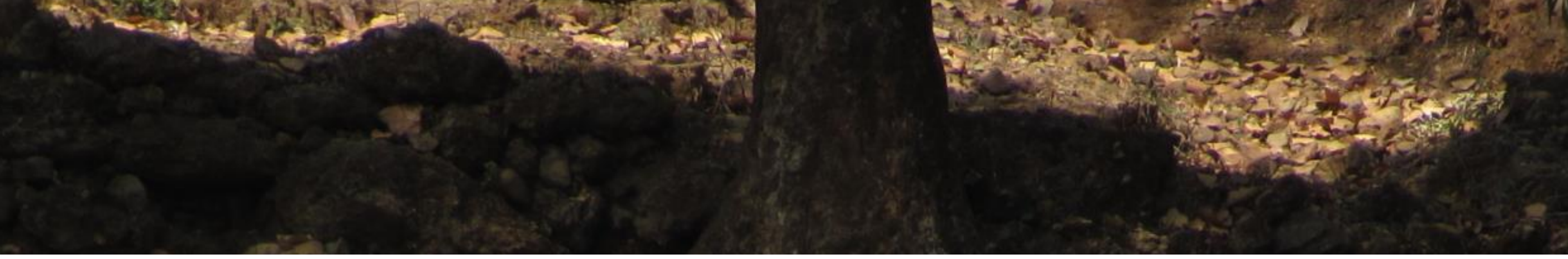

CLIMATE CHANGE, CHANGING RAINFALL AND INCREASING WATER SCARCITY

An integrated approach for planning adaptation and building resilience of smallholder subsistence livelihoods in Nepal

IGES Research Report

Institute for Global Environmental Strategies
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CLIMATE CHANGE, CHANGING RAINFALL AND INCREASING WATER SCARCITY

An integrated approach for planning adaptation and building resilience of smallholder subsistence livelihoods in Nepal

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Climate change, changing rainfall and increasing water scarcity: An integrated approach for planning adaptation and building resilience of smallholder subsistence livelihoods in Nepal

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FOREWORD

The impacts of climate change are felt increasingly all over the world and water is the key medium through which these impacts unfold. For some regions, climate change could exacerbate water scarcity through more erratic rainfall. Water scarcity is already severe in some areas because of growing socio-economic pressures on water resources. The Food and Agriculture Organisation of the United Nations (FAO) estimates that in 2025, 1.8 billion people will be living in countries with absolute water scarcity, and two-thirds of the world's population could be living in water-stressed conditions. Local communities in the developing world, where over 700 million people already lack access to safe drinking water (mostly in rural areas) will find it hard to cope with water scarcity resulting from climatic and non-climatic stresses. For them, securing drinking water is difficult due to a lack of water supply facilities and/or the remoteness of water sources. In addition, uncertain rainfall and inadequate irrigation means they cannot grow sufficient food for an adequate diet. Addressing water scarcity is thus not only important to climate change adaptation, it can contribute to achieving the Millennium Development Goals (MDGs) and the future Sustainable Development Goals (SDGs) related to water and food security.

The Institute for Global Environmental Strategies (IGES) is an international research institute conducting practical and innovative research for realising sustainable development in the Asia-Pacific region. In line with its mission, improving water security in the region is one of IGES' core areas of research. In this report, the authors provide an in-depth analysis of causes and impacts of water scarcity on smallholder subsistence livelihoods in rural areas of Nepal. For Nepal climate change means altered rainfall patterns as well as melting of glaciers in the Himalayas. Nepal's climate future is thus one of increased water scarcity and increased vulnerability of most smallholder subsistence livelihoods, which are highly dependent on water. In this context, this study proposes an integrated approach for planning adaptation measures to deal with water scarcity problems in local contexts, where decisions are often taken in an ad-hoc manner and climatic data are generally not available. I believe this study will be useful to policymakers and practitioners seeking practical solutions to the challenges posed by water scarcity brought about by climate change to rural development.

Hideyuki Mori
President
Institute for Global Environmental Strategies

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EXECUTIVE SUMMARY

This research report assesses water scarcity and its impacts on smallholder subsistence livelihoods in the context of climate change in Nepal, a mountainous country located entirely within the Ganges River Basin. It identifies and analyses existing coping responses and assesses options for introducing an adaptive response strategy to improve resilience of households and local communities to increasing water scarcity. The aim of this study is to contribute towards development of an integrated approach for planning adaptation measures to unprecedented and increasingly challenging local level water scarcity problems.

This research was conducted in selected hill and plain areas of the Koshi River Basin in the east and the Karnali River Basin in the west of Nepal. This research relied on both the analysis of rainfall data and social research methods (key informant interviews, questionnaire surveys and focus group discussions) to understand local perceptions of water scarcity and household response strategies.

In the first stage of the assessment the report finds that changing rainfall patterns – a likely manifestation of climate change – have triggered local water scarcity by widening the gap between water supply and demand. Socio-economic drivers, such as deforestation, population growth, contamination of water sources and increasing use of water have also exacerbated water scarcity. The resultant imbalance between water supply and demand has increased pressure on natural water sources such as springs, rivers and groundwater.

In the second stage the report explores the impacts of water scarcity on the main four pillars of smallholder subsistence livelihoods identified during the study: households, forestry, crop farming, and livestock. The study finds that water scarcity has heavily impacted on livelihoods and weakened all its four pillars, which are strongly dependent on water. It has resulted in declining productivity and income loss, and this in turn is affecting the wellbeing of the households.

In the third stage, the report examines coping responses of the households and communities to deal with the various manifestations of water scarcity. This study categorises the existing coping responses into five sets of strategies that reflect the decreasing range of choices available to households as water becomes scarcer. The first two strategies (S1: Enhance capture and storage; and S2: Improve distribution, allocation, efficiency) are meant to prevent potential impact and losses, while the other three strategies (S3: Limit water uses; S4: Accept losses in income and use savings; and S5: Responses of last resort) are meant to minimise them. However, households and communities have adopted these strategies autonomously without proper understanding of long-term consequences. Standalone actions that are uncoordinated and lack planning are amongst the main barriers to enhancing the effectiveness of these coping responses.

In the fourth and final stage, the report examines and develops options for strengthening the existing coping responses and improving resilience of the smallholder subsistence livelihoods. The analysis reveals that the effectiveness of the coping responses can be enhanced by approaching the water scarcity problem from an integrated perspective. A systematic understanding of the dimensions of the water scarcity problem and its impacts on local communities is the basis for planning adaptive strategies and hence to build resilience at the local level. The report proposes one potential way for applying an integrated approach which coordinates three domains of the socio-ecological systems (SES), namely, landscape, economy, and socio-institutional. The effectiveness of the proposed integrated approach can be evaluated by examining the resilience of the SES with the help of indicators provided in this report.

The proposed integrated approach, however, should be followed by taking into account the local realities and priorities of the smallholder subsistence livelihoods. Longer timeframe for implementation and a high need for resources can be a barrier for adopting an integrated approach as communities are mainly prepared for small-scale interventions that result in immediate returns to support their day-to-day needs. These needs can be addressed by prioritising actions that improve productivity of the water and land management systems and by focusing on the low cost options that provide immediate benefits to households, but can also be sustained over a long period. Such land and water management interventions should be backed by appropriate technology, investment (finance) and institutional support. This support should follow a planned step-wise manner and be provided as a "packaged solution" for enhancing the capacity of communities. Such a solution involves identifying deficiencies of existing coping measures and prioritising actions to overcome them, by promoting participation, experimentation and learning.

This research report makes an attempt to address the issue of changing rainfall — a prominent impact of climate change highlighted by the recent IPCC Fifth Assessment Report — and specifically focuses on the water scarcity triggered by changing rainfall. We hope that the proposed integrated approach can be usefully applied for planning local adaptation measures not only in Nepal but also in similar hill-plain landscapes found across the Ganges River Basin and other types of smallholder subsistence livelihoods. The report is expected to inform governments, local and international organisations, experts and stakeholders involved mainly in adaptation planning and dealing with water resources management at the local level. Being an interdisciplinary area, the relevant stakeholders and organisations working in agriculture, forestry, and local development may also find this report useful.

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LIST OF ACRONYMS

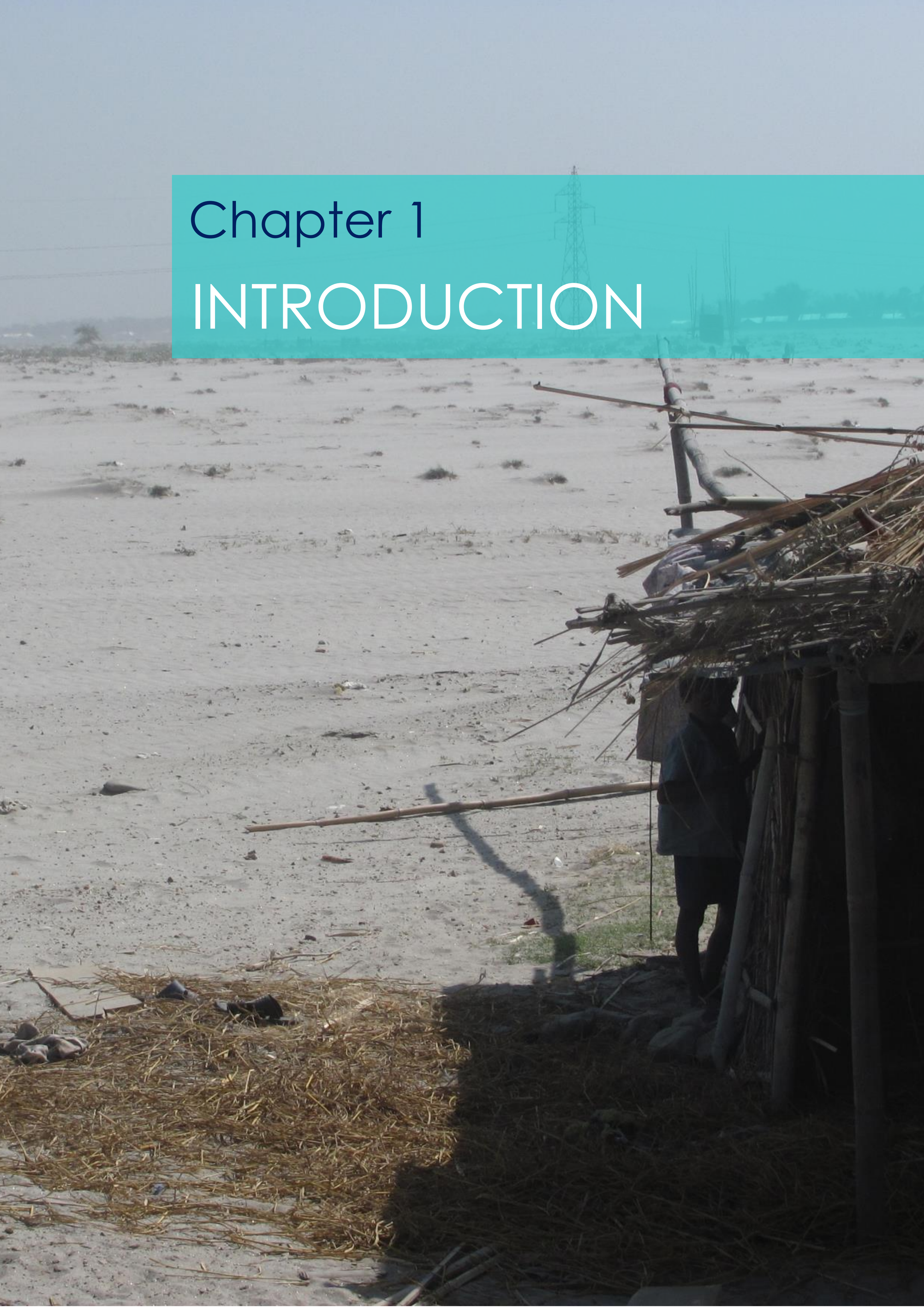
CFUGs	Community Forest User Groups
DWUA	Drinking Water User Association
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GRB	Ganges River Basin
HKH	Hindu Kush Himalayan region
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
ISET	Institute for Social and Environmental Transition
IWMI	International Water Management Institute
IWUA	Irrigation Water User Association
LAPA	Local Adaptation Plan of Actions
NAPA	National Adaptation Programme of Actions
NARC	Nepal Agricultural Research Council
NGO	Non-governmental Organisation
NPR	Nepalese Rupees Currency (1 US$ ≈ 94 NPR)
REDD+	Reducing Emissions from Deforestation and forest Degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks
SES	Socio-Ecological Systems
SPCR	Strategic Program for Climate Resilience
VDC	Village Development Committee
WUA	Water User Association
WWF	World Wide Fund for Nature

Key words: climate change adaptation, changing rainfall, Nepal, resilience, smallholder subsistence livelihood, water scarcity

LIST OF FIGURES AND TABLES

Chapter 1

INTRODUCTION



1.1 Climate change, water scarcity and smallholder subsistence livelihoods

Water scarcity occurs when demand for freshwater exceeds the supply in a specified domain due to physical lack of water availability, inadequate infrastructures to store, distribute and access water, or a lack of institutional capacity to provide necessary water services (FAO 2012). It is a relative and dynamic concept, it can occur at any level of supply and demand, and it is also a social construct as its causes are related to human interference in the natural water cycle (ibid). If identified correctly, causes of water scarcity can be predicted, avoided or mitigated. However, a challenge to the study of water scarcity impacts is that it can be inherently difficult to discern the starting point, longevity and cessation of the impacts. Unlike fast onset events such as floods, which result in immediate structural damages, water scarcity results in non-structural losses (Pereira, Cordery and Iacovides 2009). The intensity and impacts of water scarcity can be heterogeneous as prior experiences, preparedness and socio-economic status determine the coping capacity of each individual. There are often more coping choices in the early stages of water scarcity than in the latter stages. These complexities often complicate the framing of fair and equitable response strategies in a timely manner.

Climate change can exacerbate water scarcity by raising both climatic and non-climatic stressors to a higher level (Bates, et al. 2008). Climate change impacts on precipitation, which is one of the key climatic drivers that determine water availability at a particular location, are of particular concern. According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (WGII AR5), climate change has been found to alter rainfall patterns and thus water availability in different parts of Asia (IPCC 2014a, IPCC 2014b).

Smallholders are particularly vulnerable to climate change impacts on precipitation, especially increases in the irregularity of rainfall. Their existing coping responses and strategies are likely to prove inadequate to deal with major shifts in rainfall timing and volumes. However, it is challenging to frame an adaptive response strategy in a situation where it is difficult to detect the signals of climate change and to attribute their impacts (IPCC 2014a). Unevenly located meteorological stations and a lack of adequate historic rainfall data are major constraints for detecting signals and predicting precipitation trends. Attributing impacts is difficult as water scarcity involves complex feedbacks from multiple causes. Meeting these challenges is necessary for an effective adaptive strategy.

1.2 Climate change in the Hindu Kush Himalayan region

The Hindu Kush Himalayan (HKH) region, which is also known as the water tower of Asia, stretches over 2,000 km crossing several countries and includes the flow of 10 major river systems that support the livelihoods of over 1.3 billion people, directly or indirectly (Singh, et al. 2011, NAS 2012). Subtle changes in climate occur with differential elevation gradients and can have large impacts on livelihoods. Rural livelihoods in the region are thus highly "climate sensitive," meaning that climate change poses a serious threat to the wellbeing of rural households.

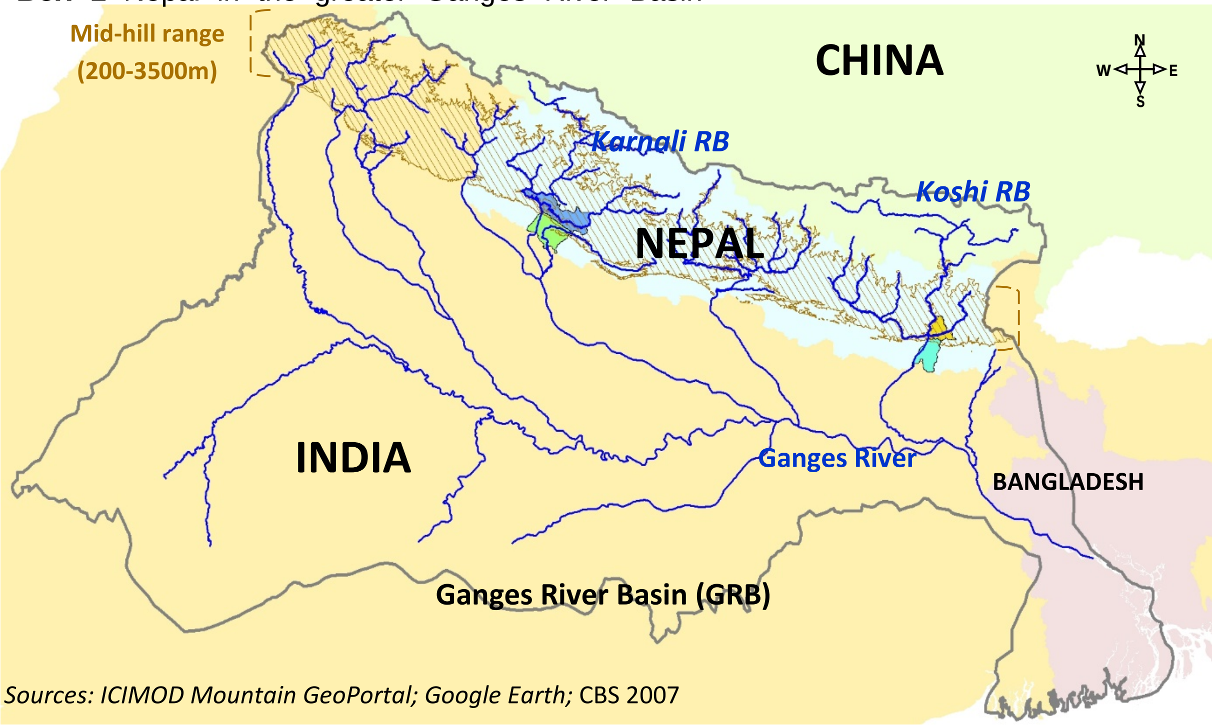
The annual average temperature has increased by 1.4°C over the last 100 years in the north-western Himalayas, leading to expectations of further increases in surface temperatures in the HKH region (Bhutiyani, Kale and Pawar 2009, Hosterman, et al. 2012). This warming trend is expected to further intensify in the near future. The Himalayan region, which acts as a natural reservoir of freshwater locked in the form of snow and glaciers, could experience unprecedented loss of frozen water due to reduced snowfall coupled with rapid melting of snow/glaciers as the climate warms (Hua 2009, Hosterman, et al. 2012, IPCC 2014a). This melting trend is expected to translate over the long term into reduced flows in snow-fed rivers. Fluctuations in precipitation are also projected and could intensify extreme climate events such as floods and droughts. For these reasons, the HKH region is likely to face climate change induced water scarcity (IPCC 2007, Singh, et al. 2011).

Local people have developed sets of coping mechanisms to deal with water scarcity through centuries of interaction, experimentation and adaptation within the HKH. However, intrinsic negative specificities of mountain areas, such as marginality, poor accessibility, and fragility of the resource base (Jodha, Banskota and Partap 1992), and the typically weak asset base of rural households mean that local communities are ill-prepared to cope with new forms of and more intense water scarcity. This makes the preparation of an adaptation strategy to deal with increasing water scarcity a high priority for the region. However, this is not an easy task. Framing an adaptive response is challenging because of the large diversity and interrelationships in topography and landforms, micro-climates, biodiversity, and socio-economic community characteristics, as well as strong upstream-downstream linkages. Moreover, a growing population and the resultant competition for natural resources could increase the vulnerability of communities and limit their adaptive capacities.

1.3 Research focus and questions

This research report focuses on water scarcity and smallholders in the HKH in Nepal, which shares part of the Ganges River Basin (GRB) (Box 1) with China, India and Bangladesh. Changing rainfall and increasing water scarcity are already apparent in different parts of Nepal (Jones and Boyd 2011, MOE 2010, Gurung, et al. 2010, WaterAid in Nepal 2012, Ghimire, Shivakoti and Perret 2010, Prabhakar, et al. 2013). According to an analysis of precipitation trends, the annual average precipitation over Nepal (with an exception to the Koshi River Basin) is decreasing at a rate of 9.8 mm/decade (WECS 2011). Assessments carried out by the government highlight the increasing impacts of climate change on water resources and increasing vulnerability due to droughts (MOE 2010, WECS 2011).

Box 1 Nepal in the greater Ganges River Basin



Sources: ICIMOD Mountain GeoPortal; Google Earth; CBS 2007

As a part of HKH region, the GRB is one of the most populous transboundary river basins globally, providing a home for over 500 million people. The GRB covers a total area of 1.094 million km^2. Nepal is located entirely within the upstream catchment of the GRB. Elevation gradients that extend from low lying plains (<200 m), mid hills (200-2,000 m), high hills (2,000-4,000 m) to the higher Himalayas (>4,000 m), and micro-climatic regions (sub-tropical to temperate) along each topographic belt physically differentiate Nepal from other geographic settings. Water resources along different topographic belts show wide variation both in terms of occurrence and access.

Nepal is rich in water resources with an estimated 230 billion m3 per annum of surface and groundwater (Hosterman, et al. 2009). In terms of area, only about 13% of the GRB lies within the borders of Nepal, but within this 13% an extensive network of glacier-fed perennial rivers, numerous spring sources, and seasonal streams are estimated to contribute nearly 70% of dry season and 40% of total annual flows of the GRB (ibid). Despite abundant water resources in Nepal, access to them is usually non-uniform and they remain widely under-utilised (about 15 billion m^3) (WECS, 2011) due to physical and socio-economic barriers, especially in rural areas.

In Nepal, changes in rainfall – either in frequency, duration, magnitude, or intensity – will influence wet season flows and affect the recharge of natural springs and micro-basins across the upland hills and groundwater aquifers along the plain areas. The primary impact of changing rainfall will likely be observed in the form of decreasing water availability for domestic uses and for irrigation, while the secondary impacts of climate change will be felt in the form of human-induced water shortages due to a variety of factors such as lack of supply capacity, misallocation, competition, and degradation of water quality. Some assessments have suggested that increasing water scarcity has already resulted in a rise in local conflicts over water in different parts of the country (WaterAid in Nepal 2012).

