IWMI Research Report

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Climate Change, Out-migration and Agrarian Stress: The Potential for Upscaling Small-scale Water Storage in Nepal

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Sugden, F.; Shrestha, L.; Bharati, L.; Gurung, P.; Maharjan, L.; Janmaat, J.; Price, J. I.; Sherpa, T. Y. C.; Bhattarai, U.; Koirala, S.; Timilsina, B. 2014. *Climate change, out-migration and agrarian stress: the potential for upscaling small-scale water storage in Nepal*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 38p. (IWMI Research Report 159). doi: 10.5337/2014.210

/ climate change / water storage / ponds / tanks / migration / water availability / gender / women farmers / agrarian structure / hydrology / models / economic aspects / political aspects / social aspects / land management / property rights / case studies / Nepal /

ISSN 1026-0862
ISBN 978-92-9090-792-3

Front cover photograph shows a plastic storage pond and irrigated vegetable cultivation in Moli, Okhaldhunga District, Nepal (*photo:* Fraser Sugden).

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Acknowledgements

The core part of this study was funded by the Department of Foreign Affairs, Trade and Development (Canadian International Development Agency). Invaluable support in data collection was provided by Prabin Ghimire (former consultant with IWMI-Nepal), Pratibha Sapkota (former consultant with IWMI-Nepal) and Ramesh Tamang (IWMI-Nepal). The authors are grateful for the field support provided by local contacts in the study districts including Amrit Magar, Tika Rai and Saroj Bomjan, and would like to thank Rajendra Shrestha, Rajendra Uprety, the field office staff at the Water and Energy Commission Secretariat (WECS) in Chautara, and the Department of Irrigation in Kathmandu, all of whom provided logistical advice and local expertise. The valuable feedback and comments provided by Brady MacCarl (former intern with IWMI-Nepal) and Vladimir Smakhtin (Theme Leader – Water Availability and Access, IWMI) are greatly appreciated. The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) provided future climate projections, which were used in the analysis of climate change. CCAFS also supported the latter part of the study, which involved collecting case study information on existing water storage infrastructure.

Project

This research study was initiated as part of the *Preparing for an uncertain water future in Nepal through sustainable storage development* project.

Collaborators

This research study was a collaboration of the following organizations:

International Water Management Institute (IWMI)

University of British Columbia, Canada

Donors

This research study was funded by the following:

Department of Foreign Affairs, Trade and Development (formerly Canadian International Development Agency)

This work was undertaken as part of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), which is a strategic partnership of CGIAR and Future Earth. CGIAR is a global research partnership for a food secure future. The views expressed in this document cannot be taken to reflect the official opinions of CGIAR or Future Earth.

Contents

Summary

Climate change could have a critical impact on agriculture in Nepal due to changes in the variability of water availability and associated uncertainty. In this context, small-scale water storage—most notably ponds and tanks—can moderate this variability. This report explores the potential role of small-scale storage infrastructure in two subbasins within the larger Koshi Basin in central and eastern Nepal. It is shown that upscaling small-scale storage requires an appreciation of the other drivers of change in agriculture aside from climate, and identifies the social relations and dynamics which could mediate in future interventions for their success.

A distributed hydrological model was used to assess the impacts of climate change in the two subbasins. In both subbasins, precipitation is highest during the monsoonal months, June-September, which is then reflected in the water yield and evapotranspiration values. In the Indrawati and Pankhu subbasins, annual total water yields are 74 and 57%, respectively. Therefore, both subbasins have underutilized water resources and high potential to develop storage infrastructure. Climate change projections suggest dry-season water shortages as well as increases in variability, which make water-storage systems increasingly important.

However, through an analysis of existing irrigation systems with and without storage, a number of constraints to upscaling small-scale storage become evident. First, out-migration is affecting male farmer incentives to invest in irrigation as some farmers prefer to pursue livelihoods outside of farming rather than investing in dry-season production. Second, the increased work burden of women left behind and often with limited access to funds constrains women from taking a lead in maintaining existing irrigation systems, particularly when they still have a limited role in management of communal infrastructure. Third, management institutions for existing water resources and stress on community relations due to out-migration impact the success of past interventions. Last, inequitable landownership structures and property rights have not only skewed the distribution of benefits from past interventions but also contributed to underlying conflicts over water. Unequal power relations in decision making have also shown to be a concern, particularly when the priorities of households with regard to water storage solutions vary according to one's position in the agrarian class structure.

It is clear from the research that, while small-scale water storage has the potential to significantly strengthen livelihoods in the Nepali hills, it is necessary to tailor projects to the existing socioeconomic context. This includes, first, the need for targeted engagement or training for new interventions for potential migrant youths, and the women and elders who stay behind. Second, it is necessary to identify and understand successful irrigation management institutions in potential beneficiary communities, so that they can be harnessed. Third, it is important to build new infrastructure of an appropriate scale according to levels of out-migration and other social stresses. Fourth, it is critical to integrate water-storage development with appropriate agricultural extension. Last, storage development should be integrated with water basin management at a larger scale to ensure the sustainability of springs and other resources which feed new infrastructure.

