	16.9
Single year data from January to December 2014														
Tinpiple/pilot study (967 masl)	Rainfall (mm)	0.0	6.2	20.0	8.5	45.8	75.5	206.8	152.2	59.8	42.4	0.0	17.2	634.4
	TMax	22.1	24.4	25.0	25.0	32.4	31.3	29.8	29.0	25.3	26.1	20.3	15.7	25.5
	Tmin	9.8	10.8	11.0	11.0	22.2	23.7	24.1	23.5	19.4	21.5	13.1	8.6	16.6
	Tdaily	15.9	17.6	18.0	18.0	27.3	27.5	26.9	26.2	22.3	23.8	16.7	12.1	22.2
Daraune Pokhari Daraune Pokhari/ pilot study (1640 masl)	Rainfall (mm)	0.0	10.0	18.6	10.9	66.4	99.0	129.5	153.9	82.7	62.4	0.0	12.5	645.9
	TMax	14.5	13.8	20.4	25.5	28.2	27.2	26.3	25.1	24.5	22.8	18.0	14.1	21.7
	Tmin	5.5	7.9	11.8	16.1	18.3	20.6	20.3	19.8	18.7	15.4	11.4	7.5	14.4
	Tdaily	10.0	10.8	16.1	20.8	23.3	23.9	23.3	22.5	21.6	19.1	14.7	10.8	18.8
Namobuddha Resort/private (Elevation)	Rainfall (mm)	0.0	0.0	22.0	9.0	77.5	159.0	96.8	228.6	84.8	27.4	0.0	2.2	449.1

rainfall = total received over the month; temperatures= average for month

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