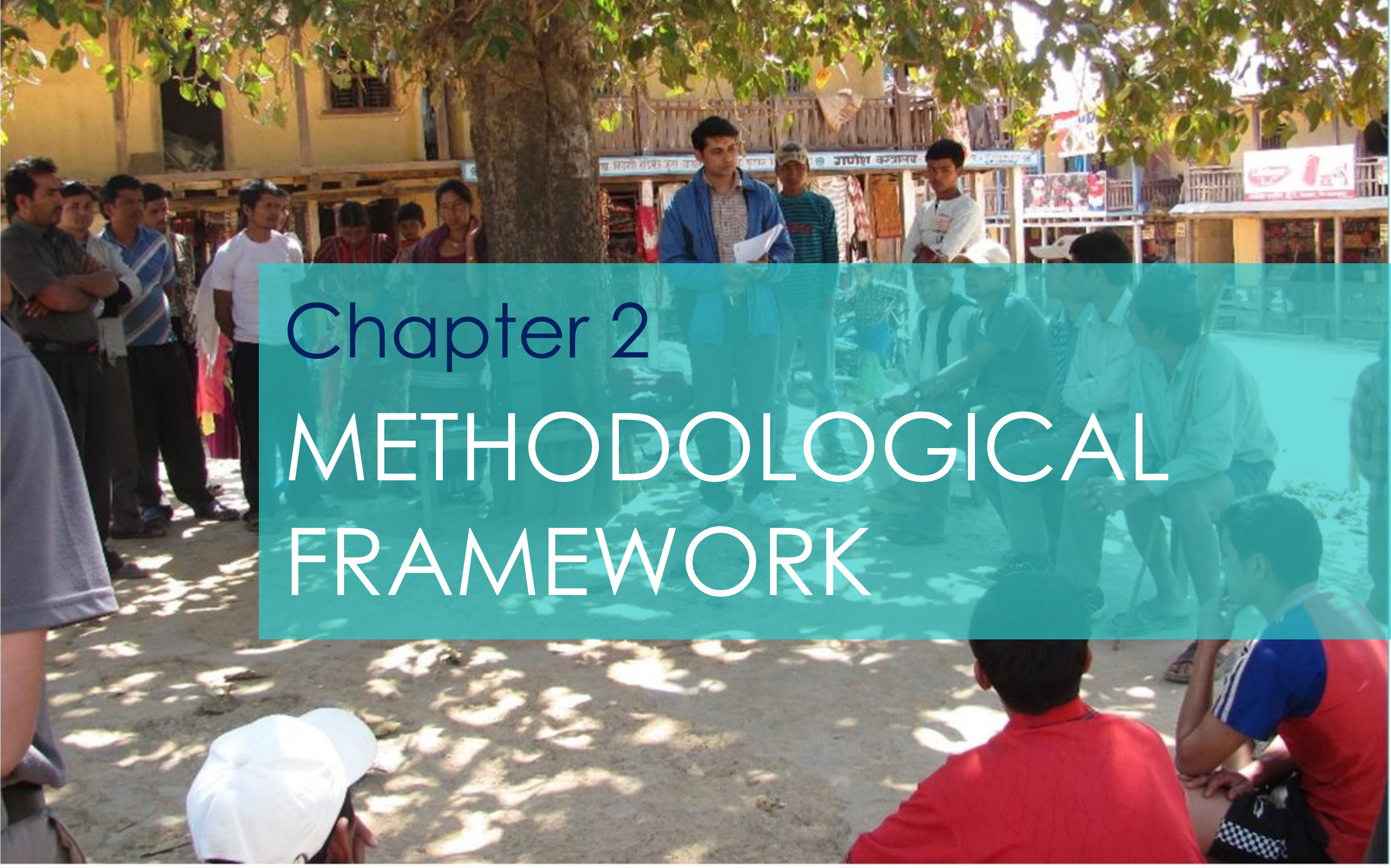
In Nepal, most farming communities depend on smallholder subsistence livelihoods. These generally consist of four pillars – households, crop farming, livestock, and forestry. They incorporate land and water management systems and practices to meet nearly all household subsistence needs (water, food, fibre, and forest products). Smallholder subsistence livelihoods may also generate some surplus that can be saved, exchanged or sold.

Because of their low asset base and heavy dependence on rainfall and natural surface flows for their agriculture, smallholder subsistence farmers are particularly vulnerable to climate change. A systematic understanding of dimensions of the water scarcity problem and its impacts on smallholder subsistence livelihoods can provide a basis for planning adaptive strategies and building resilience at the local level. With this understanding, the key research questions taken up by this study are:

- In the context of changing rainfall, what are the causes and impacts of water scarcity on smallholder subsistence livelihoods?
- What are the main response strategies adopted by local people and communities to deal with different levels of water scarcity and do these response strategies need further strengthening?
- How can a comprehensive understanding of the water scarcity problem be employed to enhance the resilience of smallholder livelihoods in a planned and integrated manner?

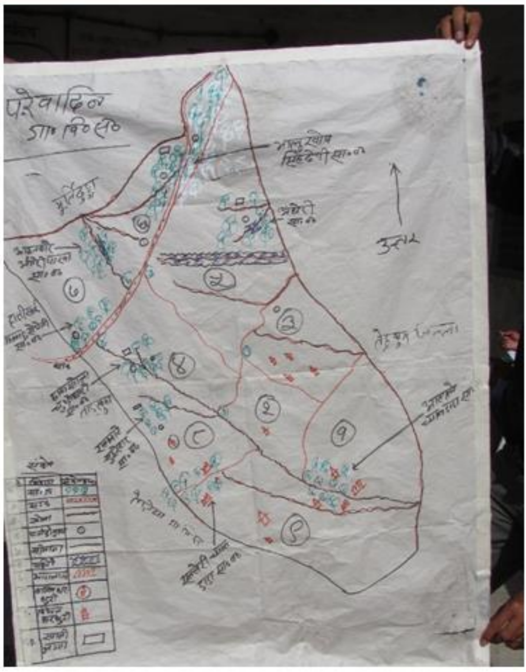
To address these questions, this report first identifies the main drivers and impacts of water scarcity. It then reviews the effectiveness and limitations of responses that local people have developed to cope with water scarcity. Based on this analysis, the report explores options to strengthen these coping responses through an adaptive response strategy.

The overall aim of this case study is to contribute to the development of an integrated approach for planning adaptation measures that effectively tackle unprecedented, increasingly challenging local level water scarcity problems and assist decision-making to improve resilience of households and local communities to increasing water scarcity scenarios. It is hoped that a comprehensive understanding of the specificities of water scarcity in the context of Nepal can be helpful for planning and up-scaling potential measures to address water scarcity problems faced by smallholder subsistence livelihoods in the GRB and beyond. The findings of this study are directed at authorities and other stakeholders involved in planning and implementing an integrated approach to climate change adaptation and water resources management at the local level. In Nepal, the findings may be useful for central and local government agencies, donors, and other stakeholders working on adaptation plans and programmes including Local Adaptation Plan of Action (LAPA), National Adaptation Programme of Action (NAPA), and Strategic Program for Climate Resilience (SPCR).



Chapter 2

METHODOLOGICAL FRAMEWORK



The methodological framework follows a systematic approach to assess water scarcity and identify integrated options to solve this problem. The method is suitable for situations where adequate data and information on water scarcity problems are usually lacking but where the local communities have an understanding of the problems and are already responding to them. It consists of three major steps: (1) selection of study locations based on their specificity; (2) a comprehensive assessment of water scarcity problem; and (3) identification of integrated measures to strengthen the resilience of smallholder subsistence livelihoods (**Figure 1**).

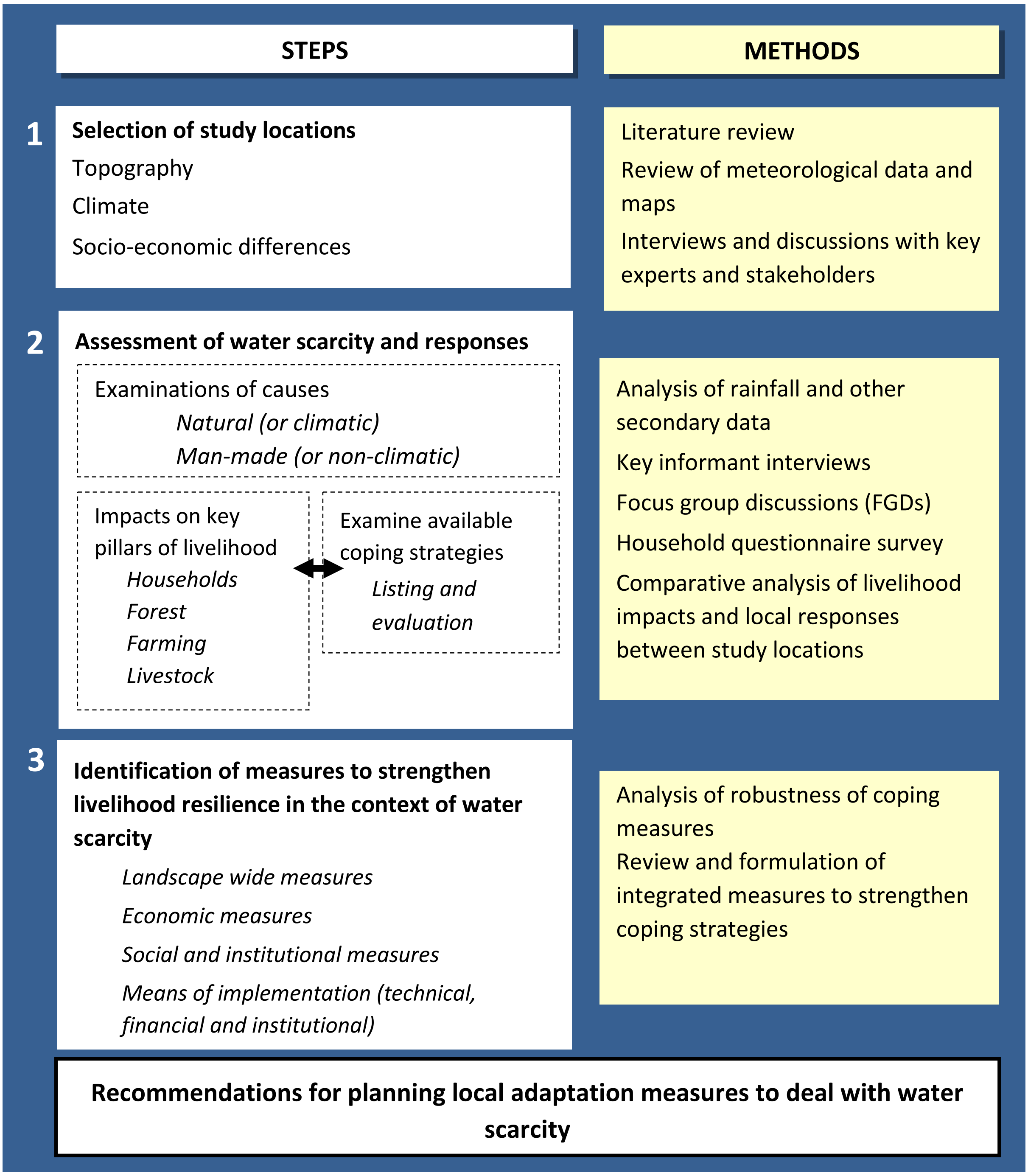
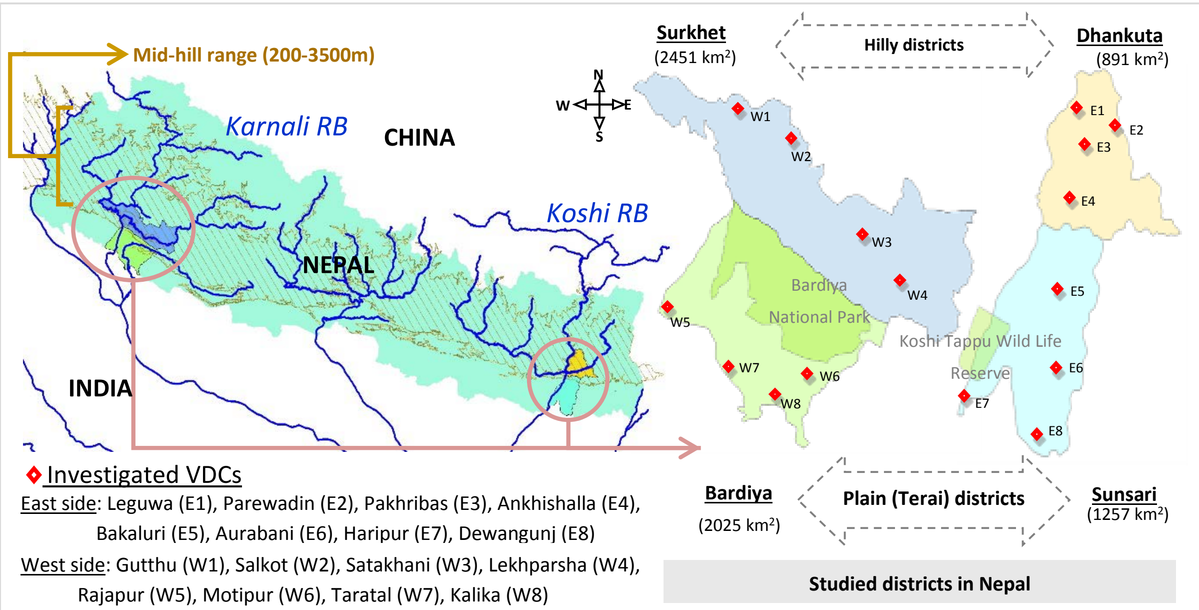


Figure 1 Methodological framework of the study

2.1 Selection of study locations

Study sites were selected with contrasting features both in terms of topography and climatic conditions, based on an extensive literature review, available precipitation data, and a series of consultations with key informants from line agencies and research institutes. The experts consulted included officials in the Irrigation Department, Department of Forests, and the Water and Energy Commission Secretariat, as well as researchers and experts from the International Centre for Integrated Mountain Development (ICIMOD), International Water Management Institute-Nepal (IWMI-Nepal), Institute for Social and Environmental Transition-Nepal (ISET-Nepal), the Nepal Agricultural Research Council (NARC), Small Earth Nepal (SEN) and the World Wide Fund for Nature-Nepal (WWF-Nepal).

Adjoining hill and plain areas of two sub-basins of the GBR – the Koshi River Basin (Koshi RB) in the east and the Karnali River Basin (Karnali RB) in the west of Nepal – were chosen as the broad locations for the study (**Figure 2**). In the east, the Tamor River and Arun River are the two main branches of the Koshi River, and have their origins in the Himalayas. Similarly, in the west, the Bheri River and the main channel of the Karnali River also originate in the Himalayas.



(Sources: ICIMOD Mountain GeoPortal; Google Earth; CBS 2007)

Figure 2 Overview of the surveyed districts in Nepal.

Hills and plains are two common types of topographic settings in Nepal – the mid-hills (upstream) and the immediate plains (downstream, locally known as "Terai") to the south – which both stretch as parallel belts to the south of the Himalayas. Topographic gradients give rise to multiple micro-climate regions within each district. For instance, hill districts often experience cooler climates while the plains experience warm or hot sub-tropical climates for most of the year. Four districts – two in the plains and two in the hills – were selected for detailed investigation. In the

Koshi RB, Dhankuta (as hill) and Sunsari (as plain) districts, and in the Karnali RB, Surkhet (as hill) and Sunsari (as plain) districts were selected (**Figure 2**). **Table 1** provides basic data for each district.

Table 1 General overview of surveyed districts

Features		Koshi RB		Karnali RB	
		Dhankuta	Sunsari	Surkhet	Bardiya
Area (km^2)		891	1257	2451	2025
Rural areas (%)		95	87	99	95
Elevation range (m above mean sea level)		120-2702	152-914	198-2367	138-1279
Average temperature (1991-2009)		1210 m**	200 m**	720 m**	200 m**
	Max (Average±SD*)	20.8±3.5	29.9±3.6	28.1±4.7	31±5.2
	Min (Average±SD*)	12.4±4.5	18.4±6.2	15.6±4.2	18±6.8
Land Cover	Agriculture	52	65	21	30
	Forest	40	18	71	63
	Others	8	17	8	7
Number of micro-basins or small rivers		28		35	
Road density (km/km^2)		0.219	0.375	0.135	0.150
Population ('000s)	1981	129.8	334.6	166.2	199
	2001	166.5	843.2	288.5	382.6
	2009 (projected)	184.5	1068.1	350.2	475.7
Rural population (%)		88	74	88	88
Annual population growth rate (%)		1.29	3.0	2.45	2.76
Average household (HH) size		5.11	5.02	5.34	6.42
Literacy (%)		64	61	63	46
Population employed in agriculture and forestry (%)		72	49	68	66
Average farm size of a HH (ha)		0.84	1.04	0.54	1.04
Irrigated area (%)		12	53	24	80
Forest user HHs (%)		98	4	45	14
Access to drinking water and sanitation (%)	Tap/piped water	81	20	69	24
	Groundwater		77	13	73
	Rivers, springs		0.25	16	
	Others (incl. unspecified sources)	19	2.6	2	3
	Population without access to toilets	35	46	48	72

*SD stands for standard deviation; ** indicates elevation of respective meteorological stations
Source: CBS 2007, ISRC 2010

Water scarcity in the hills is partly subject to topographic variability, which has a large impact on water sources and access to these sources, and hence economic opportunities. Less topographic variability in the plains means easier access to water sources (both surface and groundwater) and more economic opportunities.

The hills and immediate plains were selected to examine potential upstream-downstream inter-linkages in terms of water resource sharing and the exchange of goods and services. As an immediate downstream area, the plains are negatively impacted by unusual weather patterns in the hills in the form of floods and sedimentation in the wet period and low river flow during the dry period. East and west locations were chosen due to distinct features in the timing of monsoon rainfall. Figure 2 shows the location of the study area and the village development committees (VDCs) that participated in the research. All VDCs, other than E3, E5, W4 and W6, were included in the focus group discussions (FGDs; see section 2.2).

2.2 Assessment of water scarcity and local responses

The second methodological step was the assessment of the dimensions, causes and impacts of water scarcity, with a focus on both climatic and non-climatic drivers. This included an examination of impacts on key livelihood assets (forestry, crop farming, and livestock) and households, which the study took as the main pillars of typical smallholder subsistence livelihoods in Nepal. Available coping options were categorised according to the severity of impacts on smallholder subsistence livelihoods and evaluated. FGDs and questionnaire surveys were used to gather data and information.

FGDs with 12 selected VDCs were organised across the four surveyed districts by inviting community members, including local leaders, women, farmers, and members of local organisations to participate. Each FGD was attended by between 15 and 40 people. The FGDs aimed to (1) explore the overall conditions of water scarcity in the district and its impacts, and the communities' coping responses, and (2) engage participants in discussions on options to improve the existing coping measures and their feasibility. In order to guide the discussions, each FGD used participatory tools, such as a) sketching a village map including topography, water sources (natural and artificial water supply) and major land cover (forest, agriculture, settlements, etc.), b) writing a timeline of changes over the past two to three decades, paying attention to rainfall patterns, population growth, infrastructure development, and major changes in local lifestyles, and 3) listing coping responses and measures to strengthen them. The qualitative information and data collected in the FGDs included what local people observed to be the major changes in rainfall and their impacts on water availability, and provided an understanding of local institutions, rules, and collective responses to cope with water scarcity. The FGDs also identified issues that need urgent attention as well as existing technical, financial, and management related barriers to the adaptation interventions.

The questionnaire-based household survey was conducted in all studied areas. About 200 (±10%) households covering four VDCs in each district participated in the questionnaire survey. Responses were received from a total of 790 households. The questionnaire survey was mainly intended to provide further understanding of livelihoods, impacts of water scarcity and response strategies.

Comparative analysis of the distinct impacts of water scarcity on the local livelihoods and the various local responses to water scarcity was conducted between the four contrasting study locations.

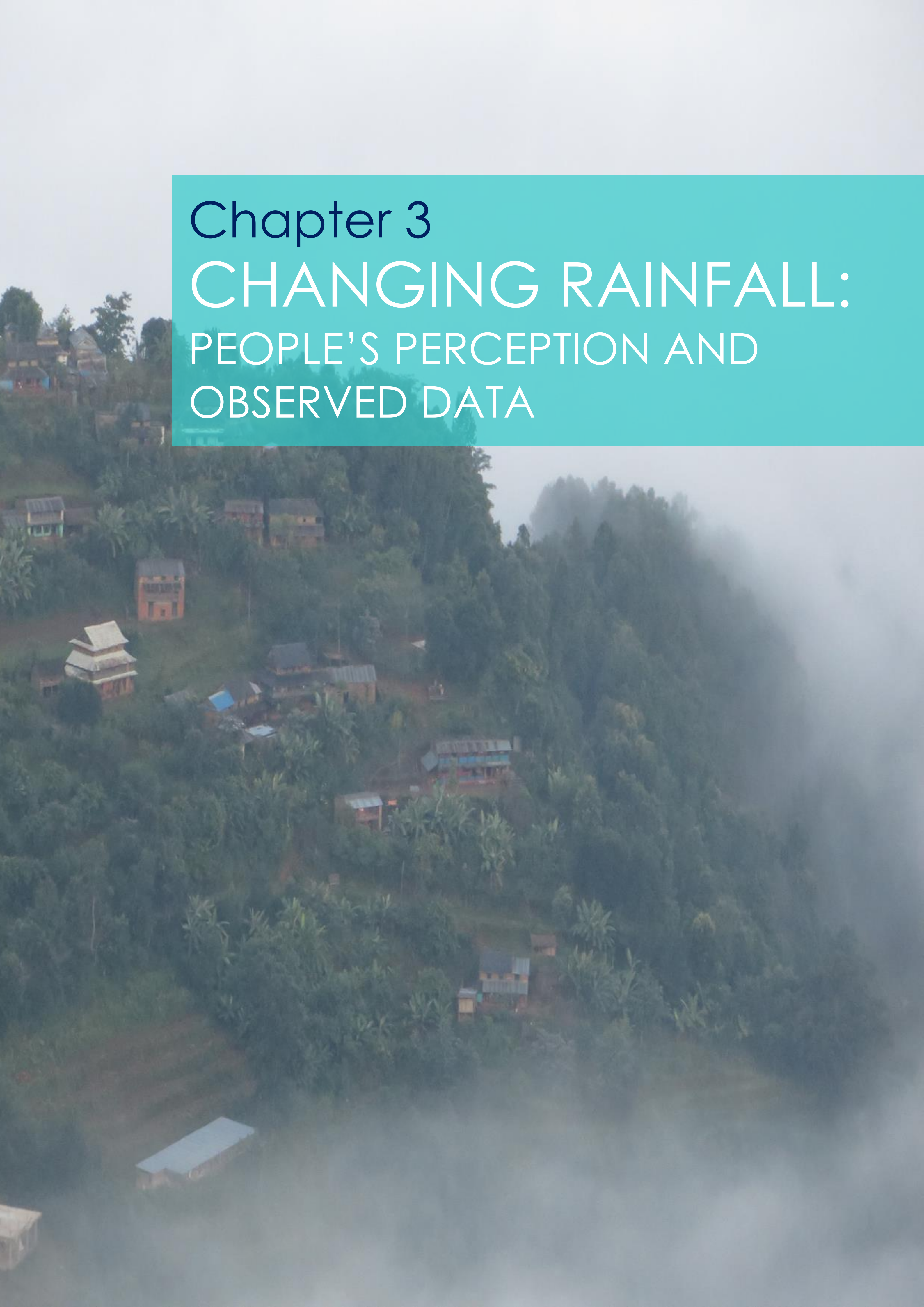
2.3 Identification of integrated measures to strengthen livelihood resilience

In the third methodological step, data collected through both the FGDs and the household questionnaire survey were analysed to assess the effectiveness of the existing coping measures and to identify measures to strengthen them. Analysis of the data and findings led to the proposal for an integrated approach to dealing with water scarcity. The feasibility of implementing the proposed measures was also studied.