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Introduction

A critical challenge for farmers in developing countries is how to cope with increased variability and uncertainty in current and future rainfall patterns, a phenomenon which is affecting rain-fed and irrigated farming alike. In Nepal, despite the fact that its per capita greenhouse gas emissions are negligible, the country remains particularly vulnerable to climate change, given its disproportionate dependence on climate-sensitive sectors and a topography which makes the ecosystems particularly sensitive and vulnerable to extreme climatic events such as droughts and floods (Webersik and Thapa 2008).

The hydrology of Nepal is primarily monsoonal-driven. Around 85% of rainfall falls during the four monsoonal months from June to September. The temporal variability of rainfall and runoff is hence very high, and the problems of excess water during the monsoon and water scarcity during the dry season affect all aspects of life in the country. Climate change predictions however, suggest dry-season water shortages will further increase, and throughout the year weather patterns will be characterized by greater variability and unpredictability, with a significant impact on agriculture.

In this context, storing water during times of availability to utilize it during dry spells is of critical importance in climate change adaptation (Hua 2009; Smakhtin and McCartney 2010). Water storage systems can include any natural or artificial infrastructure which retains water, and can include ponds, reservoirs, groundwater reserves, and even retained soil moisture (Smakhtin and McCartney 2010). Enhancing water storage to facilitate climate change adaptation involves both making better use of natural storage such as lakes, groundwater and wetlands as well as establishing artificial water storage systems such as farm ponds and check dams. In Nepal, access to naturally stored groundwater for 'on demand' for irrigation is applicable predominantly in the Terai and the Kathmandu Valley only. In the hills, where pumping groundwater is not feasible, the villages do not have access to natural springs, which are usually upstream of perennial rivers. Any stored water which can be accessed during periods of scarcity must come from artificial open ponds and enclosed tanks – the focus of this study.

Thus far, such infrastructure is poorly developed in the Nepali hills. According to the National Sample Census of Agriculture in 1991/92, only 0.73% of the sampled irrigated land area in the middle hills of Nepal was reported as being irrigated from ponds or tanks, or just 18,000 ha. By the 2001/02 sample census, there had been a significant increase of 24.2% in the area under irrigation, with the expansion of government-sponsored canal systems. However, the proportion of the irrigated area under pond irrigation remained at just 0.84% due to the far more rapid increase in canal irrigation, which now represented 95.3% of the irrigated area (CBS 1992, 2002). Canal irrigation, while valuable for hill agriculture, is expensive to develop and can be vulnerable to the same seasonal fluctuations in availability that farmers dependent upon rain-fed agriculture face. Furthermore, canals have limited utility for the vast number of Nepalese hill communities which are situated on ridge lines, far above perennial flowing water resources. Storage ponds and tanks, by contrast, can be built anywhere where water is available for part of the year, with different designs suitable for different topographical contexts.

The development of new storage infrastructure could play a critical role in improving food security in Nepal in an era of climate change, by developing dry-season agriculture, and taking advantage of improved transportation and market access. However, the report makes the crucial argument that when developing new storage interventions, technical solutions alone will not facilitate adaptation. This report makes the following arguments. First, climate change, however real the risks, cannot be considered a single driver of change (Nellemann and Kaltenborn 2009). In Nepal, it complements exiting stresses on agriculture including high prices for fertilizer and seeds, lack of infrastructure and investment and unreliable institutions. The impact of climate change in this report will be understood not in isolation, but as a combination of circumstances, including ecological, economic and political processes (see also Sugden et al. Forthcoming). Any potential adaptation options through water storage development must account for the broader stresses on agriculture which are shaping farmer decision making.

Second, the process of autonomous adaptation itself in the context of agrarian stress (both climatic and non-climatic) may undermine the success of externally imposed interventions. This is most relevant with respect to male out-migration (Ansorg and Donnelly 2008; WEN 2010), which must be accounted for when considering the sustainability of new storage infrastructure.

Third, communities are by no means unified entities, with deeply entrenched social structures of class, caste and gender, which shape development outcomes. This is all the more critical in the case of Nepal, where the failure to push through a meaningful land reform program in the post-conflict period has resulted in a skewed agrarian structure, impeding investment (Adhikari 2006; Wily et al. 2008; Sugden and Gurung 2012). At the same time, the social geography of the Nepali hills means that lower castes often reside on the more marginal land, affecting the distributional outcomes of agricultural interventions. The process of out-migration itself is intricately connected to these local-level social relations, with the lower caste or poorer farmers at the base of the agrarian structure often being the first to migrate (Sugden et al. Forthcoming).

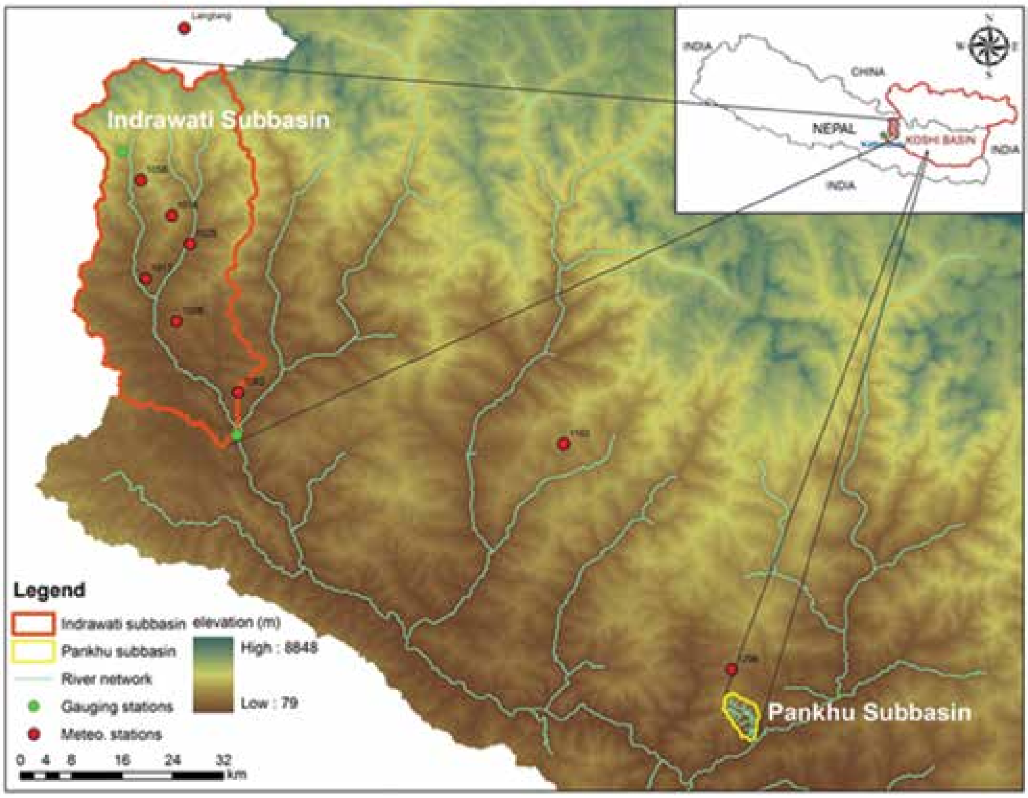
This report is part of a larger study on water storage in the Koshi Basin done in collaboration with Canadian International Development Agency, International Water Management Institute, the Department of Irrigation, Nepal, and the University of British Columbia. Focusing on two subbasins, those of the Indrawati River in Sindhupalchok District and the Pankhu River of Okhaldhunga, this report aims to first assess the current hydrology and the impact of climate change in water availability. Second, it reviews the existing artificial storage interventions in these basins. Last, it analyzes the larger sociopolitical context, including non-climatic stresses and drivers of change. It assesses how these pressures affect the operation of existing irrigation infrastructure, offering lessons for socially sustainable storage development and upscaling in the future.

Study Area

The international Koshi River Basin (crossing China, Nepal and India) is the largest river basin in Nepal and serves as a smaller 'model' of the larger physiographic region. The study subbasins within the Koshi, i.e., the Indrawati subbasin, located in the central mountainous region and the Pankhu subbasin located in the eastern hill region, can be seen in Figure 1. The Indrawati subbasin is north of Kathmandu in the transition zone between the hills and mountains. The area is around 1,230 km^2 and the elevation ranges between 589 and 6,124 meters (m). While above 2,500 m, the only settlements are seasonal herders' camps, the lower slopes are very fertile and densely populated.

The remote Pankhu subbasin is much smaller, and is situated east of Kathmandu in Okhaldhunga District (see Figure 1). The Pankhu River flows into the Dudh Koshi, a major tributary of the Koshi which drains the Khumbu Mountains to the north. The highest point is around 2,300 m, while most of the population resides between 600 and 1,800 m, with the upper parts of the watershed covered with temperate forests. The lowest part of the watershed where the Pankhu River enters a shallow gorge is steep and cloaked in dense *sal* (shorea robusta) jungle, with the exception of a few gentle paddy lands near the confluence with the Dudh Koshi at around 300 m.

FIGURE 1. The Koshi River Basin showing the Indrawati and Pankhu subbasins and location of gauging and meteorological stations.