Chapter 3

CHANGING RAINFALL:

PEOPLE'S PERCEPTION AND OBSERVED DATA



This aim of this chapter is to review and comprehend the available information on changing rainfall patterns. The study draws from the perceptions of local communities and contrasts these with an analysis of the rainfall data observed at meteorological stations in the studied districts.

Changing rainfall patterns – timing and amount – was an emerging concern shared by local communities univocally in all investigated areas. People who participated in the FGDs stated that the amount of rainfall had decreased over the past two to three decades and that there was a shift in the timing of the rainfall. The normal summer monsoon was delayed by a month or more in recent years. Similar cases of locally observed changing rainfall patterns have been pointed out by other studies, not only in the Himalayan region (ICIMOD 2009, Ghimire, Shivakoti and Perret 2010, Macchi, et al. 2011, Gurung, et al. 2010) but also other parts of the world (Mubaya, et al. 2012, McDowell and Hess 2012, SEI 2013, IPCC 2014a).

Formal climate records from the three to seven recording stations in the studied districts cover the period 1971-2009. Climate data assists in understanding normal rainfall variability such as wet and dry periods, and it can cast some light on local claims about changing rainfall patterns. However, the small number of recording stations and the fact that data has been recorded for a relatively short period means that the potential for using precipitation time series records to validate local observations of changing rainfall patterns at the micro-climatic scale is limited. Moreover, comparing observed data with local people's experiences might not allow for identifying plausible parallelism as, for example, Mubaya, et al. (2012) found a mismatch between local experiences and recorded precipitation data in other parts of the world.

Figures 3 and **4** depict the yearly and monthly distribution of rainfall observed during 1971-2009 at weather stations of the Department of Meteorology and Hydrology located in eastern (Dhankuta and Sunsari) and western (Surkhet and Bardiya) districts, respectively[1]. The topmost part of each figure shows total annual rainfall amounts during the four decades at different stations, while the average and standard deviation (SD) ranges are based on observations from all stations in a district. The range of average rainfall was 1,251 – 2,096 mm/yr in four districts; highest in Bardiya and lowest in Dhankuta. Similarly, average annual rainfall was higher in the plains than the adjacent upstream hills. Close inspection further reveals that specific stations (notably, A3-5, A7, B2, C3, D3-6) had received relatively low (below average) to very low (below lower SD range) amounts of annual rainfall during the three decades. However, considering the wide fluctuations of annual rainfall amount in consecutive years among the stations there was no clear trend of continuous decline in rainfall amounts except for Station C3.

In order to provide a deeper understanding of possible trends, the rainfall data was broken down into a seasonal scale as shown in the middle and lower most parts of **Figures 3** and **4**. The

[1] It should be noted that there was non-uniformity in terms of years of available data and missing data for some observation years. For convenience and to avoid uncertainty, the years or months with missing data were not included in the analysis.

rainfall patterns were differentiated into four arbitrary periods: pre-monsoon (April-May), summer monsoon (June-September), post monsoon (October), and dry period (November-March). A large portion of the rainfall (74-85%) occurred during the four months of the summer monsoon and can be attributed to the moist easterly winds (NAS 2012). Frequency, intensity and duration of the rainfall during these four months are critical for the availability of water not only during the wet period but also to recharge the area, which contributes to dry season discharge from springs, small rivers and groundwater. There were also marked differences in the amount of rainfall during the monsoon between eastern and western districts. Generally, the monsoon begins earlier in the east than the west due to the proximity of the area to the Bay of Bengal, which is the source of the easterly monsoon. In the eastern districts, most of the rainfall occurred during the pre-monsoon (11.7-15.6%) and summer monsoon (74-79%). In marked contrast, in the western districts, relatively lower amounts of rainfall occurred during the pre-monsoon (<7.2%) with a higher concentration of rainfall during the summer monsoon (81-86%), which indicates the time-lag for the monsoon to reach the west. There were also cases of minor rainfall events during the dry period in the west, which were the result of the westerly monsoon influence in the winter (NAS 2012). Therefore, the amount of dry period rainfall was slightly higher for the west (6-9%) than in the east (3.8-5.7%).

In order to assess the seasonal changes in rainfall, averages of monthly rainfall are grouped into four decades. The bars along with the average of each decade represent the minimum and maximum range, while bars in the average for the whole period represent the standard deviations (±SD). The seasonal distribution of rainfall provides a clear picture of fluctuations in average rainfall amounts during the monsoon (June-September) especially in the decades after 1990. Changes in the timing of rainfall after 1990 can be observed in the monthly figures for June and July in all districts. The average June rainfall for the period 1991 to 2000 is lower than for 2001 to 2009; however, the trend is opposite in July. This trend might indicate a delay in the timing of rainfall from June to July.

A trend in decreasing rainfall can be observed in the lower parts of **Figures 3** and **4**, which show that all months received rainfall amounts below average for more than 50% of the observed years between 1971 and 2009. This figure reached 60% in Dhankuta (September), Sunsari (August, September) and Surkhet (June, September) during months of the peak monsoon.

The monthly resolution of the data constrains our understanding of specific variations in rainfall frequency, intensity and duration, and more frequent and a longer period of observation would be helpful. Nevertheless, although the analysis of formal records provides only an average representation of the data, the patterns observed are in close agreement with the residents' views on decreasing rainfall and changed timing of rainfall in the past two decades.

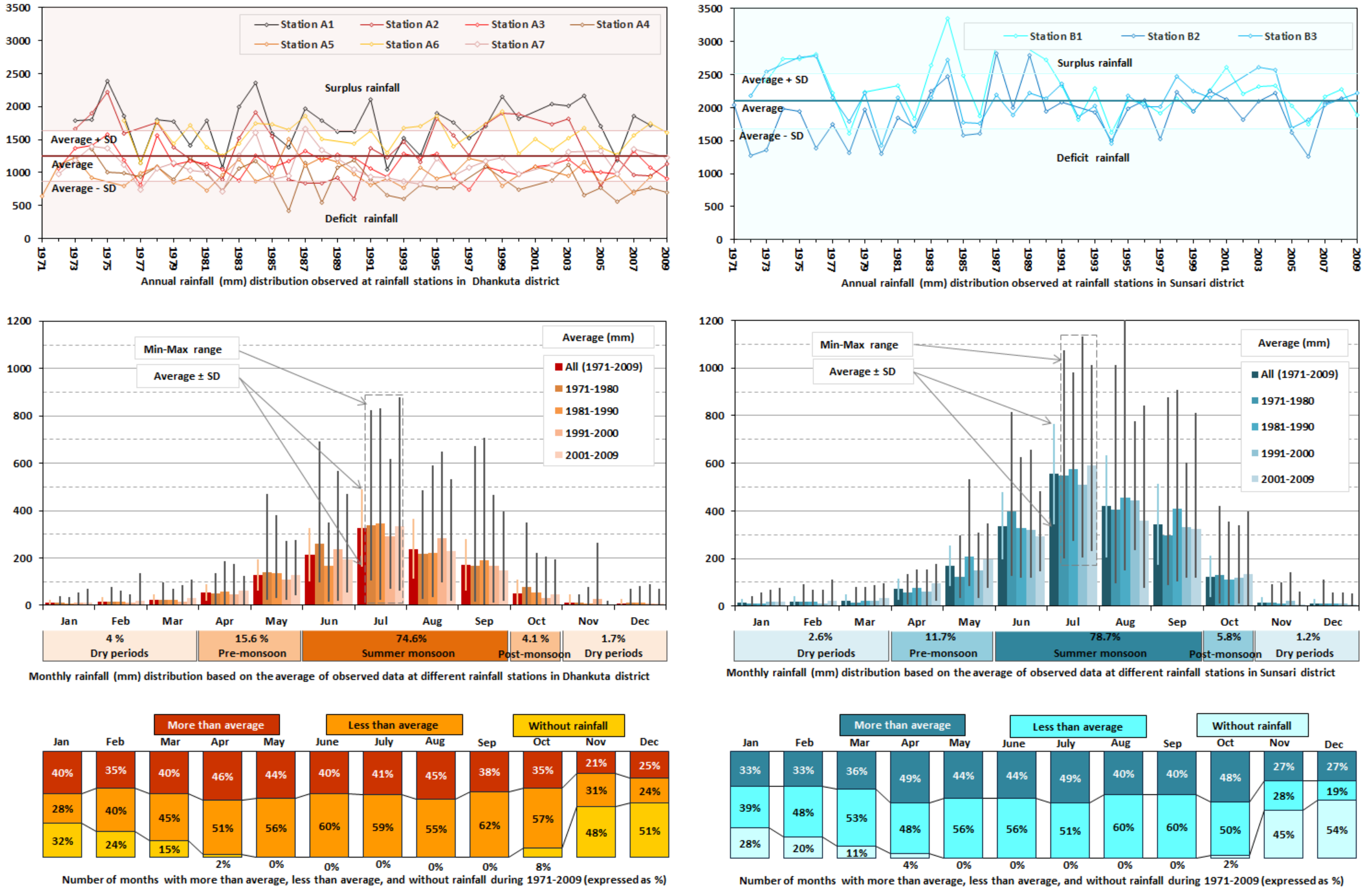


Figure 3 Yearly and monthly distribution of rainfall (mm) observed at different weather stations during 1971-2009 in two districts (Dhankuta and Sunsari) of the Koshi River Basin

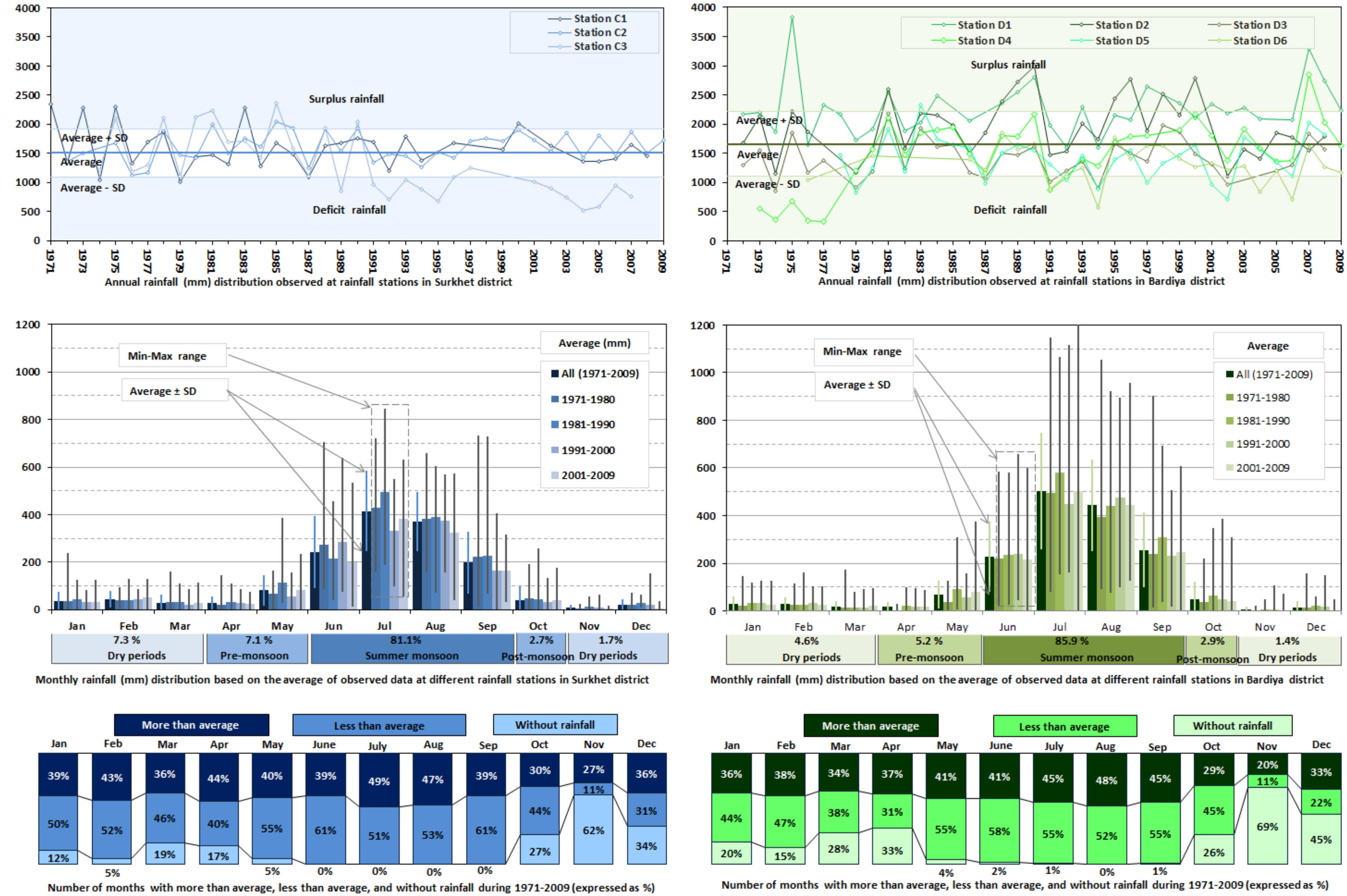
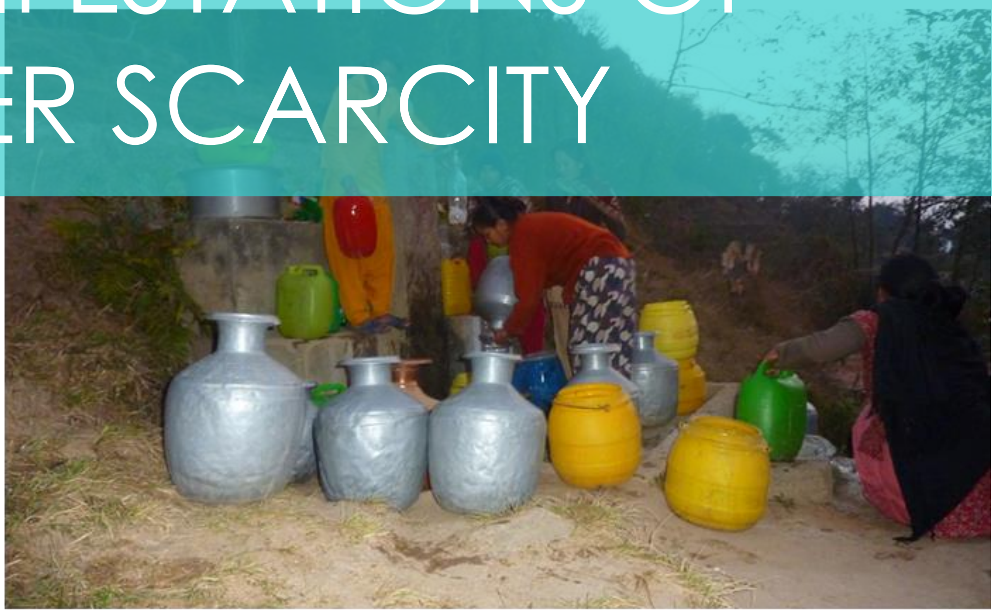


Figure 4 Yearly and monthly distribution of rainfall (mm) observed at different weather stations during 1971-2009 in two districts (Surkhet and Bardiya) of the Karnali River Basin

Chapter 4

MULTIFACETED MANIFESTATIONS OF WATER SCARCITY



As noted in the previous chapter, all the studied districts are experiencing changes in rainfall patterns and the immediate impact of this is decreasing water availability. The decreasing availability of water may cause an imbalance in water supply and demand and increase water scarcity. The purpose of this chapter is to understand and analyse both the state and causes of water scarcity in the studied areas.

Water scarcity is contextual. Its expressions vary across locations and periods, and it affects exposed people differently. Water scarcity is mainly driven by climatic factors, such as inadequate rainfall, but it can be also intensified by non-climatic stressors. **Figure 5** shows the responses from the questionnaire survey about recent trends in water scarcity at district level. In all four districts, there was general agreement that water scarcity is increasing in recent times, more so in the hill districts (73-87% of respondents, according to district) and less so in the plain districts (40-66%). Some of the respondents opined that water availability has remained static (10-24%) or even increased (3-48%) due to improvements in water supply such as piped water, enhanced storage capacity, or groundwater pumping. Among those reporting increasing water scarcity, most (57-97%) were experiencing it annually, but some respondents, mainly from the plain areas of Sunsari (42.5%) and Bardiya (7.3%) and fewer (<3%) from the hill areas of Dhankuta and Surkhet, opined that acute water scarcity was only intermittent. Regarding the seasonality of increasing water scarcity, more than 71% of the respondents in each district indicated that the impacts of water scarcity were most severe during the dry periods, though some respondents, especially in Sunsari (23.7%), explained that water scarcity can be acute throughout the year. Only a few respondents in all districts were experiencing water scarcity in the wet seasons due to floods.

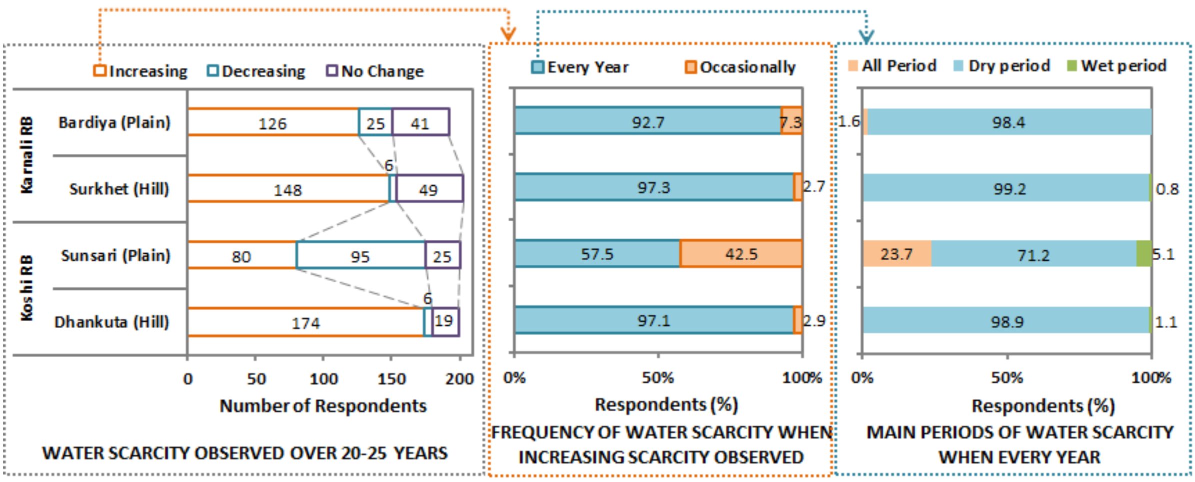


Figure 5 State of water scarcity for the past 20-25 years in studied districts (based on the questionnaire survey)

Overall, the responses indicate increasing water scarcity in all studied districts. The following sections discuss the primary causes for this.

4.1 Water source depletion

Changing rainfall patterns, especially the observed trend of decreasing rainfall amounts, has led to a reduction in water availability in small rivers, springs and groundwater sources. Volumes of water in manmade structures (ponds, overhead tanks, etc.) and volumes distributed through canals and piped systems were also affected.

Figure 6 shows the various types of water sources and proportion of interviewed households dependent upon them. In the hill districts of Dhankuta and Surkhet, most communities were dependent on springs and rivers for their water supply, while rivers and groundwater were the major water sources in the plain districts of Bardiya and Sunsari. Households were also using manmade structures such as canals, ponds, and piped distribution systems that mainly rely on natural sources.

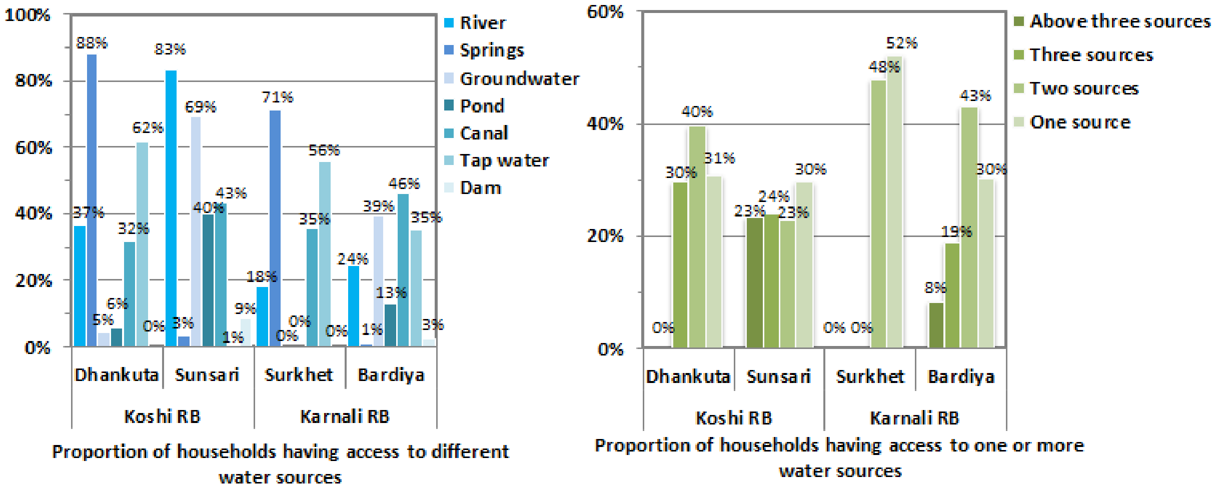


Figure 6 Household access to water in studied districts

A diverse picture was found in terms of household capacity to access multiple water sources. Households in the plains had relatively more choices to access water than households in the hills. In Surkhet, households could access one or at most two water sources, while in Dhankuta 30% of households had up to three water sources. In contrast, in the plain districts some households had access to more than three water sources.