Methods

Hydrological Assessment

An interdisciplinary approach was used to gather data for this study. For the hydrological assessment, as spatially distributed information on climate and hydrology was not available at subbasin level, the Soil and Water Assessment Tool (SWAT) was used to calculate water balances of Indrawati and Pankhu subbasins. The SWAT model is a process-based continuous hydrological model that predicts the impact of land management practices on water, sediment and agricultural chemical yields in complex basins with varying soils, land use and management conditions (Arnold et al. 1998; Srinivasan et al. 1998).

Conceptually, SWAT divides a basin into subbasins. Each subbasin is connected through a stream channel and further divided into Hydrologic Response Units (HRUs). An HRU is a unique combination of a soil and a vegetation type in a sub-watershed, and SWAT simulates hydrology, vegetation growth, and management practices at the HRU level. Since the model maintains a continuous water balance, the subdivision of the basin enables the model to reflect differences in evapotranspiration for various crops and soils. Thus runoff is predicted separately for each subbasin and routed to obtain the total runoff for the basin. More detailed descriptions of the model can be found in Srinivasan et al. 1998.[1]

The hydrometeorological stations installed by the Department of Hydrology and Meteorology and used for the modelling (SWAT) within and around the basin are shown in Figure 1. The 39 years of data (1971-2010) from the stations within the basin were used in the model. The SWAT model was calibrated and validated using daily discharge data from two hydro-stations for the Indrawati subbasin. The Nash-Sutcliffe Efficiency (NSE) Index and the Coefficient of Determination (r^2) were used to assess model performance. For the model calibration period at the Indrawati subbasin outlet, the monthly and daily NSE were 92 and 77%, respectively, and the monthly and daily r^2 were 92 and 82%, respectively. Similarly, during the validation period, the monthly and daily NSE were 97 and 86% and the monthly and daily r^2 were 98 and 88%, respectively. The model simulations were therefore considered to be very good and acceptable for further analysis. As there were no discharge data available within the Pankhu subbasin, model simulations were compared with results from a previously calibrated Koshi Basin Model (Bharati et al. 2012). The r^2 when comparing monthly flows from Pankhu subbasin and flows from the calibrated Koshi Basin Model was 0.98 which shows excellent agreement between the two modelling results.

Following satisfactory model calibration and validation, the SWAT model was run with climate data from the MarkSim weather generator for the baseline (1971- 2000), 2030s (average from 2016 to 2045) and 2050s (average from 2036 to 2065) to simulate water balances and runoff from the basin. The impact of climate change was based on comparing the baseline with the projected data from the 2030s and 2050s.

The MarkSim weather generator (Jones et al. 2002) downscales climate data from global circulation models (GCMs) (gismap.ciat.cgiar.org/MarkSim GCM). The GCMs used to generate daily climate data are CNRM-CM3, CSIRO-Mk3.5, ECHam5 and MIROC3.2, and the projected data are averages of these four GCMs. Future scenarios considered for this study are A2 and B1, and the periods of future simulations are from the near to mid-range future - 2030s (average from 2016 to 2045) and 2050s (average from 2036 to 2065) – the time horizons for which water management decisions have to be made.[2]

[1] SWAT requires three basic files for delineating the basin into subbasins and HRUs, i.e., Digital Elevation Model (DEM), Soil map and Land Use and Land Cover (LULC) map. For this study, 90 m Shuttle Radar Topography Mission (SRTM) was used for the DEM. Both the land cover and soil map were obtained from the National Land Use Project, Government of Nepal) (Carson et al. 1986).

[2] The A2 scenarios were chosen because they represent regionally oriented economic development with increases in temperature ranging from 2.0 to 5.4 °C and the B1 scenarios represent global environmental sustainability. The B1 scenarios of a world are more integrated, and more ecologically friendly and the temperature increases are from 1.1 to 2.9 °C (IPCC 2007).

Socioeconomic Methods and Selection of Case Study Communities

For the socioeconomic research, mixed methods were used to give depth and new angles to the data (McKendrick 1999). A quantitative survey collecting data on agricultural production practices, irrigation access, land tenure and livelihoods was combined with a series of qualitative interviews and focus groups in selected villages. Focus groups allow researchers to interview groups of people who share certain attributes to discuss a specific topic or set of issues (Bryman 2004). Understanding the importance of the participants' composition in the group, sociodemographic factors, such as age, sex and ethnic group and caste were considered when selecting participants. After focus groups, one-to-one household interviews were held to gain a deeper understanding of the issues at the household level. Interviews were carried out with both women and male household members to gain different gender perspectives. Participants were selected through a process of 'snowballing,' usually with the assistance of village leaders.

In June, 2012, a set of qualitative focus groups and a pilot survey were initially conducted in Okhreni and Lekharkha villages in the Indrawati subbasin to gain a deeper understanding of the social structure, livelihood trends, water use patterns, water management institutions and aspirations in the subbasins. The survey was later refined and administered in the Indrawati in October 2012 – the survey being part of a choice experiment to explore water storage preferences (see Price et al. Forthcoming). Villages were dispersed over a large area, making the selection of specific settlements to sample difficult. However, eventually seven 'clusters' of settlements were selected to capture a range of altitudinal zones from 1,500 to 2,300 m. These were 1) Kotgaun and Lapse, 2) Okhreni and Gobre, 3) Namlang and Kaphale, 4) Gurungtol and Silwaltol, 5) Gunsa, 6) Lekharkha, and 7) Thanpal Dhap.

From across these seven settlements in the Indrawati subbasin 150 households were randomly sampled. In the Pankhu subbasin, a smaller survey was carried out in October 2012 given that it was a much smaller area. It focused on three village clusters in an altitude zone from 700 to 1,700 m. The three villages were Ketuke, Moli and Foksu; and 90 households were selected across these settlements.

Although these two samples are not large enough to make concrete conclusions for the whole of each basin, they offer important insights into the diversity of livelihoods across the region. By capturing villages at different altitudes the research team was able to cover not only the ecological diversity of the basins, but the ethnic diversity. Across Nepal, different ethnic groups reside in different altitudinal zones, often with quite different livelihood patterns and agricultural practices. Figure 2 shows that in the Indrawati Valley the villages above 2,000 m, such as Okhreni and Gobre, are home to Sherpa and Tamang communities, while the upper-middle elevation villages between 1,600 and 2,000 m, such as Namlang, Kaphale, Gunsa and Lekharkha are predominantly Tamang comprising one of the main indigenous or *janajati* communities in the region. The lower-middle elevation villages such as Gurungtol and Silwaltol (and Tarnamlang and Badegaun which are not included in the survey), are home to Brahmins and Chetrris, the traditionally dominant caste in Nepal, as well as Tamang and other *janajati* communities such as the Gurung. The Pankhu subbasin lies at the edge of the Rai homeland, an indigenous community residing across the eastern hills. As in much of the region, most Rai villages are within the paddy cultivation domain below 1,600 m, such as Foksu and Moli, while the upper-altitude villages such as Ketuke which are above 1,600 m are home mostly to the Tamang community (see Figure 2).

The second round of data collection included a series of 12 qualitative interviews and 13 focus groups focusing on the advantages and challenges of existing storage infrastructure (see Table 1). In the Indrawati subbasin, the originally sampled villages had little existing infrastructure, so two new villages were also included for focus groups and interviews. These were Taranamlang and Badegaun. In the Pankhu subbasin, there were already a large number of water storage systems operating in the three sampled villages; focus groups and qualitative interviews were conducted at the same time as conducting the survey.

FIGURE 2. Ethnic composition of survey sample.