This information on water sources provides insights into the relative susceptibility of people to source and access related water scarcity. As rivers and springs are the main sources of water in the hills, any changes in their flow patterns can have serious repercussions on household and agricultural uses. **Table 1** shows that there are about 28 rivers originating from the micro-basins inside Dhankuta and 35 in Surkhet. Each micro-basin holds one or more natural springs that are periodically recharged by rainfall and mist (occult precipitation). The volume of river flows throughout the year is primarily governed by the distribution (amount, intensity and duration) of rainfall during the monsoon period and the recharge condition of the surrounding land cover. Any changes in rainfall could have serious implications on the flow regimes of these local water sources.

Communities in all studied districts shared a common concern about the declining flow in rivers and springs. Among the users of rivers and springs consulted through the questionnaire survey, 84% in the Dhankuta survey area and 96% in the Surkhet survey area were of the view that these water sources are declining in number and size. People have been experiencing marked reduction in flows, or even periods without water, of springs and rivers at least for one month and in some instances extending up to eight months during dry periods.

Communities in the plains were mostly dependent on groundwater, rivers and canals. Although groundwater is an easily accessible water source, communities close to the main river systems, such as the Koshi River in Sunsari, and Karnali, Bheri and Babai Rivers in Bardiya, are able to use surface water through irrigation canals. Communities in the plain districts thus had more water choices than those in the hills where the steep relief prevents them from accessing water from large sized rivers such as the Arun, Tamor, Bheri and Karnali Rivers. In contrast to the hills, depletion of sources was not pointed out as the main problem in the plains, although people were experiencing declines in river levels (43% in Sunsari and 90% in Bardiya) and canal flows (24% in Bardiya) during the dry months. Only 15% of the users in Sunsari and 22% in Bardiya, where groundwater abstraction during the peak dry period was becoming difficult, were concerned about the lowering of the groundwater table. Some participants of the FGDs in Bardiya stated that they experienced a decline of the groundwater table of up to 15 to 18 metres during the dry season; however, no scientific assessment had been carried out to trace the root causes. Participants in W7 and W8 VDCs explained that in recent times there had been a huge number of boring and tube wells constructed all over the district, and this appears to be a plausible explanation for the observed lowering of the groundwater table. Increased abstraction during the dry period by a large number of users might have depleted groundwater in some places as the groundwater table is not uniform due to unevenness in the topography of Bardiya.

4.2 Increased water demand from a growing population

As shown in **Table 1** above, population is increasing in all studied districts. Population growth rates are higher in the plain districts at 2.8-3.0%/yr than in the hill districts at 1.3-2.4%/yr. Participants in the FGDs in all districts opined that the area was already over-populated, given the available natural resources. **Table 1** shows that population has increased several times over the past 50 years, which has exerted direct pressure on natural resources, as livelihoods of the people in the studied districts are based on subsistence. Population growth has resulted in fragmentation of land holdings in these areas. Average household landholdings are less than 1 ha in the hills and about 1.04 ha in the plains. Participants in the FGDs feared that the shrinking size of arable land holdings and decreasing food production per household could lead to demand to develop more land, intensify land use, and collect forest products. This could result in deforestation and land degradation.

All surveyed districts have experienced a considerable shift in economic activities and lifestyle changes due to improved access to information, services and new income earning opportunities. Along with an increase in demand for natural resources, population growth and lifestyle changes have driven water demand to new heights.

4.3 Deforestation

Deforestation, i.e. the conversion of forests to other land uses, and forest degradation, i.e. a sustained decline in the quality of forests, have a long history of over two hundred years in the hills of Nepal. Mahat, Griffin and Shepherd (1987) claim that deforestation in Nepal has been tolerated and even promoted by the government in the past. The government's resettlement programme encouraged the clearance of forests in some parts of the Terai during the 1960s and 1970s as it aimed to “help solve the immediate population problem” and to bring “additional lands under cultivation” (Elder 1976). The trend of deforestation intensified after the successful eradication of malaria by the late 1950s in the Terai, where the dense hardwood stands came under intense pressure from migrant farmers from the Nepalese hills, as well as from commercial logging (Poffenberger 2000). The annual deforestation rate in Nepal was 1.39% between 2000 and 2005 (FAO 2010).

The introduction of community forestry in Nepal, primarily in the hill districts, in the 1980s contributed to reducing deforestation rates. The community forestry model in Nepal involves the transfer of forest management and use rights of national forests to local community institutions, namely the Community Forest User Groups (CFUGs). Macro level studies and mapping exercises have revealed that Nepal’s forest coverage and condition is significantly improving because of community forestry (Kanel 2007). More than 1.66 million ha of national forest is managed by 17,808 CFUGs, and currently about one third of the total national population are members of the CFUGs (DoF 2012). Despite the achievements of the community forest management regime, deforestation remains a national problem due to the increasing demand for forest products (fodder, fuel wood, timber) and land for farming and settlements.

Long-term deforestation processes have led to a significant decrease in forest cover in the studied districts. Forest cover is particularly low (only 18%) in Sunsari (**Table 1**) and this is mainly confined to the Siwalik ranges and small parcels of the Koshi Tappu Wildlife Reserve. Large-scale forest clearing has also occurred in Bardiya, but significant forested areas are preserved in the Bardiya National Park. Dhankuta, in the hills, has 40% forest cover. FGD participants mentioned that while deforestation has decreased significantly, mainly because of community forestry, illegal logging is taking place and is responsible for some deforestation. Participants from Surkhet, which had the highest forest cover among the studied districts, were especially concerned about this issue. Mature forests of hardwood species such as sal (*Shorea robusta*) are under pressure because new roads linked with markets that pay better than local prices for timber have increased their accessibility. FGD participants explained that increased illegal logging had reduced forest cover by more than half in some parts.

Deforestation can have negative impacts on water sources. Forests have been conventionally viewed as a source of water and a regulator of hydrological cycles, especially in smaller catchments. They are key determinants of water supply, quality and quantity, and they can contribute to drought and flood mitigation (Bates, et al. 2008, FAO 2013). In the FGDs, participants acknowledged that deforestation has contributed to increasing water scarcity by impacting flows in natural water sources. In the past when there was extensive forest cover, the water flows in springs and rivers could be depended upon throughout the year, but water flows have decreased in areas that experienced deforestation.

The FGDs also highlighted the complexities in the linkages between forest cover and water scarcity. Some FGDs participants in Dhankuta pointed out that some species of trees can reduce available water. As some studies have found, depending on the species composition, forests can lose a significant amount of moisture through evapotranspiration (FAO 2008). Other FGD participants felt that the loss of water sources was not associated with a change in forest area, but with a shift from natural to planted forests. Natural forests were converted for cultivation or for settlements. Reforestation subsequently took place, but it could not substitute for the hydrological function of natural forests as the only areas left for tree planting were marginal sloppy lands, which do not support high levels of forest biomass.

4.4 Increasing value of water and resultant competition over access

Depleting sources and increasing demand for water have transformed available water resources into a commodity with high economic value. A jump in household water use and new market opportunities for agricultural products, both of which are closely related to population growth and lifestyle change, have increased competition over water.

These days people are facing fewer water constraints because of improvements in water supply through investments in water storage and piped distribution of water close to the point of use. As shown in **Table 1**, more than 80% of households in the surveyed districts have access to an improved drinking water supply. **Figure 4** shows that 56-62% of households in the hilly surveyed areas had a tap water connection, while over 70% of households in the plain districts had access to tap water and groundwater. Improved access to water has increased water use, often by several times. Prior to the improvements in water access, a family would normally use 20 to 50 litres of water per day, but because of improved water access, including the installation of tap connections near houses, recent household water use has peaked in the range of 100 to 500 litres per day at almost all of the surveyed sites. This increase in water use has escalated water shortages among users.

New market opportunities for agricultural products through the expansion of road networks are also responsible for water scarcity. In the surveyed districts there was a high demand for water to irrigate vegetables or rear livestock, which can fetch attractive prices in both nearby and distant markets. Because water is one of the limiting factors for agricultural production, there is already high competition for water particularly in Dhankuta, Sunsari and Bardiya districts, where links to markets are relatively better established than in Surkhet. The increased demand for water for agriculture has placed pressure on local water resources such as springs, rivers, and groundwater, especially during the dry periods when water is naturally scarce.

Water is increasingly viewed more as a commodity rather than a freely available resource; for instance in Dhankuta, some respondents in FGDs mentioned high prices attached to land with good spring water sources. During the FGDs participants mentioned that despite prevailing economic problems, people are now willing to pay for piped water as they prefer not to walk far distances to fetch water. People were paying for drinking water either as members of community water supply systems or through other forms of cost sharing. Preference for convenient access to water, despite the associated cost, is a clear indication of increasing water use and its value.

4.5 Location of water sources

There was a close relationship between location and water scarcity at the study sites as locational factors determine the ease of accessing water in terms of distance, time, and terrain. The uniform topography in the plain areas reduces water scarcity as it is relatively easy for people to travel to the water sources. The situation is quite variable in the hills, where distance usually has both horizontal and vertical dimensions and physical difficulty determines the effort and time required to cover a set distance. People depend on nearby sources such as springs or small rivers, more so than the main tributaries located far from and below the settlements, such as the Koshi River (Arun and Tamor Rivers) in Dhankuta and Karnali River and its tributary Bheri River in Surkhet. In contrast, water from the Koshi and Karnali Rivers can be utilised for irrigation through canals in the plain districts.

Three variables were examined to understand potential vulnerability to water scarcity given the location of the sources: distance to water sources, time required to reach the water sources, and the method to bring water to the household (**Figure 7**). Tap water was the nearest source (<100m) for the majority of households in the studied sites, and more than 68% of the respondents mentioned that they required less than 10 minutes to reach a water source. However, 31% of households in the hills found tap water to be relatively far from their houses (>100m), even exceeding one kilometre in some cases, as compared to only 3% of households experiencing the same problem in the plains. Tap water is delivered from natural sources such as rivers and springs in the hills through pipelines. Forty-eight percent of tap water users are connected through piped water supply systems, and 62% are diverting water from spring sources through private pipes, which is only possible when the sources are located upstream. Limited uses of pumps in the hills indicate a potential difficulty in lifting water from the lowland to the highland. Piped water has reduced the burden of fetching water, but a significant number of households were still collecting water manually because their houses are located above or far away from the water sources.

		Location	Hills			Plains				
		Sources	Tap	Springs	River	Tap	Hand Pump	River	Canal	Tube well/ Boring
Distance	≤100m	<10m	43%	19%	10%	69%	78%	10%	45%	31%
		10-100m	26%			27%	12%			
	>100m		31%	81%	90%	3%	9%	90%	55%	69%
Time	<10 min		68%	16%	9%	95%	98%	22%	59%	44%
	>10-60 min		22%	72%	43%	5%	2%	65%	29%	55%
	>60 min		10%	12%	49%	0%	0%	13%	12%	1%
Method	Manual		52%	29%	31%	93%	90%	2%	1%	0%
	Pumps		0%	1%	3%	7%	10%	14%	2%	100%
	Pipes		48%	62%	10%	0%	0%	23%	3%	0%
	Canal		0%	8%	56%	0%	0%	61%	95%	0%

Figure 7 Types of water sources and effort needed to access them (time and distance) in the studied areas

Rivers, canals, and groundwater (hand pump, tube well, boring) are the main sources of water in the plains. Taps and hand pumps have made it easier for households to access water both in terms of time and distance. Even when available sources were located far from the settlements, most households (> 85%) could reach them in less than one hour. Most of the households depend on manual power to access water from taps and hand pumps (52%-93%) as water must still be carried to the point of end-uses. River, canals and tube wells/boring, which are usually located far from the household, are mainly used to supply water to irrigate crops.

4.6 Low affordability and ineffective allocation

Water shortage is a form of water scarcity that results from poor management capacity (Pereira, Cordery and Iacovides 2009). The inability of some households to pay for water withdrawal from available sources and allocation problems are the two major causes of periodic water shortages in the study areas. Terrain and the implementation of appropriate technologies were major constraints to enhancing water storage and supply in the hill regions. In the plains, rather than geographical or technical barriers, the operation and management costs for groundwater abstraction were pointed out as the main reasons for water scarcity. According to the FGD participants, the increasing costs for groundwater abstraction are suppressing the profit margin of agricultural production, as large amounts of groundwater are required to irrigate crops. People were typically investing 25,000 NPR[2] for groundwater pumping; the cost to run a diesel pump was 100-200 NPR/hour, though this does not include pump maintenance costs. Normally, one farmer needs to operate the pump for 24 hours to irrigate one hectare of land using a shallow tube well. If electricity from the grid was available, the pumping cost could be reduced in the range of 8-75 NPR/hour depending on the capacity and efficiency of the pump. However, lack of access to the grid and only intermittent supply of electricity are forcing farmers to rely on expensive diesel. An increasing fuel price was the main limiting factor for groundwater use in Sunsari. In Bardiya, decreasing groundwater tables during the dry season, when demand for groundwater is highest among farmers and households, was found to be the main problem. Considering the high cost of groundwater, the people interviewed were in favour of surface water irrigation, as farmers only need to pay a flat rate tariff of 300 NPR/ha/yr to access the water. However, not all farmers have access to reliable surface water irrigation in plain areas.

Ineffective allocation of available sources also affects water access. This was most apparent in Surkhet, where an increase in settlements in the low lying areas has created additional pressures on traditional irrigation canals that are controlled and managed by local upstream residents. This is a typical example of lack of upstream-downstream coordination on water sharing. In Dhankuta, too, intensive use of water by upstream residents during the dry season diminishes the flow of water for downstream users. In the plains, despite low tariffs, the allocation issue was prominent in areas served by major irrigation canals, particularly at sites E6 and W5. Unresponsive organisations, inadequate repair and maintenance of canals and lack of cooperation between users at head and tail ends of irrigation canals were pointed out as some of the main issues. Consequently, competition over water took place during the peak agricultural periods, while over-application of water and indifference to closing canal gates led to water wastage and resulted in water shortages for farms located at the tail-end of irrigation canals. Since users were required to pay the tariffs irrespective of the water they consumed, users facing shortages were reluctant to pay for tariffs on time and to participate in management activities.

4.7 Water quality

Pollution can intensify water scarcity as it reduces the amount of usable water. Three issues were identified as potential causes of water quality deterioration, namely improper sanitation and waste disposal, runoff and erosion, and naturally borne contaminants. Sanitation is one of the unmet targets of the United Nations Millennium Development Goals (MDGs), particularly in rural areas (UNICEF/ WHO 2014). The data in **Table 1** indicates that a significant number of households had no toilets (35-48% in the hills and 46-72% in the plains) in all studied districts,

[2] NPR: Nepalese Rupees Currency (1 US$ ≈ 94 NPR)

though even lower numbers were recorded during the survey (29% in the plains and 15% in the hills), as shown in **Figure 8**. Participants in the FGDs explained that the use of toilets has increased and that open defecation was no longer as common as in the past. Open defecation is still practiced however, because of the costs of building toilets, the inconvenience of travelling to the toilets when working in the fields that are located far away from the houses, and low familiarity with and awareness of the importance of using toilets.

Runoff and soil erosion were the main causes of water quality deterioration, especially, during the rainy season. Waterborne diseases, notably diarrhoea, were common health problems in both the hills and plains during the rainy season when there are high chances of contamination from diffuse sources. In addition to diarrhoea, people also complained about negative health effects that they associated with using water sources contaminated by agro-chemicals and improper waste disposal.

In the dry season, the problem was direct contamination at the sources. Unlike the rainy season, water is physically scarce during the dry season when the natural water sources have to be shared for different uses. Repeated uses of the same water sources in the dry season, when volume is at its lowest level, such as for bathing, washing clothes and utensils, and watering of livestock increases the risk of contamination. Open defecation near to sources and disposal of solid waste and wastewater also contribute to the deterioration of water sources. Disposal of solid waste and wastewater into irrigation canals were identified as major problems in Sunsari. Accumulation of solid materials obstructed water flow, while dirty water posed a health risk as it is common for people living near canals to use the canal water for household purposes.

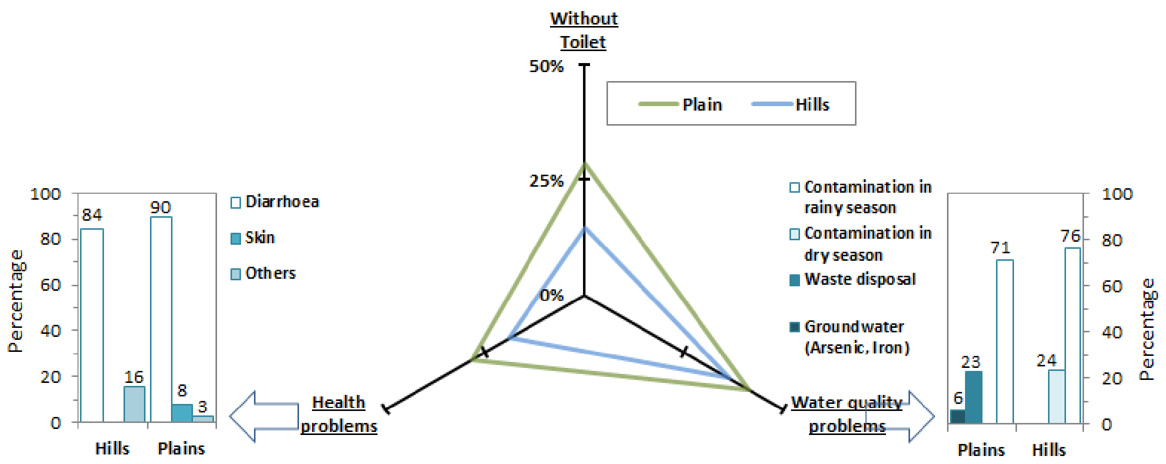


Figure 8 Accessibility to toilets and significance for water quality and health

Naturally occurring arsenic and iron in the groundwater was identified as the main water quality problem in the plains. High iron content causes the water to become a yellowish colour, while water contaminated with arsenic poses a serious risk to health. People who ingested arsenic-contaminated groundwater suffered skin-related and other health problems.

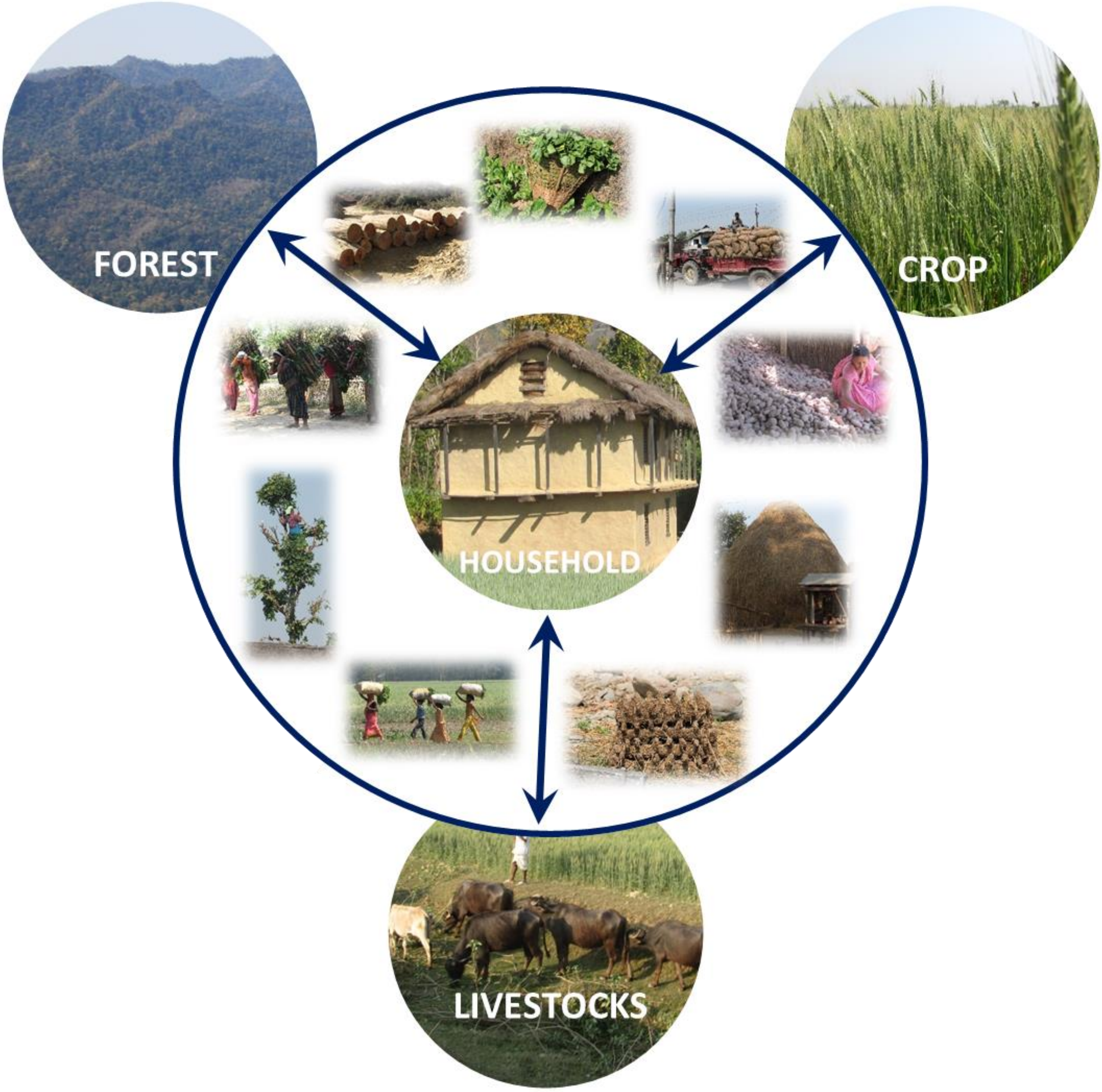
4.8 Other specific concerns

Three other issues were also identified as contributing to water scarcity. First, local residents felt that temperatures had increased in recent times. They felt that the period of winters was shortening and that summers were hotter and drier at higher elevations in the hill areas where the air is normally cooler. These observations are supported by formal records, which indicate that Nepal has experienced a temperature rise of 0.04-0.06°C per annum, with more pronounced warming in higher altitudes (MOE 2010). People reported that there was a marked reduction in mist formation and associated this with the increase in temperature. In the plains, where the climate is usually sub-tropical, people felt summers were becoming hotter. This increase in temperature in recent years is responsible for lower humidity, the drying of vegetation, and increased water consumption.