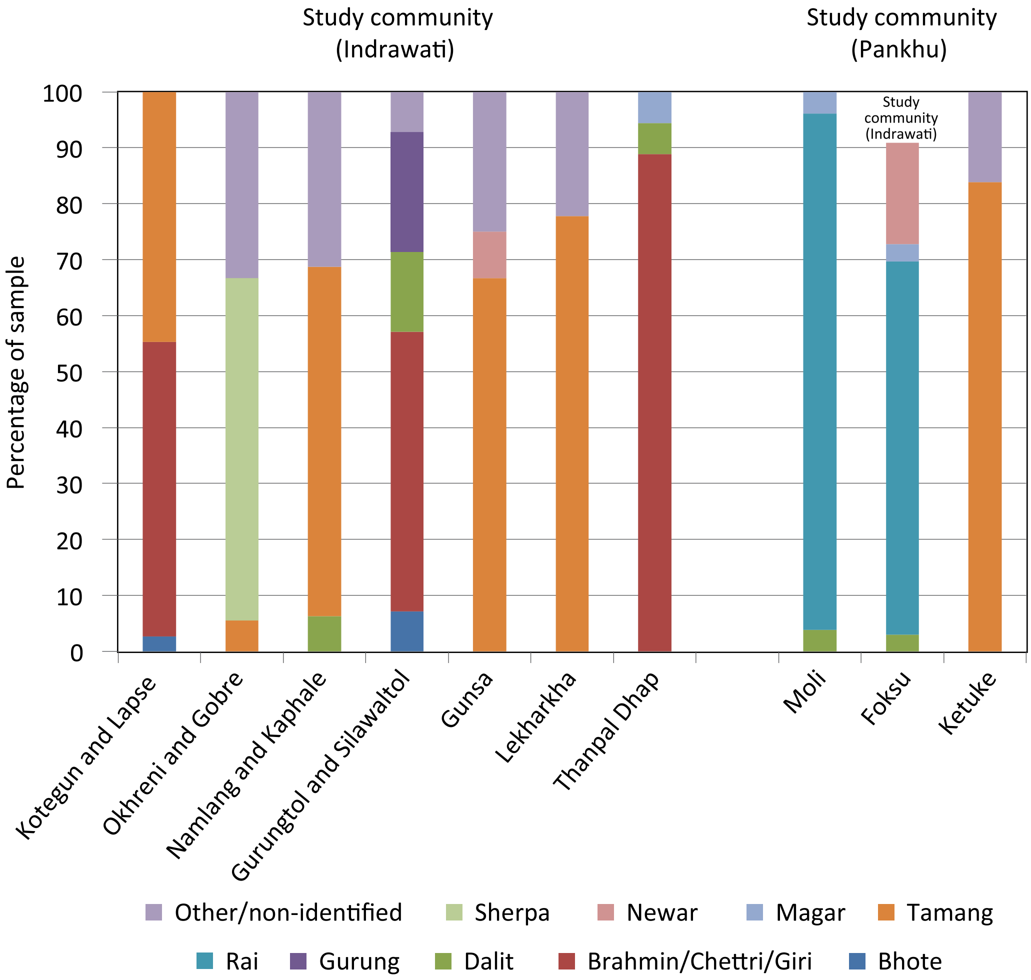


TABLE 1. Focus area for qualitative study on existing infrastructure.

District/Basin	Village	Storage system	Focus group discussion	Households interviews
Okhaldunga (Pankhu subbasin)	Moli	Concrete pond Plastic ponds	2	2
Okhaldunga (Pankhu subbasin)	Fosku	Concrete pond 1 plastic pond	1 1	3
Okhaldunga (Pankhu subbasin)	Ketuke	Rainwater harvesting system	2	2
Sindhupalchok (Indrawati subbasin)	Badegaun	Concrete pond	3	3
Sindhupalchok (Indrawati subbasin)	Okhreni	No system	1	1
Sindhupalchok (Indrawati subbasin)	Tarnamlang	Plastic pond under construction	2	1

Climate Change and Water Stress in the Study Basins

Seasonal Water Availability

Tables 2 and 3 show the monthly precipitation, evapotranspiration and water yield (i.e., discharge generated within the subbasin) for the Indrawati and Pankhu subbasins, respectively, which are based on the SWAT model outputs. The hydrology of the study sites is dominated by the monsoon. In both subbasins, precipitation is highest during the monsoonal months of June-September, reflected in the water yield and ET values. In the Indrawati and Pankhu subbasins, 74 and 57%, respectively, of annual precipitation leaves the subbasins. Therefore, both subbasins

TABLE 2. Monthly average (1975-2010) water balance components: Precipitation, Evapotranspiration (ET), Water yield (WYLD) and change in storage in the Indrawati subbasin.

Month	Precipitation (mm)	ET (mm)	WYLD (mm)	Change in storage/balance closure
Jan.	29	24	60	-55
Feb.	38	37	45	-44
Mar.	51	62	44	-55
Apr.	68	68	38	-38
May	156	95	58	3
June	432	97	187	148
July	768	96	444	228
Aug.	782	91	522	169
Sept.	407	77	348	-18
Oct.	78	67	172	-161
Nov.	12	40	104	-132
Dec.	17	26	79	-88
Sum	2,838	780 (27%)	2,101 (74%)	-43 (-1%)

TABLE 3. Monthly average (1981-2010) water balance components, i.e., Precipitation, Evapotranspiration (ET), Water yield (WYLD) and change in storage in the Pankhu subbasin.

Month	Precipitation (mm)	ET (mm)	WYLD (mm)	Change in storage/balance closure
Jan.	11	11	5	-5
Feb.	12	15	4	-7
Mar.	25	29	7	-11
Apr.	55	46	18	-9
May	145	73	58	14
June	285	82	131	72
July	452	68	266	118
Aug.	391	63	260	68
Sept.	235	59	159	17
Oct.	60	50	49	-39
Nov.	10	25	11	-26
Dec.	13	14	6	-7
Sum	1,694	535 (32%)	974 (57%)	185 (11%)

have underutilized water resources and have high potential to develop storage infrastructure. In the Indrawati subbasin, the portion of discharge is higher than the portion of ET even during the water-scarce winter months. Therefore, increasing storage capacity in the subbasins to increase water availability, especially in the dry season, and reducing runoff leaving the subbasin, is a good water management strategy for the area.

Perceptions of Water Stress by Community Members and the Link to Climate Change

Water shortages for agriculture were perceived as a critical issue in all study communities. Table 4, drawn from the survey revealed the answer to a number of questions relating to water where respondents were asked to rank responses from 'strongly agree' to 'strongly disagree.' While the percentage of respondents stating 'strongly agree' for drinking water problems was much lower, at 56% in the Indrawati and 46% in the Pankhu subbasins agricultural water shortages are clearly a major constraint, with 'strongly agree' responses invariably above 90%.