Second, water scarcity is associated with the relief of the hills, with windward hill slopes usually receiving much more rainfall than the leeward slopes, because of the orographic effect. Similarly, the aspect of slopes has been a determining factor for moisture availability and vegetation growth, as sun-facing slopes are drier due to their higher exposure to solar radiation than the north-facing slopes. Residents living on the drier sides of the hills are under pressure to cope with water scarcity caused by increasing rainfall variability.

Third, flooding in the plains can impact water scarcity by destroying water supply facilities and through sedimentation. The most serious case was found in areas surrounding site E7 (Sunsari). Major flooding of the Koshi River in August 2008, caused by the collapse of the eastern embankments of the Koshi Barrage (NCVST 2009), destroyed all water sources and infrastructure, and at the time of the survey residents were still facing acute water scarcity. As affected land has been covered with a thick layer of sand and silt, local people were facing difficulty in accessing water both for household use and farming. Flooding was also identified as the principle threat to people in Bardiya living along the Karnali River (site W5) as flood water often damages their irrigation canals as well as nearby farmland and property. The area is thus vulnerable to acute water scarcity in a post-flooding situation.

Chapter 5
LIVELIHOOD IMPACTS



Earlier chapters have shown that changing rainfall patterns have directly and indirectly driven water scarcity to a new level. Water scarcity is of particular concern for smallholder subsistence livelihoods, which are the mainstay of household economies in the study districts and in rural Nepal as a whole. This chapter discusses the key impacts of water scarcity on smallholder subsistence livelihoods. It distinguishes and analyses four important pillars (households, forest, crop farming, and livestock) of smallholder subsistence livelihoods. The analysis views the natural-physical system (primarily land, biodiversity, water and climate) as constituting the foundation of all these pillars. **Table 2** presents the inter-linkages of the four main livelihood pillars and how they are impacted by water scarcity.

Table 2 Matrix of inter-dependency between the four pillars of smallholder subsistence livelihoods and water scarcity impacts

Livelihood pillars	Recipients				Impacts	Major consequences
	FR	FL	LV	HH		
FOREST (FR)						
Micro-climate (humidity, temperature, shade)	•	•	•	•	Negative	Drying of trees and saplings and reduction of primary production ↓ Diminished forest products, biomass and its services
Fodder and forage			•		Negative	
Timber and fuel-wood				•	Negative	
Food and non-timber products				•	Negative	
Space		•	•	•		
Water (forest hydrology)		•	•	•	Negative	
Reduced floods, landslides and erosion		•	•	•	Negative	
Compost and nutrients		•			Negative	
Employment and income				•	Negative	
FARMLAND (FL)						
Space	•		•	•		Insufficient water (rainfall, irrigation) for crop farming ↓ Reduction in cropping intensity and production losses (food, biomass)
Food and biomass			•	•	Negative	
Compost and nutrients		•			Negative	
Employment and income				•	Negative	
LIVESTOCK (LV)						
Urine and droppings	•	•			Negative	Insufficient water (drinking, feed preparation, cleaning) and feed ↓ Fewer livestock heads
Power (tillage, draft)		•	•	•	Negative	
Food (dairy, meat, eggs)				•	Negative	
Employment and income				•	Negative	
HOUSEHOLD (HH)						
Labour and inputs	•	•	•	•	Negative	Insufficient water for drinking, cooking, sanitation and hygiene ↓ Loss of time and resources to fetch water, negative health impact
Investment capital	•	•	•		Negative	
Management	•	•	•		Negative	
Conservation activities	•				Negative	

Forests are an important livelihoods' pillar as they supply biomass (timber, fuel woods and fodders), as well as space, compost, nutrients, and other non-timber forest products (herbs, fruits, nuts, etc.). Forests also regulate micro-climates (humidity, mist, temperature, shade, etc.), and water cycles, sequester carbon, provide socio-ecological functions (biodiversity, forage, recreation), and help to prevent soil erosion, landslides and runoff (flash floods). Crop farming is important to household livelihoods as it provides food, employment, feed and biomass for livestock, and occasional income from the sale of surplus products. Besides providing nutrition, livestock rearing also supports households in a number of ways. The selling of livestock products, such as dairy products, meat and eggs, provides supplementary income for the household, and livestock are also a type of safety net when crop failure occurs as they are easily sellable in the market.

The household is a livelihood pillar in terms of its capacity to deal with threats and opportunities. Access to and productivity of forests, crop farming, and livestock all depend on household capacity to mobilise and manage them. As the social and economic centre around which livelihoods are generated in rural areas, the household provides organisational capital (allocation and management of resources), human and social capital (techniques, skills, physical health, social networks), and economic capital (income and outputs). These assets, together with elements of the natural-physical system, largely determine the outcome of household investments in forests, cultivation and livestock.

The direct or indirect impacts of increasing water scarcity were evident in all four pillars of smallholder subsistence livelihoods. Nearly 88% of respondents from the hills and 83% from the plains mentioned that water scarcity has negatively impacted their livelihoods. The main losses they report include direct economic losses in terms of decreased income from crop farming and livestock rearing, lost work and time and ill-health associated with collecting and saving water, and money spent to secure water supplies. The major impacts of increasing water scarcity on rural subsistence livelihoods in the study areas are as follows.

5.1 Households

Households are affected by water scarcity in terms of their immediate needs (e.g. drinking, hygiene and sanitation), as well indirectly through the water requirements of forests, crop farming and livestock. The three main direct uses of water by the households in the studied areas as shown in **Figure 9** were domestic water use, which is necessary for the day-to-day household survival, livestock rearing (71% of households in the hills and 75% in the plains) and irrigation (41% in the hills and 75% in plains).

Although there was a significant improvement in access to drinking water either through tap water or hand pumps, households were increasingly facing water shortages during dry periods. The severity of household water scarcity was higher in Dhankuta and Bardiya than in Sunsari and Surkhet, which had better access to natural water sources. In the hills, many people must walk for up to several hours to fetch water from community taps, springs or rivers. The time spent in collecting water affects other household and community activities. Women are mostly responsible for collecting water and FGDs participants mentioned that every day women spend hours to fetch water, getting up early to beat the queue. Women were facing health related problems from carrying large volumes of water (for instance, 10-50 litres per time for up to four to five times a day in Dhankuta).

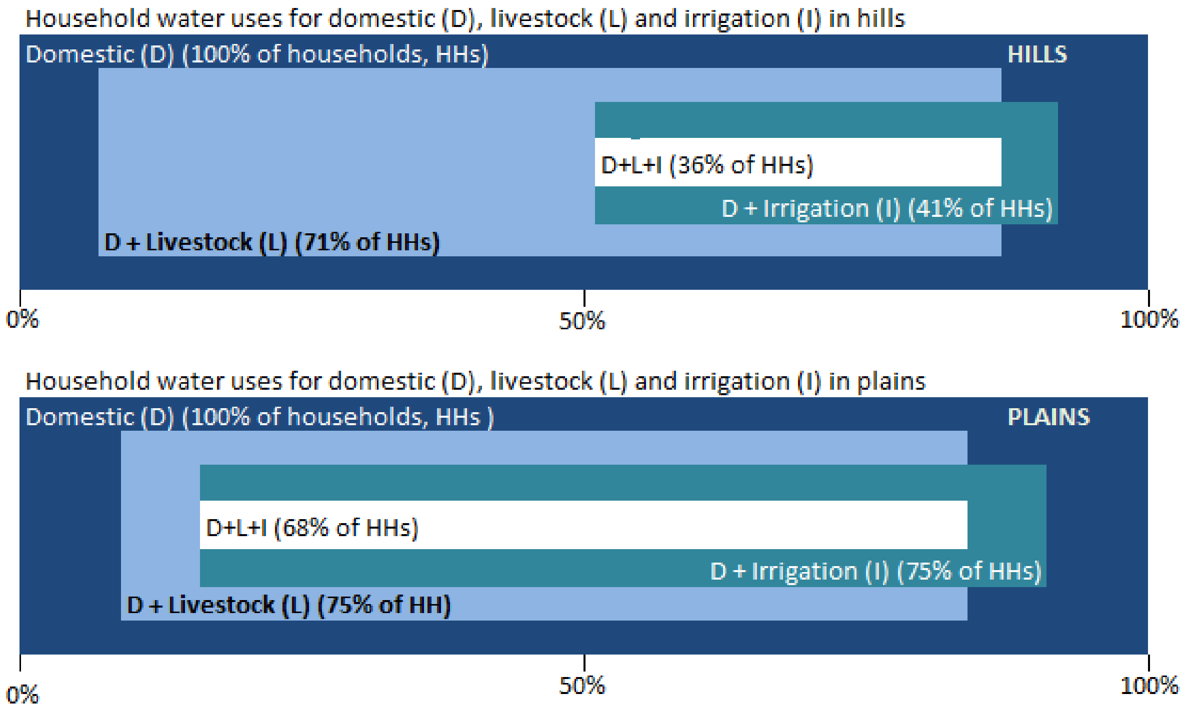


Figure 9 Major water uses for domestic (D), livestock (L) and irrigation (I) in hills and plains (expressed as % of households on the horizontal axis)

In the plains, especially in Bardiya, the decrease in the groundwater table during the dry season has increased household water stress as people have to either invest more on pumping groundwater or carrying water manually from the neighbourhood. Households are often forced to use contaminated water during water scarce periods and this potentially exposes them to health risks as the water may carry harmful microbes, agrochemicals or naturally occurring arsenic. In sum, loss of income and time for work, and deteriorating health were the direct impacts of water scarcity on households and their wellbeing.

5.2 Forests

Table 3 shows the main uses of forest products in the studied areas. Fuel wood and fodder/forage from forests are used on a daily basis to support household and livestock needs. Their use was found highest in the hills where there are no other reliable alternatives. In the plains, where forest cover is lower and access restricted (i.e. in the Bardiya National Parks and Koshi Tappu Wildlife Reserve), crop residues (such as straw) are often used as animal feed, and cattle dung (dried or to produce biogas) is a common source of fuel. Local people use timber for construction or to earn cash. The use of timber was found to be highest in the western study areas, especially in the hills (Surkhet), and this could be due to easier forest access, the prevalence of the community forestry regime, traditional practices and unavailability or higher cost of modern construction materials.

Table 3 Main forest products used in studied areas

Districts		Forest cover (%)	Three main uses of forest products (in % of households)		
			Fuel wood	Fodder/forage	Timber
Hills	Dhankuta	40	72.9	59.3	23.1
	Surkhet	71	81.8	79.3	80.8
Plains	Sunsari	18	42	42	29
	Bardiya	63	64.2	37.8	42

Although we did not quantitatively assess the impacts of water scarcity on forests, participants of the FGDs in all sites mentioned that increasing water scarcity had diminished services provided by the forest, which were already under pressure from the growing population and (resultant) deforestation. In particular, reduced rainfall was responsible for the drying of trees and saplings, resulting in lower biomass production. Drying forest cover could also be partly linked to less mist formation in hill districts because some species may be dependent on mist as a source of water (Bates, et al. 2008).

Decreasing precipitation was found to have impacted forest productivity in all the studied areas of Dhankuta, Bardiya National Park and its buffer zones, and partly in Surkhet (mainly low density national forests), in terms of reducing the supply of fuel wood and fodder. A decline in forest productivity due to water scarcity could result in negative feedback. For example, people may be less interested in conserving low productivity forests that do not produce high value timber, which was observed in the case of Surkhet, and such forests may be exploited for fodder and fuel wood at above sustainable levels, resulting in further degradation.

5.3 Crop production

Growing crops is by far the main occupation in the rural economy of Nepal. It accounts for roughly one-third of national gross domestic product (GDP) and employs two-thirds of the economically active population (CBS 2012). Farmers can grow a range of crops throughout the year when the conditions are favourable.

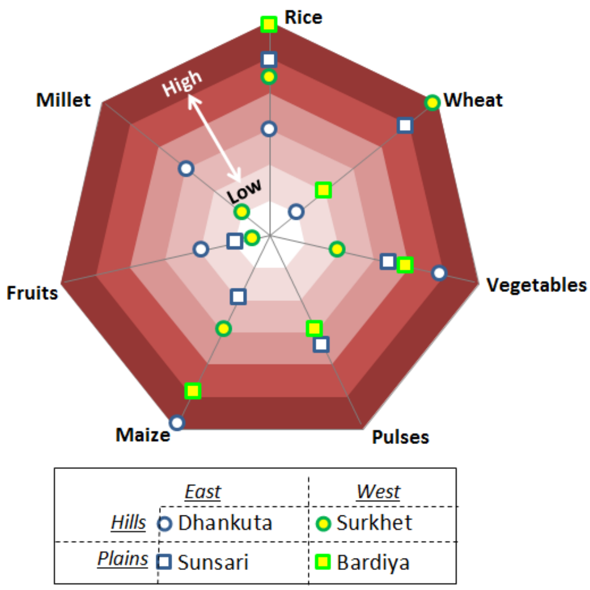


Figure 10 Ranking of crops grown by respondents based on their dominance (high-low)

In the studied sites seven major crops were identified. **Figure 10** shows the ranking of the major crops grown in terms of quantity. Rice, maize and wheat were the most common staple crops, though vegetable cultivation is also becoming popular. Rice and maize are grown in summer, depending on rainfall and irrigation. Rice is grown when water is abundant or on irrigated land, whereas maize is mostly preferred on rainfed land. Wheat is a winter crop grown on both irrigated (mainly in Sunsari, Surkhet and certain parts of Bardiya) and rainfed land (certain parts of Surkhet, Bardiya). Other crops, including sugarcane (in the plains), cardamom (in Dhankuta) (both not shown in the figure), millet and fruits are grown in limited cases only. Crops are usually intended for direct consumption and for sale when there is a surplus, though the main products and biomass are also used as animal feed. Biomass can also be used as a household fuel and for making compost or other local products, such as mats made from rice straw.

Water is a critical input for crop production. The correct timing and volume of water application, as well as an acceptable quality of the water, is vital for successful crop production. In the studied districts, only 12-24% of the farm lands are under irrigation in the hills, while the share is significantly higher (53-80%) in the plains (**Table 1**).

During the questionnaire survey, three types of households were identified in terms of the condition of farmlands as shown in **Figure 11**. The first type of households exclusively owned fully irrigated farmlands; their share is lower in Dhankuta (15.5%) and Bardiya (16.8%) and relatively higher in Sunsari (58%) and Surkhet (>95%). The second type of households owned both rainfed and irrigated fields. About 58% of interviewed households in Bardiya possessed both irrigated and rainfed plots, while this figure was less than 25% for other districts. The third type of households only had access to rainfed lands; their share was highest in Dhankuta (>59%) and lowest in Surkhet (<1%).

A decline in crop production was the main impact of water scarcity on both irrigated and rainfed lands. As shown in **Figure 11** (right side) most households have reported this experience, though less in the eastern districts than the western districts. People expressed increasing uncertainty about rainfed farming, which is mainly governed by the amount and timing of rainfall.

Unavailability of water is especially significant for crops with high water requirements, such as rice or vegetables, which were dominant in one or more areas (**Figure 10**). Participants in the FGDs explained that farmers were forced to adjust their cropping or leave their land fallow due to increasing uncertainty in rainfall. A similar situation has been reported by Gurung, et al. (2010) in other parts of Nepal. Participants also mentioned that they are forced to reduce their cropping intensity because less rain has meant less water for irrigation.

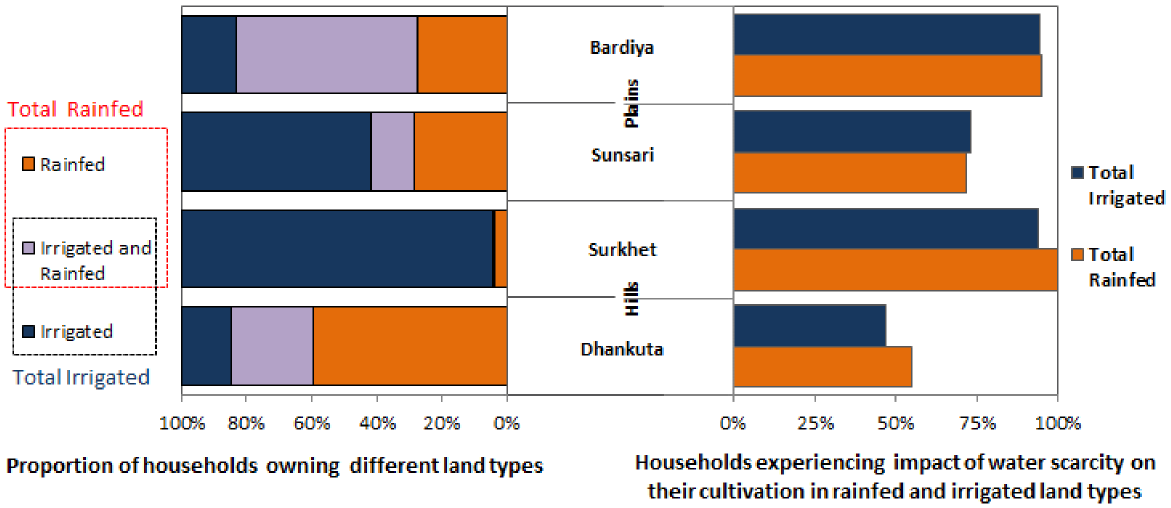


Figure 11 Proportion of households owning different land types, and the impact of water scarcity on their cultivation

In the plains, groundwater was a reliable water source when supply from irrigation canals was low, but pumping costs reduced profit margins. Fears were expressed that greater water scarcity might transform irrigated land into rainfed land and rainfed land to fallow. Increasing water scarcity is most worrisome for households with small land holdings (i.e. of about 1 ha), which are the majority of households (**Table 4**). While most farmlands in Surkhet were served by irrigation, more than 95% of households owned less than 0.5 ha. Households with such small landholdings are particularly sensitive to fluctuations in water supply because they rely on the land for their subsistence.

Table 4 Proportion of households with irrigated and rainfed land holdings in studied districts

Land type	Land holding#	Hills		Plains	
		Dhankuta	Surkhet	Sunsari	Bardiya
Total Irrigated	<0.5 ha	21.6%	95.2%	18.1%	35.8%
	0.5-1 ha	15.5%	1.2%	16.1%	30.5%
	>1 ha	3.6%	0.0%	37.3%	6.3%
	All	40.7%	96.4%	71.5%	72.6%
Total Rainfed	<0.5 ha	41.2%	4.2%	19.7%	43.2%
	0.5-1 ha	28.9%	0.0%	8.3%	32.6%
	>1 ha	14.4%	0.0%	14.0%	7.4%
	All	84.5%	4.2%	42.0%	83.2%

Local units of land holdings were converted to ha as follows: 1 ha ≈ 1.5 Bigha in the plains and ≈ 19.96 Ropani in the hills.

5.4 Livestock

In rural areas of Nepal it is common for households to keep some livestock. **Figure 12** shows the proportion of households holding specified numbers of livestock and their income generated from livestock. The majority of surveyed households had less than four units of livestock or none, and few households owned more than five units of livestock. Most survey participants mentioned that they keep livestock for their own use and do not produce a surplus for sale. This reveals the common practice of just keeping an adequate number of livestock units to fulfil household needs. If there is a surplus, people consider selling (or exchange) livestock products to neighbouring households or nearby markets. In some cases, household income from livestock exceeded 50,000 NPR/yr, which is a significant amount in the rural context. Besides providing nutrition and direct income, livestock convert forest biomass into manure, which is valued by households as an organic fertiliser. More than 85% of the households in the hill districts mentioned that they are applying cattle manure to their fields. In the plains, cattle manure was used as both a fertiliser (39-45%) and as a source of energy for cooking (either as dried dung or used to produce biogas). Cattle also contribute physically to tillage operations and are used to transport loads and people over short distances.

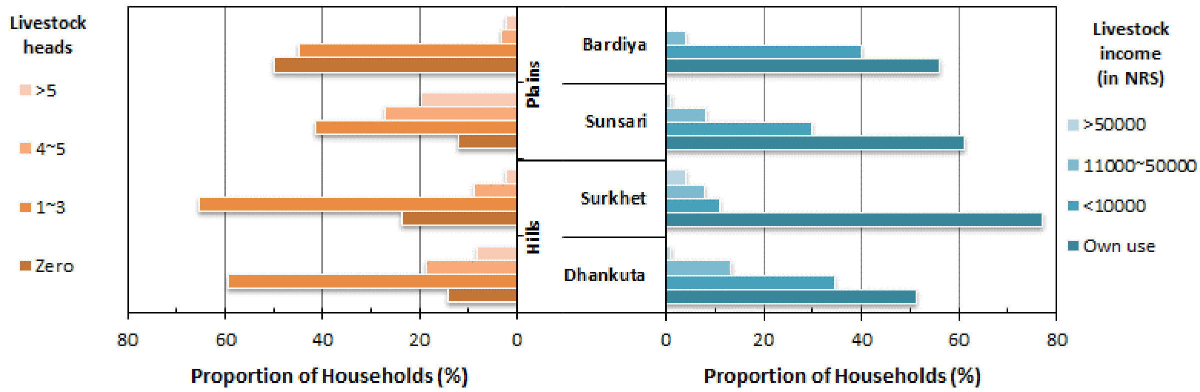


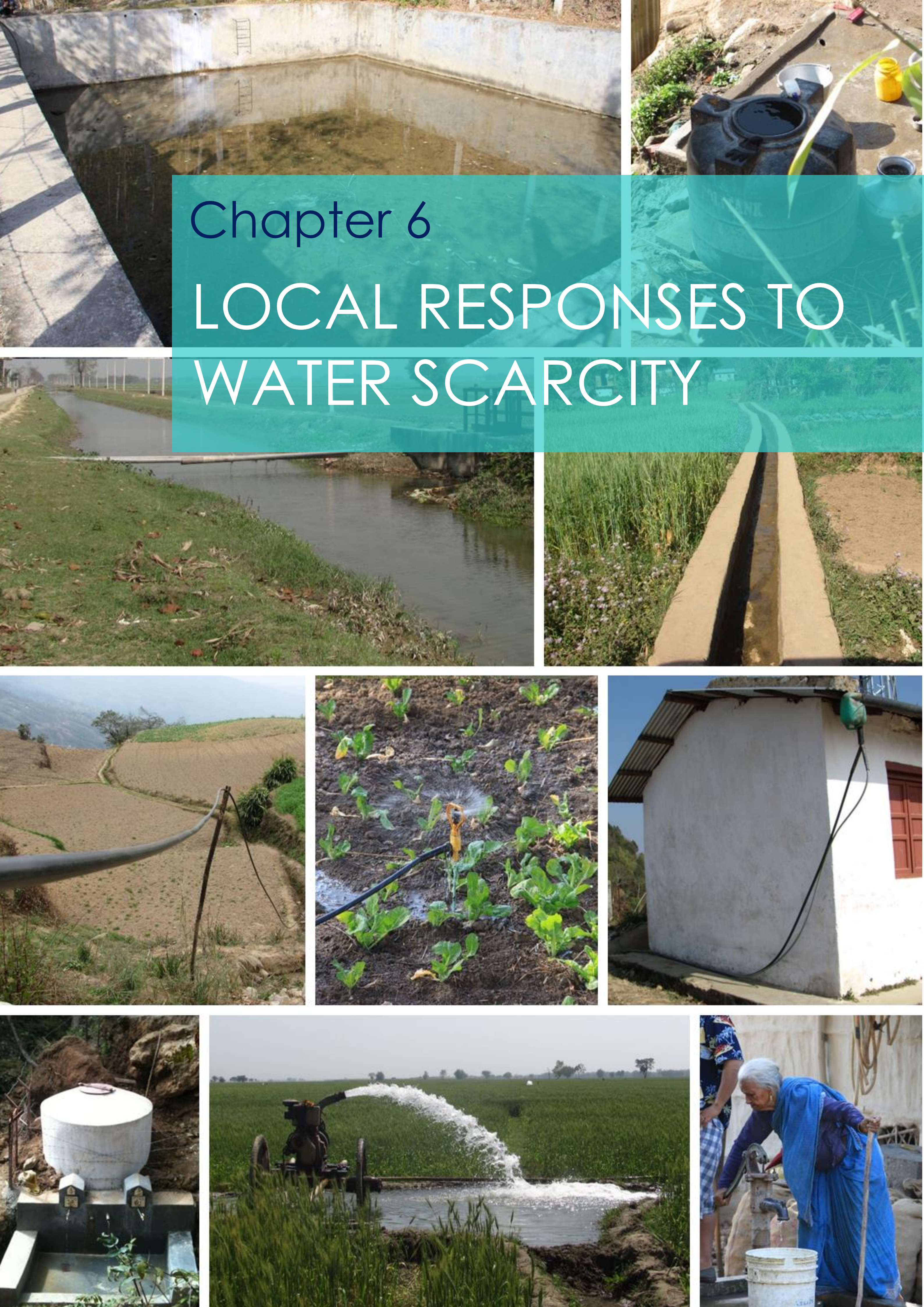
Figure 12 Household livestock holdings (left) and annual income from livestock product sales (right)

The survey found that households were forced to reduce livestock numbers for two main reasons. First, water availability during the dry season is declining and this is making it difficult for farmers to maintain a sizeable number of livestock. Each head of cattle requires 40 to 50 litres per day of drinking water, and water is also needed for feed preparation and cleaning. Second, decreasing rainfall has reduced the growth of forest biomass and the volume of crop residues, resulting in a shortage of good quality livestock feed. In the plains, rice straws were used as livestock feed, but this option was not available in the hills as some of the land is less productive than the fertile plains. As a result, in the hills a trend of households reducing their livestock and even holding no livestock can be observed in recent years. According to some FGDs participants, this situation is quite different from the past, when each household reared five to ten cattle without difficulty.

The declining number of livestock units per household has several implications. Household income from livestock is reduced, health may be impacted as a result of lower consumption of animal protein, there is less manure available, and there are fewer cattle that can be used for tillage.

Chapter 6

LOCAL RESPONSES TO WATER SCARCITY



Earlier chapters have provided strong evidence that both water scarcity and its direct impacts on smallholder subsistence livelihoods are increasing. The purpose of this chapter is to identify different kinds of response strategies adopted by local communities to cope with various levels of water scarcity. In addition, this chapter assesses the effectiveness of the adopted strategies and proposes measures to strengthen the coping responses.

The IPCC points out that the level of responses to an impact (such as changing rainfall and water scarcity) is determined by the antecedent state of exposure (such as access to water storage), sensitivity (such as dependency on rainfed farming), and coping capacity of a community or household (IPCC 2007). Impacts and responses can be heterogeneous as actual household water uses will determine the nature of response. The response can vary across space (such as hills or plains), time (such as wet and dry season), asset categories (such as forest, crop farming, livestock) and across households (Agrawal and Perrin 2008).

Households and communities in the surveyed areas were found to adopt various coping strategies to tackle increasing water scarcity. These coping strategies are either rooted in indigenous practices or influenced by newly introduced technologies and practices. The study focused on the categorisation of coping responses irrespective of the frequency they were used. The basic aim of this categorisation is to systematically understand the strategies pursued by households when faced with different levels of water scarcity and the response choices available to them. **Figure 13** shows different strategies used in the face of increasing water scarcity.

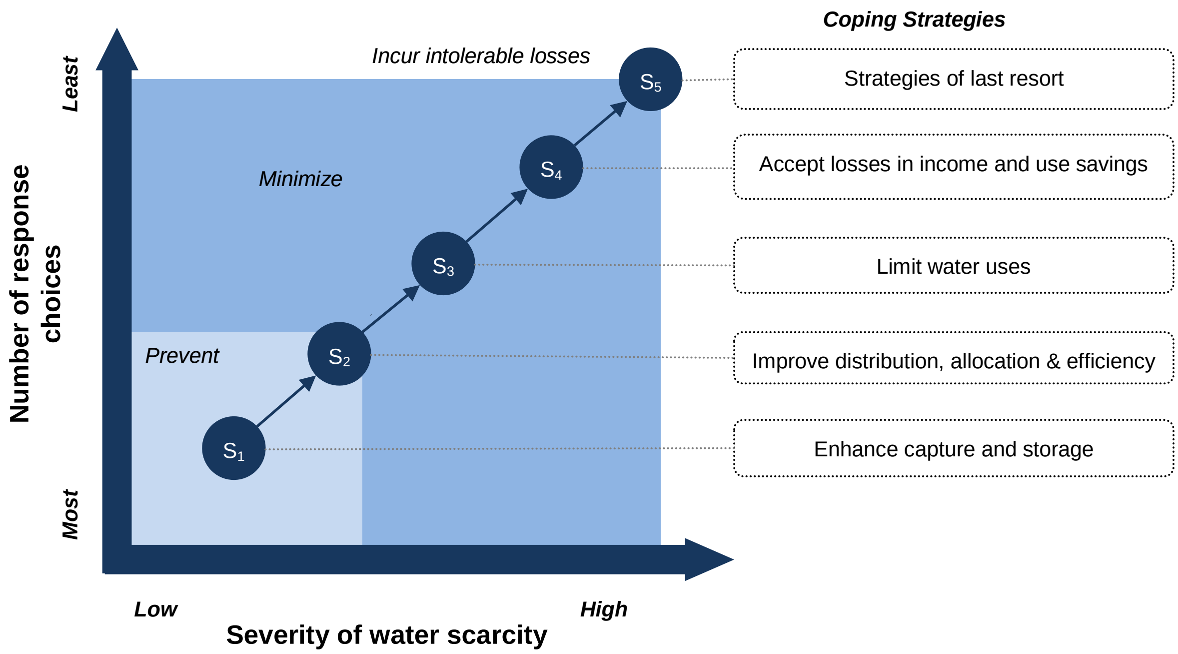


Figure 13 Identified coping strategies represented in terms of severity of water scarcity and available response choices

The study was able to categorise coping responses into five sets of strategies – S1: Enhance capture and storage; S2: Improve distribution, allocation and efficiency among users; S3: Limit water uses at the household level; S4: Accept losses in income and use savings; and S5: Strategies of last resort. S1 and S2 can be viewed as expansive and accommodating strategies that can prevent potential losses or even increase benefits, while S3 to S5 can be viewed as contractive strategies that aim to minimise losses (Wheeler, Zuo and Bjornlund 2013). S3 is adopted when losses are inevitable, as it is the least expensive coping strategy in this situation. S4 is resorted to when water scarcity becomes a threat to the fundamental water needs of the household. S5 strategies are adopted as a last resort when all other strategies are not effective. Figure 13 shows that households or communities had fewer response choices as water scarcity increased. They resort to more difficult coping responses as their earlier coping strategies are no longer effective.

6.1 Strategy-1: Enhance capture and storage (S1)

As a first measure, households attempt to enhance water capture and storage through strategies such as diversification of sources, storage and conservation.

Diversification

Preference for a particular water source is dictated by the geographic context (hills, plains), availability over time, convenience (location and ease of access), effort (time and cost) and nature of use (domestic, livestock, irrigation). In the hills, where springs and small rivers are the only natural water sources, people have expanded their access to more than one source using a variety of methods. In the past, people used to rely only on the nearest sources because the difficult terrain put other water beyond their technical and financial reach. However, in recent times, these barriers have been surmounted to some extent by structural interventions in the form of conveyance channels or piping.

In the plains, improved access to groundwater allowed for a major departure from traditional rainfed farming or dependency on irrigation canals. For many of the surveyed households, groundwater was the only water source, because of its easy access (55% of households), year-round availability (51%), and affordable cost (28%). The rapid spread of groundwater extraction methods such as hand pumps, tube wells and boring, especially over the past four to five decades, has transformed the water use habits of the households. Groundwater extraction methods have enabled on-demand irrigation even for small tracts of land occupied by smallholders for subsistence farming. Improved access to groundwater was one of the reasons for the lower impacts of water scarcity in the plains compared to the hills.

Storage

Water storage has recently emerged as a viable option to increase water security, especially in the hill districts. The building of water storage structures is one of the steps adopted to improve access to safe drinking water and to meet the growing demands for irrigation, including for commercial cultivation of high value crops. Storage makes it possible to distribute and allocate water in a scheduled manner, as well as to improve access, supply adequate water volumes to meet increasing demands, and reduce chances of contamination.

Although storage systems are mostly constructed to provide water for household use, special storage ponds/tanks have also been constructed for irrigating high value crops, such as in Dhankuta, where these crops are an important source of household income. Pilot trials for mist harvesting and rainwater collection have been conducted in some areas.

In contrast, no significant efforts have been made in the plains to improve storage capacity because of the more readily available supply of water from irrigation canals and groundwater pumping. However, there were limited instances of constructing overhead tanks to store and distribute pumped groundwater for household uses mainly for the sake of convenience.

Conserve quantity and quality of water sources

In the hills, people are gradually becoming serious about conserving water sources, especially those that are considered life-saving during prolonged water scarcity. Initiatives taken include preventing contamination by constructing protective structures or increasing greenery around the sources. While few efforts were made to conserve water in the plains, the FGD participants in Sunsari and Bardiya stressed the need for water treatment, storage and distribution systems to supply arsenic free drinking water to households.

6.2 Strategy-2: Improve distribution, allocation and efficiency among users (S2)

A second strategy focuses on improving the water distribution network and better allocation of water resources among users. This strategy is also closely tied with S1 as it enables access to water sources or stored water. In the surveyed areas, existing canals were renovated and new canals constructed to meet water needs. Training of water from upstream to downstream by the use of inexpensive plastic pipes was also found to be quite popular in the hills. These plastic pipes can bring water from sources located relatively far (sometimes even exceeding a few kilometres) to the point of use. Small-scale piped water supply for domestic use was another measure applied and well-suited to both the hills and the plains.

Rural water supply schemes supported by government and donor agencies are either in existence or under planning in all the studied districts. These schemes aim to develop an integrated system of water storage and piped networks. In addition to improving water supply, they can contribute to resource mobilisation and community solidarity, especially when they involve the formation of water user associations (WUA).

At community level, people were engaged in managing common water sources and infrastructure through one or more WUA, either Drinking WUAs (DWUA) or Irrigation WUAs (IWUA) (WaterAid in Nepal 2005). The WUAs can be registered with the government or can operate through informal rules/norms. Their main actions include conservation of sources, storage and distribution. They also undertake regular operations and maintenance, collect fees and develop rules for water use. At times of water scarcity, WUAs were found to be storing water as well as scheduling distribution. The allocation role of WUAs is crucial when a limited number of sources have to be shared among a large number of users. The WUAs prioritise users, manage queues and prevent contamination from inappropriate practices. WUAs were found taking collective actions to introduce new practices, such as constructing new storage tanks to irrigate vegetables through sprinklers.

WUAs have contributed to effective allocation of stored water, including through collective decisions on the different types of water use. During times of acute water scarcity, IWUAs and DWUAs in some survey areas were co-operating to divert water under their command for domestic uses, which were considered more urgent than irrigating crops. This kind of coordination between WUAs had evolved as a collective response to water scarcity in recent times.

6.3 Strategy-3: Limit water uses at the household level (S3)

Households resort to reducing water use when water scarcity becomes acute. While this can potentially take the form of more careful water use in terms of being more efficient and productive with water, in practice this involves curbing less essential but nevertheless important uses (such as hygiene) and prioritising more essential uses (e.g. drinking). This strategy coincides with community-wide efforts such as IWUA and DWUA collaboration to divert available water to domestic uses. In the hill contexts, during periods of acute water scarcity households limited their water uses mainly to drinking and cooking by progressively cutting water use for farming, livestock, washing, bathing and sanitation (as observed in Dhankuta (site E1)). Reducing the number of livestock and minimising cropping intensity were common strategies adopted by people on the upper slopes in Surkhet, who experienced inadequate water supply during the dry months. In Bardiya (sites W7 and W8), a lowering of the groundwater table (>15 m) during the dry season made lifting water by hand pumps laborious to the point where some were abandoned. In such situations, people were more concerned about securing water for essential domestic uses.

6.4 Strategy-4: Accept losses in income and use savings (S4)

When the above measures for improving water supply were insufficient or ineffective, households had to make unavoidable trade-off choices for containing the impacts of water scarcity. In such situations, households were found to accept losses and allocate more of their time and resources to secure water, both in the hills and the plains. This negatively impacted household assets in two ways: 1) Income generating opportunities were lost, and 2) savings (and loans) were used, either for purchasing water, transporting water in tanks or renting pumps. The problem was particularly evident in the hills, where the few water sources had to be shared among a large number of users, as people had to spend long periods of time fetching water for household use. The situation was particularly harsh for households in the upper hill areas, as when water from nearby taps is no longer available, they must send people to fetch water from springs or rivers, which are often located far away, as shown in **Figure 7**.

6.5 Strategy-5: Strategies of last resort

In cases of extreme water scarcity, coping options S1 to S4 may no longer be effective. In such cases, households resort to compromising the health of their members, selling important productive assets, taking land out of production and seeking uncertain off-farm employment. In some instances, people resorted to consuming unsafe water, either from surface or underground sources. Households also tended to stop rearing livestock as there was a high risk of deterioration of animal health in the absence of adequate water and feeds. Major impacts were seen on both rainfed and irrigated farming, which water scarcity rendered unproductive. Rather than spending time and effort searching for ways to irrigate crops, households resorted to fallowing, which avoids the risk of crop failure and allows time for off-farm income generation. The strategy of fallowing land was not limited to the hills but was also practiced in the plains where groundwater pumping in periods of extreme water scarcity had become costly for smallholder farmers because of rising fuel prices and the need for frequent pump maintenance.

Increasing water scarcity and resultant loss of farming opportunities could encourage greater seasonal migration of labour. There is a common seasonal trend among households, more so in western than eastern parts of Nepal, for some of their members to migrate to cities in Nepal and India in search of employment opportunities whenever they are free from farming. Seasonal migration is attractive to households as a strategy to cope with extreme water scarcity as it can provide cash income and as it reduces the amount of food grains that the household must use for its own consumption.

6.6 Sustainability of coping strategies

The problem of reactive adjustments

The coping responses to deal with water scarcity that were identified in the survey areas were undertaken by households or communities either independently or with external support. Even though signals of climate change, in terms of rainfall patterns or temperature, are already perceivable, the coping responses were taken without full assessment of anticipated climate impacts and were not based on a long-term perspective. The responses can be loosely categorised as reactive adjustments (inbuilt, routine, or tactical) that were intended to satisfy increasing demand for water, or to deal with a reduction in the volumes of available water, or to minimise losses in the absence of water. These kinds of coping responses are intended to avoid an imminent crisis, but without sufficient consideration for long-term implications, they can lead to maladaptation and increase future vulnerability (Moser and Ekstrom 2010, Wheeler, Zuo and Bjornlund 2013). Short-term coping responses are based on the households' tendency to mobilise their internal resources and capacity to contain water scarcity. Repeated reliance on such coping responses could deplete the resource base and increase vulnerability to future impacts as fewer resources will be available for subsequent coping measures (IPCC 2007). Further interventions or adjustments will be necessary to ensure that coping responses follow a sustainable development pathway and do not lead to maladaptation.

FGD participants in all districts explained what they understood to be the deficiencies and risks associated with their coping strategies. Potential measures to overcome these deficiencies and risks were also identified during the discussions. Through this process, this study was able to explore options to strengthen coping strategies that are feasible and acceptable to the local communities. In addition, FGD participants also examined pre-requisites for implementing the identified options. **Table 5** summarises the associated deficiencies and risks with reactive coping strategies, suggests corrective measures to lessen the risks and lists necessary prerequisites to implement the corrective measures.

In the hills, S1 and S2 are constrained by a lack of inadequate water sources and unplanned exploitation of water sources. A lack of coordination to ensure that coping responses are in the broader community interest has resulted in unplanned abstraction driven by individual household needs. Some economically well-off households have sought to take control of water sources for individual purposes by, for example, purchasing land with spring sources, a practice mainly found in Dhankuta, using pipes to divert water from distant sources, or storing and distributing water in an unplanned manner. These factors led to escalating competition over access to limited water resources and further aggravated water scarcity. Such practices can lead to local conflicts over water sharing, as has been reported in other parts of Nepal (WaterAid in Nepal 2012). The lack of strong legal and institutional intervention has allowed these malpractices to take place. Another deficiency of S1 and S2 is related to insufficient development planning and land use changes that have affected the hydrology of catchments and water sources. These include road construction, deforestation for farming and settlements, unplanned reforestation, scattered settlements, land fragmentation and sand mining along river courses.

The negative impacts of coping responses were also visible between upstream and downstream communities. Uncoordinated use of water in the upstream areas and changes in flow paths have resulted in the absence of water from some downstream springs and rivulets for much of the year.

Table 5 Associated deficiencies and risks of coping strategies and suggested corrective measures

Case	Associated deficiencies and risks	Suggested corrective measures	Prerequisites for corrective measures
S1: Enhance capture and storage			
Hills	-Inadequate sources and increasing competition to access -Loss of spring sources due to inappropriate construction of structures for water storage or distribution and lack of assessment of possible negative impacts -Unplanned scavenging of water sources; legal measures, such as Water Resource Act 1992 that maintains state ownership over natural water resources, are ineffective to control the capturing of natural water sources for private uses -Blocking and drying of spring sources due to land use changes (road construction, sand mining in rivers, deforestation)	-Storage of excess rainwater and runoff during wet season -Delineation of conservation sites at upstream recharge zones of spring sources -Making inventories of water sources (spring, ponds, rivers) and proper assessment of their supply capacity -Inter-basin water transfer based on wider consensus among on-site residents and off-site potential users -Rule setting for modifying water sources and constructing new water storage structures	-Technical and financial support to initiate rainwater harvesting, construction of recharge areas, and divert water from distant sources along difficult terrain -Technical know-how to assess impacts on water sources of construction and land-use change -Legal and institutional facilitation for conservation of sources and planning of construction
Plains	-Higher fuel costs for groundwater pumping	-Develop large-scale groundwater projects to minimise pumping costs -Use electricity to cut pumping costs -Better management of groundwater infrastructure	-Reliable supply of electricity (including use of renewable solar power) -Public private partnership to finance large scale groundwater projects -Skills for operation and management of community-based groundwater irrigation
S2: Improve distribution, allocation and efficiency among users			
Hills	-Poor/inadequate distribution facilities -Low adoption of multi-use water system -Inadequate coordination within and among WUA -Weak upstream (source) and downstream (user) cooperation on water sharing	-Improved coordination among users preferably mediated by the local government -Build or transform to multi-use water systems -Transparent and inclusive decision making -Regular maintenance of irrigation canals -Rationalise water pricing to justify benefits (such as yield)	-Relatively large investment sources for piped water supply, even when willingness of users to provide in-kind (labour) and cash contributions is high -Incentives for strengthening WUA to ensure equitable sharing of costs and benefits -Reliable service for introducing rational pricing
Plains	-Poor management and distribution in canal irrigation systems -Inadequate coordination within and among IWUAs resulting in poor regulation and maintenance of canals -Low groundwater pumping capacity and resultant discharge	-Improve coordination among users -Promote conjunctive uses of surface and groundwater -Transparent and inclusive decision making -Group-based larger capacity groundwater pumping	-Relatively large investment sources for piped water supply and groundwater irrigation, even when willingness of users to provide in-kind (labour) and cash contributions is high -Skills on community/group managed groundwater irrigation

Table 5 Continued….

Case	Associated deficiencies and risks	Suggested corrective measures	Prerequisites for corrective measures
S3: Limit water uses at household level			
Hills	-Increased vulnerability due to the reduction of income and food production -Inadequate water for domestic uses, hygiene and sanitation	-Adopt S1 and S2 -Improve water use efficiency and minimise wastage	-Government and external support to adopt S1 and S2 -Coordination/cooperation to improve S2 -Know-how on water efficient farming
Plains	-Same as hills	-Adopt S1 and S2, in particular, safe and affordable access to groundwater	-Same as hills
S4: Accept losses in income and use savings			
Hills	-Loss of savings and asset base to secure water -Reduced intake of nutrition and poor health	-Access to emergency loans and off-farm income to sustain livelihoods	-Government and external support -Preparedness on risk reduction measures
Plains	-Same as hills	-Same as hills	-Same as hills
Strategy 5: Strategies of last resort			
Hills	-Bear direct losses	-Find off-farm employment -Exchange of risks (insurance)	-Government and external support on income generating activities -Preparedness on risk reduction measures
Plains	-Same as hills	-Same as hills	-Same as hills

The problem of water supply is further intensified by a lack of adequate storage facilities, ineffective distribution and resultant poor allocation of available water. Weak coordination of the members of WUAs and a poor culture of cooperation between upstream and downstream users on the issue of water savings and cost-benefit sharing have contributed to inadequate supply and permanent water shortages among certain users.