While it is clear that water stress is perceived as an important issue in agricultural communities in Nepal, the exact pattern of change over recent decades and its links to climate change at a global scale are complex. The existing data show that for much of the Koshi Basin, there has actually been an overall increase in premonsoonal and monsoonal precipitation between 1976 and 2005 (Practical Action 2009). The monsoonal increase in rainfall has been up to 10 mm/annum for most of the Koshi Basin. However, there has been a significant decline in the post-monsoonal rainfall in much of the area in hills and mountains of the Koshi Basin, with a fall of between -1 to -7 mm/annum. This may partially explain the concerns of farmers – as post-monsoonal rain is important during the sowing of winter crops such as wheat and vegetables. In contrast, there has been an overall increase in winter rainfall of up to 2.4 mm/annum in areas such as the upper Arun and Tamur basins, and only a marginal change for much of the middle hills (Practical Action 2009).

The data can however be misleading as an overall increase in rainfall can be deceptive as it does not account for the increased variability of the rainfall. There is some evidence of an increase in the number of extreme precipitation events during the monsoon, compounded by greater seasonal dry spells (Sharma 2009; Karki et al. 2009; Bartlett et al. 2010). This puts communities in Nepal at increased risk of landslides, erosion, and flooding, while prolonged dry spells affect levels of water availability in streams and rivers, increasing seasonal scarcities (Karki et al. 2009). It is the latter which is of particular concern for this report: an increase in dry spells in all seasons, including the monsoon, has a critical impact on agriculture.

Results from annual comparisons in the Koshi Basin using CC data from the MarkSim weather generator and the SWAT model indicate an increase in precipitation in the upper parts of the basin and a decrease in precipitation in the lower part for the 2030s and an increase in precipitation in most of the basin in the 2050s. Specifically for the Indrawati subbasin, precipitation is projected

TABLE 4. Percentage of respondents selecting 'strongly agree' on a five-point scale on water stress in agriculture.

	Indrawati subbasin (%)	Pankhu subbasin (%)
Crops experience water stress	98	94
Crops fail due to water stress	98	96
Lack of water for agriculture is a major problem in the village	94	90
Drinking water is a major problem for the village	56	46

to decrease in the upper parts but increase in the lower parts, except for the A2 scenario for the 2050s. In the Pankhu subbasin however, all scenarios project an increase except under the A2 scenario for the 2030s. Annual changes in water yield are seen to be positive in most of the Koshi Basin except under the A2 scenarios for the 2030s. In the Indrawati subbasin, water yields are, however, projected to decrease in most of the subbasin in the 2030s but increase in the 2050s. In the Pankhu subbasin, water yields are found to increase in both the 2030s and the 2050s. A seasonal analysis for the whole Koshi Basin, however, shows that flow volumes will increase during the monsoon and post-monsoon but decrease during the winter and pre-monsoon. Therefore, flooding and erosion could increase during the monsoonal season and water-scarcity problems could become exacerbated during the dry seasons, thus affecting the dry season rain-fed crops. More details on the hydrological modelling using SWAT and climate change analysis can be found in Bharati et al. 2012.