The ineffectiveness of both preventive strategies (S1 and S2) to deal with cases of severe water scarcity were translated into direct losses in terms of inadequate water for essential uses (S3), increasing use of household resources to secure water (S4), and strategies taken when households no longer can access safe and adequate water supplies (S5). The unsuccessful application of these coping strategies can contribute to increased household vulnerability through impacts on human health, reduced land productivity, reduced income, use of savings, and resort to loans and unsure seasonal employment.

Corrective measures discussed and their prerequisites

In the FGDs, participants suggested several corrective measures to manage the worsening situation, such as increasing storage by capturing excess rainfall and runoff during the wet season, and making inventories of available water sources. Inventories can help to prioritise water sources according to their natural capacity and services, which is helpful for planning conservation activities (including recharge and storage of excess rainfall), restricting inappropriate modifications of sources and their catchment areas, and safeguarding future uses.

Where water sources were inadequate to meet existing needs, communities were vying to secure water sources through inter-basin water transfer. However, in the absence of cooperation and strong rules for equitable cost-benefit sharing, any such attempts are likely to face resistance and could lead to tensions over water sharing, as the targeted water sources may already be used by local people near the source, or residents may want to protect their rights to these sources because of the increasing water scarcity. On the issues of distribution and allocation, the study found that in the hills, measures to strengthen coordination and cooperation among users within a WUA as well as between upstream and downstream users are required for transparent and inclusive decision making, the introduction of cost-benefit sharing mechanisms, and the improved operation and management of facilities. The pre-requisites for these corrective actions include sufficient technical and financial capacities, and the synchronisation of planning processes and institutional interventions with technical or financial interventions to reduce negative consequences and to increase public awareness of malpractices.

In the plains, deficiencies in S1 and S2 were primarily costly groundwater pumping and ineffective use and management of irrigation canals. As the discharge capacity of individual shallow tube wells is small, respondents shared the view that installation of large capacity deep tube wells, which use electric power, could significantly reduce the per unit abstraction cost. However, the large costs of the initial investment, operation and maintenance, the required technical skills for operation and management, and the need for collective uses were identified as barriers for the adoption of deep tube wells. External support for deep tube wells would thus be required. Respondents in Bardiya mentioned that some large-scale deep tube well projects were initiated in the past, but these were discontinued after encountering major technical problems that required expensive maintenance, involving the hiring of technicians and procuring components, which the residents could not easily afford. Co-investment (government, loans and private shares), transparent rules for water allocation and cost sharing, and long-term use and maintenance plans could enable smallholder farmers to harness benefits from large-scale boring, provided that electricity is available continuously at an affordable price.

Prior to large-scale investments, the respondents explained that they prefer to improve the performance of canal irrigation systems. While improved canal irrigation systems can contribute to reducing irrigation water deficits at low cost, this must be a long-term strategy as it requires multiple adjustments in institutional and management processes. Sluggish progress in improving governance and increasing water use efficiency of surface irrigation schemes in Nepal, India and other parts of the world (Ward, et al. 2006) indicates that measures to improve distribution schemes can turn into lengthy processes.

Respondents in the plains were hopeful that through conjunctive use of surface water and groundwater the problem of water scarcity could be managed without incurring significant losses. However, even with more rationale or efficient conjunctive uses, communities could face difficulties because of the increased pressure on land and water resources from population growth. Population growth could lead to further land fragmentation and land use changes (such as conversion of arable lands to residential plots), which will negatively impact the effectiveness of water allocation – one of the key benefits of conjunctive uses of surface and ground water. Aggravation of water scarcity in the hills might also result in a gradual influx of settlers from these areas, thereby increasing the pressure on land and water resources in the plains.

Chapter 7

DEVELOPING AN INTEGRATED APPROACH FOR BUILDING RESILIENCE OF SMALLHOLDER SUBSISTENCE LIVELIHOODS IN THE FACE OF CLIMATE CHANGE DRIVEN WATER SCARCITY:

A DURABLE ALTERNATIVE TO STRENGTHEN COPING RESPONSES

Chapter six revealed both that local communities have adopted a wide range of coping strategies to deal with increasing water scarcity and that none of the coping responses identified were planned or undertaken as a long-term solution. The effectiveness of these strategies is limited and they could lead to maladaptation as they are mostly ad-hoc and uncoordinated. Difficult terrain, remoteness, poor technical services, lack of financial services, the weak asset base of households, and poor managerial skills were found to be key constraints to managing water scarcity. In particular, support for vulnerable groups that are facing severe water scarcity, due to limited coping choices (S3, S4 and S5), is challenging as they need not only improved access to water but also alternative income to support their livelihoods. An integrated approach with an appropriate mix of technical, financial and institutional interventions has to be introduced to provide an effective solution to water scarcity. An integrated approach should aim at reversing the tendency in coping responses from the frequently encountered loss making strategies (S3, S4, S5) to preventive strategies (S1-S2) and contributing to building the resilience of smallholder subsistence livelihoods.

The purpose of this chapter is to set out an integrated approach for building the resilience of smallholder farming and to identify the required preconditions for adopting this approach. This endeavour is in line with calls from others studies for an integrated approach to adaptation planning, rather than standalone approaches in water resources management and other related sectors (Cap-Net 2009, Mysiak, et al. 2010, Prabhakar, Shivakoti and Mitra 2014, Prabhakar, et al. 2013). The IPCC has also identified an integrated approach to water resources management that links with land management as a promising tool for climate change adaptation (IPCC 2014a).

A lack of clear understanding of local specificities often hampers implementation of an integrated approach to land and resource management. This was revealed during the analysis of the causes and impacts of water scarcity and local responses in the study area, where there were weak connections between management domains, mainly land and water, in the coping responses identified. As coping responses were uncoordinated, they led to avoidable trade-offs. Coping responses generally did not take into account the relationships between land and water, including between upstream and downstream processes. They were also not based on a balanced consideration of conservation concerns and livelihood needs at a landscape level. Consequently, while the coping responses brought some benefits to households employing them, they also had unintended negative impacts for others. For instance, while reactive responses to improve water supply provide immediate benefits, if not properly planned they can lead to increased consumption of water, which can exacerbate water shortages over the long term. A prerequisite for the effective creation of positive feedbacks from response actions is that the consequences of one intervention on a range of interrelated variables are fully understood in advance.

Given the multi-dimensional nature of water scarcity impacts and the potential for maladaptation from reactive coping responses in the studied areas, an integrated approach to water scarcity is essential to strengthen coping responses and for building resilience. In the case of smallholder subsistence livelihoods, an objective of integrated management is to improve the resilience of socio-ecological systems (SES). SES are coupled systems of humans and nature that constitute complex adaptive systems with ecological and social components that interact dynamically through various feedbacks (Simonsen, et al. 2014). Smallholder subsistence livelihoods are in themselves a good illustration of SES as they are built on integrated natural resource management practices at the household level. In Nepal, smallholder subsistence livelihoods have for centuries been based around relations between livelihood activities and natural processes. The century-old interactions between smallholder subsistence livelihoods and the local environment have provided local communities with an inherent adaptive capacity to deal with climatic and socio-economic changes, including intermittent water stresses, and have served as the basis for resilient SES. However, there is a widening gap between household aspirations and what subsistence livelihoods are able to provide in both the hill and plain areas of Nepal, and this can be seen in the movement towards more resource intensive modern farming practices. More intensive modern farming can increase vulnerability to climate change induced water scarcity as generating high yields from modern seed varieties usually requires well developed irrigation. Integrated approaches that enable households to avoid and cope with water scarcity become all the more important in this context.

Having assessed the causes, impacts and coping responses of water scarcity in the studied areas, this study identified three domains of integration essential to deal with the current and expected future water scarcity (**Figure 14**). The first integration domain is the landscape, i.e. areas over which strong linkages exist between ecosystems / land uses. The study found that the livelihood opportunities that are possible in the local landscapes were not fully harnessed in an appropriate manner. The second integration domain is the economy. The economic base of households is weak and can be reinforced by introducing efficient and more productive landscape management. A stronger economic base will have a positive impact on household coping capacity. The third domain is the socio-institutional domain. Households mostly make decisions over the use and management of land and water resources independently, because of the currently weak role and capacity of existing local institutions in decision-making. Strengthening local institutions can lead to better planned and more effective collective decisions on resource allocation, which can contribute to alleviating water scarcity. There is a need to incorporate these three domains within the broader perspective of SES to ensure that ecosystem health and livelihoods are linked.

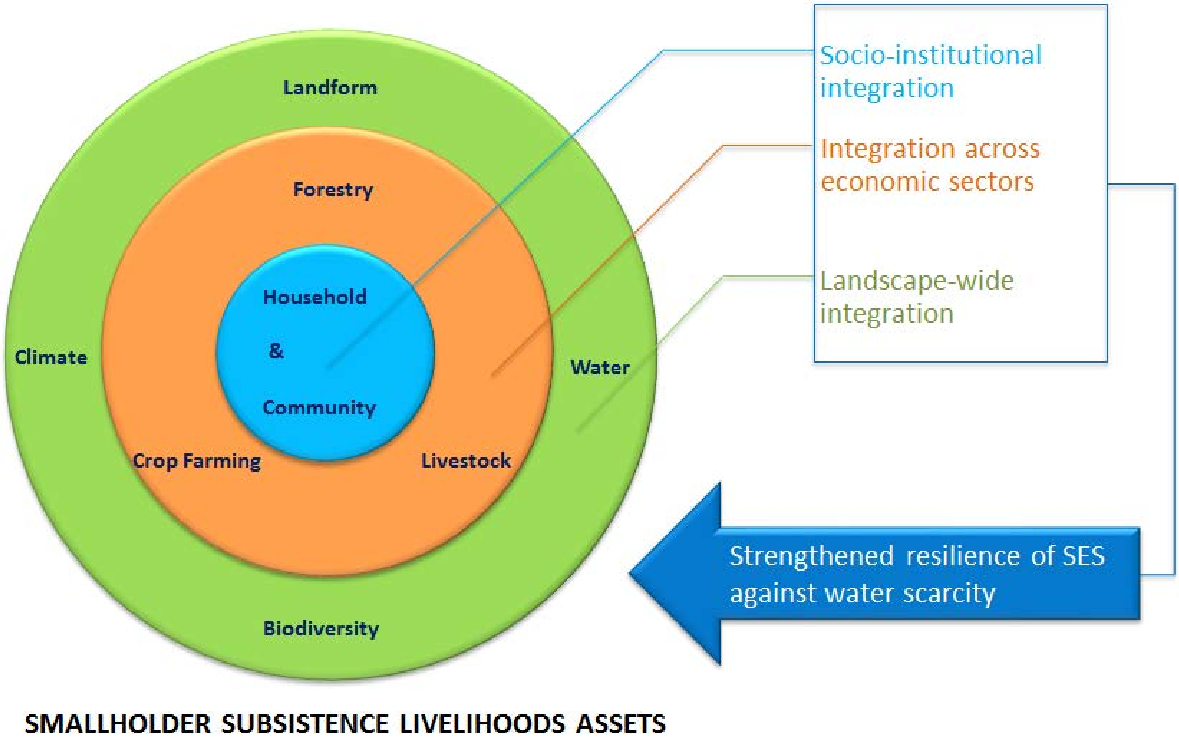


Figure 14 Conceptualisation of an integrated approach to cope with water scarcity and strengthen the resilience of SESs

The subsequent sections will examine issues and measures for integrated management corresponding to the three domains of integration.

7.1 Landscape-wide integration

The proposed landscape integration aims to maximise synergies by taking advantages of the physical and climatic setting of the whole landscape when making decisions over the use and management of natural resources (forest, biodiversity, land and water). The predominant perception by the local stakeholders is that topographic, climatic, natural and social complexities, particularly in the hills, constitute barriers to technical and financial interventions. Such barriers can to a large extent be overcome through landscape-wide planning. As explained in the previous chapter, this was not well considered in the study areas when making land and water management decisions or during the adoption of coping measures.

In order of priority, the foremost strategy to deal with depleting water sources is maximising benefits offered by the landscape to improve availability and distribution of water resources, i.e. strengthen S1 and S2. This includes enhancing one or more water storage options by capturing rainfall and excess runoff, which is the most straightforward and effective strategy to address physical water scarcity. A large portion of annual rainfall (>75%) occurs during the four months (June-September) of the monsoon (**Figures 2** and **3**), and much of this is soon lost as runoff. A capture and storage strategy can solve the uncertainty caused by erratic rainfall, such as timing, frequency, duration, magnitude, or intensity, and reduce temporal water deficits by delaying release of water so that more water is available during lean periods. The storage of rainwater by upstream users means their own water supply is more secure and river flows are less depleted, benefiting downstream users and ecosystems. Investments in capture and storage should not lead to entirely new, large, costly and lengthy construction works that local people find difficult to operate and manage. The focus should rather be on soft-structural measures that take advantage of features offered by the landscape, such as the preservation of recharge areas or restoration of natural water storages (Linham and Nicholls 2010). The main benefit of soft-structural measures is that they can be implemented relatively cheaply with minimum use of external inputs, but it is also possible to use modern technologies offering higher convenience and efficiency. Soft-structural measures will have positive impacts not only on water storage but also on the long-term recharge of natural springs and groundwater.

The study observed significant opportunities in the plains for capture and storage options in local ponds or canals, but a landscape approach needs to be implemented to stop unplanned land use change, particularly the conversion of fertile farming tracts into residential areas for urban settlers. Improved and sustainable access to groundwater is also possible by raising the aquifer level by enhanced aquifer recharge, which will reduce the cost and manual effort of groundwater pumping.

Another advantage of integrated landscape-wide planning is more effective distribution of available water. In the hill areas, the construction of a distribution network that can take advantage of gravity, thus avoiding the use of pumps, could minimise the costs of distribution. In the study areas there have already been instances of constructing canals and pipes to direct water from a higher elevation, but they were implemented without evaluating merits and demerits to the local environment. This often led to over-pressure on the same sources by many users so that many of the canals and pipes were without adequate water flow.

Improving distribution is equally relevant in the plains, where effective distribution of surface water could minimise dependency on groundwater and avoid the need to pump it using costly energy sources. The effectiveness of capture and storage in the plains depends upon the extent to which it promotes conjunctive use of surface and groundwater. Conjunctive use can minimise excessive pressure on natural sources since more water is available to end users from either source.

In the study areas, large-scale and costly irrigation systems were already distributing water through canal networks but they could not cover all areas and they were intended to only provide water for irrigation. In changing climatic and social contexts, single purpose water infrastructure, such as irrigation canals, need to be adjusted to multi-use systems. In the case of irrigation canals, this adjustment includes introducing a storage and recharge function for the canals, using the canal water for household purposes, livestock, aquaculture and crop irrigation, as well as providing more flexible distribution in terms of time and location to avoid distribution losses (e.g. through percolation and evapotranspiration).

A capture-storage and distribution strategy alone will not be effective unless this is implemented in harmony with attributes of the landscape. An integrated strategy is required that involves zoning of major land uses, such as location and area of forest, farmlands and households. Such a strategy will contribute not only to water capture, storage and distribution, but also to improving water use efficiency. For instance, restoration of degraded forest areas, increasing forest cover and density, and proper management of croplands are key conditions for improving recharge rates, while use of water efficient crops, in-situ moisture conservation, sprinkler and drip irrigation can reduce water use for growing crops. Integrated planning is part of this strategy and can strengthen the household livelihood asset base and minimise water-related risks. Integrated planning is particularly helpful for the provision of basic services (health, markets, education etc.) that are difficult when households or farmlands are scattered. This study found most households in the hills to be located far from each other so the delivery of these services was technically and financially challenging.

In the plains, the problems identified were related to small and fragmented land holdings. Shallow tube wells (STW) could solve irrigation needs but the pumping capacity of STW could not justify the high installation and operation costs. Sharing of pumps could reduce the cost per household but this was not always practical as farmlands were not adjacent to each other. Therefore, there is scope to improve access to groundwater by bundling the management of farmland based on the purpose of use.

Another important advantage of an integrated landscape wide approach is that at both the local and larger watershed-level scales, it can avoid conflicts between uphill and downhill areas by improving river flow. Rising local tensions over water source sharing in the studied areas could become more serious in the future. Part of the solution lies in incorporating recycling, reuse and recovery in land and water management practices uphill so that more water is available to downhill communities. This can also prevent water quality degradation by controlling soil erosion, runoff of agro-chemicals and waste discharge in the uphill areas.

Better uphill-downhill coordination is not only required within hill areas but also between the hills and the downstream plains. Landscape-wide integration has the potential to enhance ecosystem services in the hills, through better water conservation, capture, storage and distribution. This can benefit the plains by reducing peak river flows and sedimentation, and providing higher river flows during dry periods. Positive interactions between the hills and plains that can be promoted include improving the supply chain of food and other products from the fertile plains and promoting tourism in the hills. This will result in better livelihood conditions in the hills, which in turn could reduce hill to plain migration and the resultant problems, such as land fragmentation and conversion of farmlands to residential plots.

7.2 Integration across economic sectors

Landscape wide integration aims, *inter alia*, to improve economic efficiency and productivity of land and natural resource management without degrading the natural resource base. While taking advantage of landscape services, in its economic dimension the concept of integration comprises the design and implementation of activities that support livelihoods. These activities aim to mobilise key assets (forest, crop farming, and livestock) and human capital for the wellbeing and resilience of rural communities, including their ability to cope with water scarcity.

To tackle water scarcity, integration across economic sectors aims to minimise economic losses by improving water use efficiency at points of different water uses. Combined with better allocation and distribution, measures to increase efficiency can contribute to the sustainability of water use and an optimal mix of water uses. The approach involves good practices across water use sectors, such as agronomic practices that minimise moisture losses from the field. There is great potential for in-situ moisture conservation at the farm level, which is currently not widely practiced. Moisture conservation in farming involves planting of drought resistant crops (including long rooted crops), altering the timing and location of cropping activities to utilise soil moisture, reducing evapotranspiration through mulching, zero-tillage, shade trees/crops etc., and improving the productivity of rainfed farming through adjustment in planting time, use of short lifecycle catch crops, and supplemental irrigation. The efficiency of water use in irrigated agriculture can also be improved, such as by better crop scheduling, use of water efficient irrigation (drip or sprinkler), and promoting water recycling along upstream and downstream flow paths.

Integration across economic sectors should not just be limited to gains in water efficiency, but should also consider improvements in other areas. For instance, in all studied areas participants in the FGDs thought that decreasing forest cover, inappropriate location of planted forests and worsening quality of stands contributed to a reduction in water flows. Through strategic forest planning, these problems can be addressed by assigning multi-purpose conservation zones, including for enhancement of hydrology and erosion control, as carbon sinks (potentially under the mechanism of REDD+[3]) and habitat for biodiversity, and diversifying rural income from sustainable harvesting of timber/non-timber forest products. Lack of freely available land was pointed out as one of the barriers for afforestation. Some of the participants of the FGDs suggested that this problem could be dealt with at the local level by mandatory planting of trees on all private land, e.g. covering 10 to 20% of the area. Other options are to promote biomass production at the farm level through agro-forestry and the use of crop residues for cooking or

[3] Reducing Emissions from Deforestation and forest Degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

feeding livestock, and ensuring livestock numbers are matched with the availability of forage or feeds.

Integration is not just about introducing good water management practices that have been tested and applied in various parts of Nepal (ICIMOD 2007, WaterAid in Nepal 2012, WOCAT 2014), it is also about sustaining, up-scaling and replicating these practices. The economic dimension of an integrated approach needs to consider measures to improve the productivity of current smallholder subsistence livelihoods in order to allow widespread adoption of good practices. In the case of forestry, this involves improvements in the availability of and access to fuel wood, timber, non-timber products, fodder and grazing. In the case of livestock, higher productivity can be achieved by matching the numbers of heads with carrying capacity. In the case of farming, an integrated approach can promote crop diversity, and production of more grains, vegetables or fruits for consumption, storage and selling. In addition to these measures local governments and non-governmental organisations (NGOs) can play key roles in promoting off-farm income generating opportunities to minimise suffering during severe water scarcity when growing crops or raising livestock is not feasible.

7.3 Socio-institutional integration

Social and institutional processes facilitate integration in the landscape and economic domains. Social institutions influence the livelihoods and adaptation of rural households in three important ways (Agrawal and Perrin 2008): they structure the distribution of risks from climate change impacts, including from water scarcity; they constitute and organise the incentive structures that will determine whether responses are individual, collective or both; and they mediate (external) interventions into local contexts, such as implementation of new water saving technologies. Institutions provide space for organisation, set operational rules/norms, retain connectivity and communication, share the risk/burden, and improve participation and self-learning. The degree to which they generate these positive outcomes depends on the quality of governance of the institutional structures and decision-making processes. Meaningful participation and productive deliberation have been identified as two key pillars or principles of good governance (Cadman 2011).

In Nepal, for each major type of land and water use, local communities tend to have local community-based organisations. These groups include WUGs, CFUGs, women groups, micro-finance cooperatives, and political groups at the local level. In all the study areas the local community institutions were found to be rather weak in dealing with water scarcity even though small farmers and other local stakeholders were often organised in more than one community group. FGD participants opined that people were reluctant to take appropriate actions, such as adopting demand management measures for water saving, because they lacked institutional leadership to coordinate and implement such options.

From the perspective of integrated management, the basic problem of these groups was the lack of strong connectivity and coordination. Natural resource development and management at the national and district levels remain largely compartmentalised. This is reflected at the local level, as local communities need to interact with the line agencies to register and become formal organisations. The features and effects of the interventions between the different organisations also differ widely. In the case of forest management, interventions are generally related to the effective enforcement of policy and legal provisions and limited to activities for the conservation of forest resources or use of forest products. Irrigation systems, on the other hand, entail physical intervention with external technology and finance, but enforcement of operational and management rules is comparatively weak. This has led to differences in the institutionalisation of management structures and processes of the related community organisations. The differences between the community organisations also extend to membership and benefits. Membership and participation in CFUGs is open to people who live within and are dependent on the community forest. The benefits are shared equitably. In the case of IWUAs, membership is limited to households that have land in the command area of irrigation. The benefits from the availability of irrigation are not equitably distributed as they depend on the location and size of the agricultural land owned by each household.

These differences between the CFUGs and the WUAs make coordination of management decisions at the local level difficult. Each group was found to be operating rather independently and limiting their functions mainly to routine procedures. The conservation of water resources is not included in the mandates of CFUGs, even though the CFUG members depend to varying degrees on the water sources located in their forests and are aware of the inherent linkages between land and water. This focus on single purposes constrains the capacity of the groups to work collectively.

The problem of weak coordination was also encountered within the same types of institutions. The local water management structure was often based on separate groups with low levels of interaction even if the groups rely on the same water source or same water supply system. This was one of the main issues pointed out in the FGDs between upstream and downstream WUAs. Participants complained that it was often hard to reach consensus due to unclear understanding about off-site consequences of individual actions. Decision-making of upstream communities when abstracting water for irrigating crops did not take into account possible impacts on downstream flows, and this resulted in failures to divert water downstream after finishing irrigation or leaving taps unclosed. Cooperation on these issues was difficult due to lack of incentives for stakeholders to respect each other’s concerns. Upstream people did not see any incentive to conserve water sources or stop deforestation, nor to participate in the development of water projects or reforestation that yielded higher benefits to downstream users. At the same time, the downstream users were mainly interested in free and easy access to upstream resources (e.g. water and forest resources); they were not interested in contributing to the costs of upstream management and conservation works. Similarly, in the case of irrigation canals in the plains, water users at the head-end of the canal were indifferent to the water needs of tail-end users. As a result even minor tasks like closing of gates, conducting repair and cleaning of canals or controlling overuse and wastage of water did not happen in time. Lack of coordination has essentially diminished the effectiveness of coping measures and reduced the efficiency of resource use.

The study also found that the quality of governance within the local institutions, particularly in the WUA/IWUA, was generally low. The quality of decision-making was often compromised by issues related to the degree of inclusiveness, equality, accountability and transparency of the groups. Members were often chosen based on social status/influence or land ownership, while the real water users were often left outside of or given minor roles in decision-making. Problems such as lack of regular meetings and inadequate planning and management were found to be common.

There is a need to avoid duplication or redundancy among groups by increasing interaction and coordination among them. Even though formal relations among the groups are difficult to achieve, there is scope for enhancing collaboration with and among existing groups, at least informally, in areas where this can increase operational efficiency. There are some positive examples of effective agreements between water user groups. In one case in the hills, a WUA and an IWUA agreed to share water for domestic uses during the dry period, despite the IWUA's focus on irrigation. In another case several WUAs in the hills collaborated to construct a community water supply system (with a secure source, storage and a distribution network).

The need for larger water supply systems can be turned into an opportunity to initiate multi-purpose water institutions. Increasing the functionality of local institutions, such as WUA, can fill the socio-institutional vacuum, enhance cross-sectorial coordination and networking, and improve effectiveness of service delivery (Pradhan 2002). For example, a multi-functional WUA can collaborate (formally or informally) with other groups to expand its services to closely linked natural resource use and conservation (forest products, water), infrastructure, farm management (supply of agri-inputs such as water, fertilisers, seeds, food-grain storage and marketing), income generation (on-farm and off-farm), environmental management (clean water, minimise use of fertilisers, pesticides, proper disposal and treatment of waste/wastewater) and other local development services (health, education, communication).

The review of the existing institutionally and functionally diverse community organisations has shown that while there are difficulties, there is both potential and need for better coordination and, to some extent, integration of these user groups to promote integrated management of natural resources at the local and landscape levels. Despite the compartmentalisation of natural resource management at the national and district levels, local stakeholders, particularly farmers, typically have interests in the management and use of a range of natural resources in their locality and watershed. This explains why residents are often involved in more than one user group or farmers' organisation. However, ensuring participation of the most disadvantaged and vulnerable groups and fair distribution of benefits remains particularly challenging in the absence of stronger incentives.

7.4 Enhancing socio-ecological resilience: expected outcome of an integrated approach

This study found that in the survey areas, community groups need to develop a broad vision that encompasses the resilience of SES so they are aware of the components and limitations of natural resources and other ecosystems services, as well as the full range of consequences resulting from their choices to deal with water scarcity. Although a detailed assessment of resilience is out of the scope of this report, we prepared a list of indicators that could be helpful in examining resilience of SES in the context of water scarcity (**Table 6**).

Table 6 List of indicators to examine resilience of socio-economic system (SES) in the context of water scarcity

Components	Candidate indicators to examine
Landscape	Clarity of boundary, local climates (temperature, precipitation), topography (elevation, slope, aspects), niche areas, upstream-downstream linkages
Water	Types (natural and man-made structures), number, capacity and stability of flow/storage at different seasons, location (access), dependency (multi-usability), adequacy for uses at different times of a year, water distribution and use efficiency
Forest and biodiversity	Location and number of patches, area, species richness, biomass productivity, income and other major services (tangible and intangible)
Farmlands	Area, tenure, types (rainfed, irrigated, kitchen garden, orchards), location (with respect to water source), crops grown (types, proportion), farming method (in terms of water requirement), cropping intensity, yields and value of outputs
Livestock	Types, number, productivity, income and other outputs
Households	Total number, location (spatial distribution), heterogeneity (caste, social class), composition (family size, education and skills, roles), income (farm, non-farm), annual savings (cash, food items, livestock heads), access to services (health, schools, roads, markets)
Institutions	Types of local organisation, number of local institutions (government, non-government), rules/customs (formal, informal), networks, rights (land, water, forests), conflicts (over sharing cost and benefit of resource uses)

When identifying indicators that would be useful for assessing the resilience of SES, guidance can be taken from the seven generic principles for enhancing resilience provided by Biggs, et al. (2012). Of these principles, four represent properties and processes of SES to be managed (maintain diversity and redundancy, manage connectivity, manage slow variables and feedbacks, foster an understanding of SES as complex adaptive systems), while three are related to attributes of the governing system (encourage experimentation and learning, broaden participation, promote polycentric governance systems). The subsequent paragraphs briefly introduce these principles and relate them to the observations made at the studied sites.

Maintaining their diversity (types, numbers, differences), and redundancy (distribution) is relevant to the multiple components of SES listed in **Table 6**. Diversity and redundancy respond in a variety of ways and substitute for losses due to the disturbances to SES such as caused by water scarcity or adaptation to slowly moving variables (e.g. shifts in rainfall pattern). Too little diversity and redundancy (e.g. reliance on one single water source) can lead to brittleness while too much of both can lead to system inefficiency and stagnation. Similarly, too much of either of them can cause trade-offs such as high redundancy.

Connectivity is defined as the manner by and extent to which resources, species or social actors disperse, migrate or interact across SES. Examples include connectivity of different elements of a landscape, up-stream and downstream linkages, networks and flow of information, dependency within and among resources system (forest, water) and users (farming). Connectivity facilitates recovery after disturbance as well as enhances mutual trust. However, high connectivity can become counterproductive when there is an imbalance between diversity and redundancy. For instance, high dependency on (or connectivity to) a single water source for multiple uses (drinking, irrigation, livestock) could decrease resilience by rapidly spreading impacts on all uses if that source is affected by changing rainfall or water quality deterioration. High connectivity could also lead to synchronised behaviour such as increased pressure on same water sources or intensification of land use in response to new market opportunities.

Slow variables and feedbacks are difficult to understand and manage within the complexity of SES characterised by highly non-linear changes and regime shifts. Slow variables change over a long timescale such as changes in rainfall pattern, flow regimes of rivers, temperatures, and changes in policy and laws of a country. Feedbacks are fast responses to the condition created by slow moving variables such as adjustments in planting time of rainfed farming or the use of water storage to deal with prolonged drought. Feedbacks could reinforce positive impacts (such as rainwater harvesting increases water availability) or mitigate the negative impacts (such as by adopting water efficient farming to minimise pressure on irrigation water).

A lack of clear understanding of changes and impacts can become a barrier for enhancing resilience, as was evident from the deficiencies of the different coping strategies (S1 to S5) identified in this study. Monitoring (such as continuous observation and recording of rainfall or temperature) aids learning about ongoing changes and feedbacks and introduces appropriate interventions. In the study area we identified a need to engage individuals and communities in observing slow-moving variables in order to plan for appropriate feedback mechanisms. For instance, residents can be trained to monitor local rainfall patterns or the flow condition of water sources in order to plan or adjust appropriate cropping calendars or build new water storage facilities.

Complex adaptive systems (CAS) involve an integrated understanding of SES as a system of interconnected components characterised by emergent behaviour, self-organisation, adaptation, and substantial uncertainties about system behaviour. The basic challenge, however, is to present an integrated understanding of SES as CAS without further adding complexity. As suggested by Biggs, et al. (2012), understanding of CAS could co-emerge during experimentation and learning.

Experimentation and learning, participation, and polycentric governance are important social and institutional processes that can enhance resilience of SES. The relevant components to examine are households and institutions. Experimentation involves implementation of ideas and strategies that may or may not result in positive outcomes, e.g. a decision to construct water storage in the upstream area could provide valuable learning to deal with water scarcity but it may result in an externality for the downstream users due to reduced water flow. At household level, experimentation may involve promoting roof-top rain water harvesting, reducing in-house water wastages, or adjusting crop calendars. Learning may involve right understanding of water scarcity problems and impacts at individual or community level. Learning and experimentation can be valuable to identify and avoid potentially maladaptive practices. Participation is a key to enable experimentation and learning. Participation could range from simple information sharing to direct engagement in making plans and implementation.

Participation can strengthen the link between information gathering and decision-making. In the studied areas, communities can more actively participate in understanding system dynamics, particularly in monitoring changing rainfall or preparing inventories of water sources, to complement the administrative decision-making processes. For instance, use of mobile technology can be used as a means to provide forecasting to the local level and also for receiving feedback responses. However, the key challenge is to engage local communities in participation for a common cause, which might not happen in the absence of strong incentives. In the studied areas a lack of resources (finance, technology) was identified as a key barrier for participatory action in water management. The role of WUAs is generally limited to routine tasks, which explains why they were not taking concrete steps to find a durable solution to water scarcity. However, lessons can be learned from other types of local institutions, such as CFUGs, which do provide incentives for their members to participate.

Promoting polycentric governance is another principle for enhancing resilience. Polycentricity refers to governing authority at different scales and involves all relevant stakeholders. In polycentric governance, the diversity of independently operating governing systems (or organisations) are allowed to connect horizontally on common issues (such as the proposed collaboration between WUA and CFUG over conservation of headwater) and also nested vertically with broader government units (such as VDCs, district forest offices and irrigation offices). Polycentric governance also provides the environment for promoting diversity, engaging all relevant stakeholders, and increasing connectivity through experimentation, learning, broader participation and collaboration opportunities. Ultimately this will contribute to understanding the SES and CAS.

There are very few examples of polycentric governance in Nepal, as in other parts of the world. In the studied areas, the aim of the polycentric governance is to link various groups towards a common purpose so that duplication of efforts as well as unnecessary redundancies can be avoided. It is also advisable that the examination of variables under each component contributes to developing options for experimenting with polycentric governance to deal with water scarcity.

7.5 The building blocks for an integrated approach

The proposed integrated approach faces technical, financial and institutional challenges. Rural households depend heavily on subsistence livelihoods and have low asset bases, which can act as disincentives for households to engage in new land uses and experimentation with uncertain outcomes. Any intervention should not interfere with the ability of households to meet their daily needs or place their wellbeing at risk. Integrated approaches that present households with high upfront costs and long gestation periods and uncertainties in future income flows should be avoided. Ideally, the proposed actions should incorporate immediate benefits, such as improvements in water supply, higher crop productivity, and the growing of high return crops such as vegetables. Practical, cost-effective solutions are required. One possible example is solar electricity, which has become an attractive energy alternative in some communities (Pelt, Weiner and Waskom 2014). Solar energy can be used to pump groundwater and surface water uphill, as already put into practice in the case of groundwater in India (Shah and Kishore 2012) and in the hills of Nepal (RWSSP-WN 2014). To increase their viability, such measures could be aligned with existing coping strategies so that the necessity for new learning is minimised. For example, rather than proposing large-scale reforestation or adoption of entirely new farming systems, more appropriate measures would be improving water storage by restoring local ponds or introducing water conservation and efficiency practices to improve the productivity of rainfed farming.

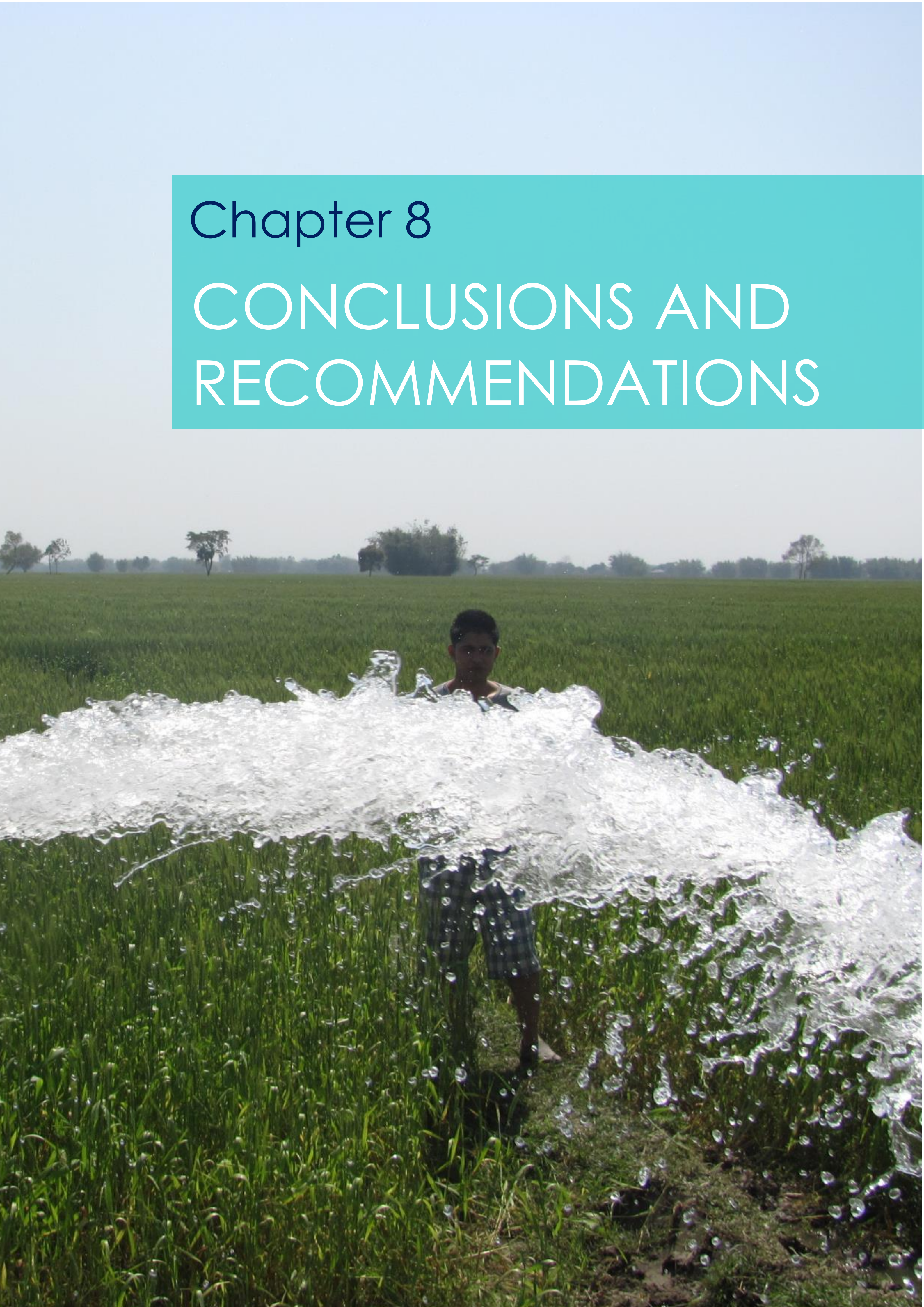
Although options that are easy to use can increase the willingness of the communities to adopt improved practices, they are not sufficient to deal with all problems in a holistic manner. Additional support is required to facilitate the introduction of integrated approaches. Participants of FGDs in the studied sites felt that they need at least three types of external support to find a durable solution to water scarcity by integrating land and water management. One is the provision of technical support to improve the efficiency and productivity of their livelihood activities, e.g. technological interventions, such as sprinkler irrigation to grow vegetables, which they feel are required for them to remain competitive in the market place. Technical support, training and advisory services are required on affordable solutions, the design of water supply systems, procurement of the correct equipment, such as pumps and pipes, and capacity for operation and maintenance. Operation and maintenance were pointed as the most important concerns.

Funding for investment is the second required support. Some large-scale interventions are not possible without financial support from government, local financial institutions, or developmental agencies. Financial services are especially important for interventions over large areas, as most households are smallholders.

A final pre-requisite is institutional support. Participants in the FGDs argued that local governments should play a role in organising, mediating and providing support on issues of public interest. They suggested that local government institutions such as the VDCs can provide legitimacy (even if only symbolic) to local actions and enhance trust, while specialised institutes related to forest, agriculture, and water resources can provide the required technical support. Local institutions and groups also have important roles to play in building capacity and organising and mediating to allow for experimentation and learning.

Chapter 8

CONCLUSIONS AND RECOMMENDATIONS



The study has reported on and analysed the manifestations, impacts and trends of water scarcity caused by changing rainfall patterns in the context of smallholder subsistence livelihoods in four districts in Nepal. Changing rainfall represents the main driver of increased water scarcity, but the problem has been further aggravated by socio-economic stressors.

The study found that water scarcity has weakened the four pillars of subsistence livelihoods – forestry, farming, livestock and households. The study identified different types of coping strategies adopted by households and communities under different severity scenarios. None of the identified coping measures were found to be designed and implemented based on a systematic and comprehensive assessment of long term pros and cons, nor of possible negative implications for other users sharing the same water sources. Although the adopted coping strategies were able to provide short-term relief to certain users, their sustainability and effectiveness is questionable.

The situational analysis found that local communities lack the necessary capacity and resources to design and implement robust measures to deal with increasing water scarcity. This situation clearly demands an integrated approach to ensure that loss-making reactive coping strategies can be replaced by preventive strategies.

In order to strengthen and institutionalise coping measures, the study proposes the development and introduction of an integrated approach that coordinates the three domains of the socio-ecological system (SES), i.e., landscape, economy and socio-institutional. In order to examine the effectiveness of an integrated approach, the study has proposed a list of indicators that can be used to assess generic resilience principles.

The identification of entry points for an integration approach is crucial. Without visible and immediate benefits and a strong support from the government, households may find an integrated approach unattractive due to their low asset base and their dependency on subsistence livelihoods for their day-to-day survival. Integrated approaches should thus aim to improve on existing systems of land and water management, rather than introduce entirely new systems, and to the extent possible focus on low cost options that provide immediate benefits to households, but that can also be sustained over the long term. An integrated approach should also seek to use topography, rather than reconstruct it; provide incentives for upstream users to incorporate downstream interests in their water management practices; and encourage movement towards polycentric forms of governance.

With these points in mind, this study provides the following recommendations to the relevant stakeholders dealing with the planning and implementation of adaptation measures and water resources management:

Local level

- **Local governments and their specialised departments, in particular water resources, agriculture and forestry, to raise the capacity of local communities to understand climatic signals, which could be achieved by involving them in the monitoring and recording of rainfall and flow regimes, and to integrate climate knowledge and projections into their livelihood decisions.**
- **Mobilise local resources, tools and techniques to prevent water scarcity.** This includes creating 'water banks' by enhancing capture and storage of rainfall and excess runoff in tanks, ponds, or the recharge of springs and groundwater, at individual household or community level.
- **Help local communities to create stronger local institutions by providing external support (mainly technical and financial) to effectively improve water distribution, allocation, and use efficiency and to minimise water wastage.**
- **Move towards coordinated management of land and water resources with the aim of implementing measures that improve productivity within the forest-farming-livestock-household nexus.** Local institutions, especially local governments, should play a leading role in conducting a systematic landscape-wide review of land and resource use patterns.
- **When implementing future programmes on climate change adaptation, create incentives to establish linkages (formal or informal) among local organisations, including WUA and CFUG, to strengthen their connectivity by enhancing coordination and collaboration on common issues of land and water resource management.** Strongly connected local institutions can harness opportunities for synergising efforts and improving the efficiency of existing institutions through polycentric governance.
- **Align local practices with the underlying socio-ecological system (SES) to allow for effective integration of land and water resources management.** A SES perspective makes it possible to foresee short and long term consequences of integrated measures, which is vital for building resilience.
- **Utilise experiences of community participation, experimentation and learning in the implementation of integrated land and water management in order to identify deficiencies as well as priority actions to overcome them.** This will provide valuable inputs to the Local Adaptation Plans of Action (LAPA) and thus feedback to national institutions implementing the National Adaptation Programme of Action (NAPA) and the Strategic Program for Climate Resilience (SPCR).

National level

- **Introduce policy interventions to enhance and upscale the above local level actions.** This will strengthen existing government strategies in Nepal to deal with water scarcity issues in the context of changing rainfall patterns. Such policy interventions include mobilising resources in the right local contexts and within specified timeframes to enable the adoption of appropriate technologies (such as capture and storage), channelling necessary investments to catalyse actions, and supporting the formalisation processes of informal local users and other stakeholder groups. Extension of support could become a good entry point to contribute to designing and promoting integrated land and water management.
- **Incorporate multi-stakeholder approaches in climate change policies and programmes to increase interaction between government, NGOs and local communities, with the aim of jointly developing strategies for promoting integrated land and water management.** This will increase the effectiveness of the above listed interventions.
- **Make the resilience of socio-ecological systems a long-term policy goal when designing integrated land and water management.**
- **Explore options to harmonise integrated land and water management strategies with mitigation actions such as REDD+, and alternative energy production (hydropower, solar and biogas).** This can create synergies and thus increase the effectiveness of policy intervention.

The findings of this study are based on an analysis of the impacts of changing rainfall on water scarcity and local responses in several districts in Nepal. Further research on the institutional structures at local and national level would be useful to develop guidance to operationalise the recommendations of this study.

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