The Potential for Water Storage

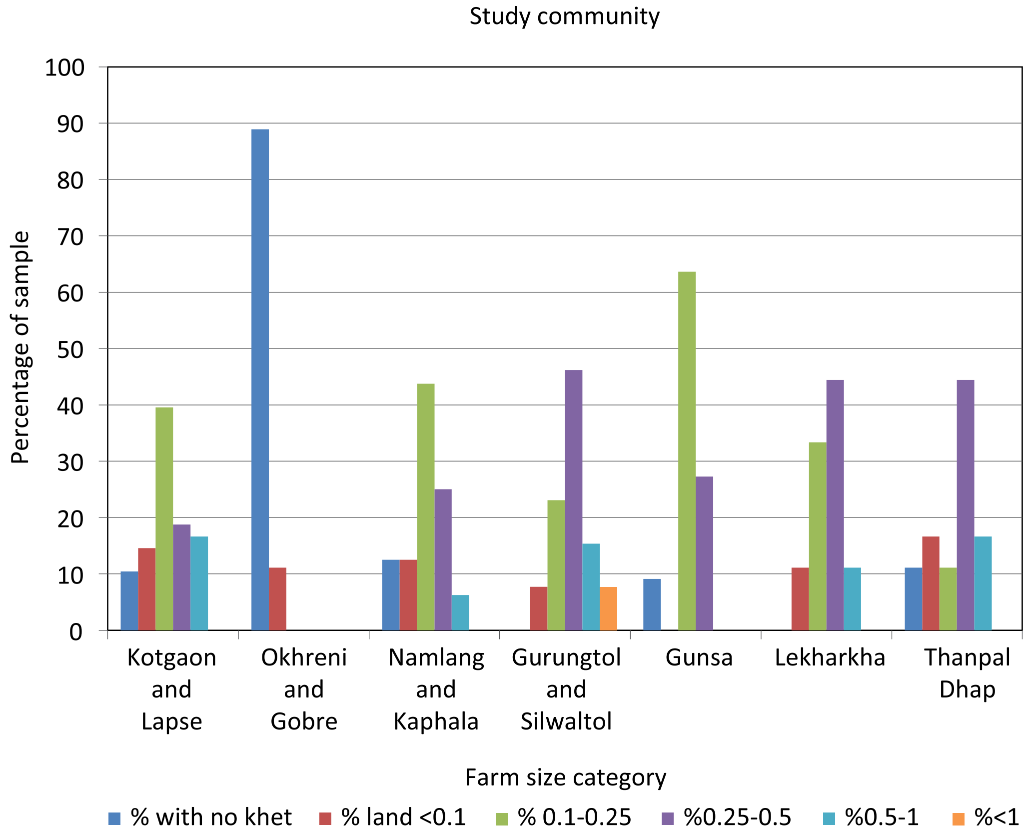
It is clear from the models above, that seasonal shortages of water coupled with excess water in the monsoon are going to be a critical issue for agriculture in the years to come. This raises the question as to how it will impact ongoing agricultural practices. There are two main types of private farmlands owned by households in the middle hills of Nepal, the highly productive *khet* land, which is usually low-lying (below 1,600 m), retains water well, and is used for rice production. Such land is often irrigated by rivers and streams year-round, while it can also be rain-fed for monsoonal cultivation. The other type of land is *bari*, the less-fertile fields, usually on steeper slopes which do not retain water well. They are used for other crops such as millet, maize and vegetables. Such fields can be found at heights from 300 to 2,500 m, and even higher in the mountain regions.

The vast majority of landholdings which already have year-round irrigation in both basins are the low-lying *khet* lands. For many of these holdings, water availability during temporary dry spells is not considered a problem by farmers as they are fed by perennial rivers. From Figure 3 it is evident that all villages in the Indrawati have some *khet* lands with the exception of the high-altitude settlement of Okhreni. Most of this land lies far below the villages near the rivers where there is reliable irrigation. Most of the households have very small plots, each between 0.1 and 0.5 ha, with bigger holdings in the lower altitude Gurungtol and Silwaltol. It is clear from Figure 4 that almost all households in the Indrawati also have some *bari* land, with the size of plots again quite marginal, each lying between around 0.1 and 0.5 ha. When compared to *khet* lands however, more households appear to have large holdings of *bari* over 1 ha.

In the Pankhu subbasin, despite the lower overall elevation, *khet* lands are much more limited. Unlike the broader Indrawati Valley, the Pankhu forms a steep ‘v’ shaped valley, with most of the population residing along the ridgelines and upper valley slopes. Figure 5 shows that in Foksu and Moli villages over a third of households have no *khet* land, while in the Tamang settlement of Ketuke there is no *khet* land at all. Each of most holdings in the two lower Rai villages is less than 0.25 ha, although over 10% have quite large holdings of more than 1 ha suggesting there is some inequality – an issue that will be discussed later. Figure 6 suggests that on the whole, households are more dependent on rain-fed *bari* lands with each of most holdings between 0.1 and 1 ha.

Despite the importance of *bari* land, in both basins, the amount of *bari* land with irrigation is marginal (see Figure 7), with only some irrigation in the Gunsa, Namlang and Kaphale clusters of the Indrawati subbasin. While such lands have no potential for rice cultivation, some dry-season irrigation can at least facilitate the year-round cultivation of cash crops such as vegetables, and can increase the yields of dry-season crops such as maize.[3] The limited coverage of reliable irrigation and perceptions of water stress suggest there is considerable potential to expand the reach of irrigation on marginal *bari* lands in the two subbasins through storing excess monsoonal runoff in ponds and tanks. The irrigation which is present for *bari* lands is usually from very small springs or streams, and is highly vulnerable to seasonal fluctuations in rainfall. Storage would help to even out the fluctuations and could provide a more reliable source of water throughout the dry season.

FIGURE 3. Distribution of *khet* (paddy land)holdings from the sample survey carried out in selected study villages in the Indrawati subbasin (ha).



[3] Interestingly, many households had reported no irrigation even in areas with pond systems such as Moli. This suggests that the small kitchen gardens served by pond systems are not considered as part of one's standard agricultural holdings. It could also be because these small-scale spring-fed sources of irrigation are too unreliable for the fields to be counted as 'irrigated' plots.

FIGURE 4. Distribution of bari (non-paddy land)holdings from the sample survey carried out in selected study villages in the Indrawati subbasin (ha).

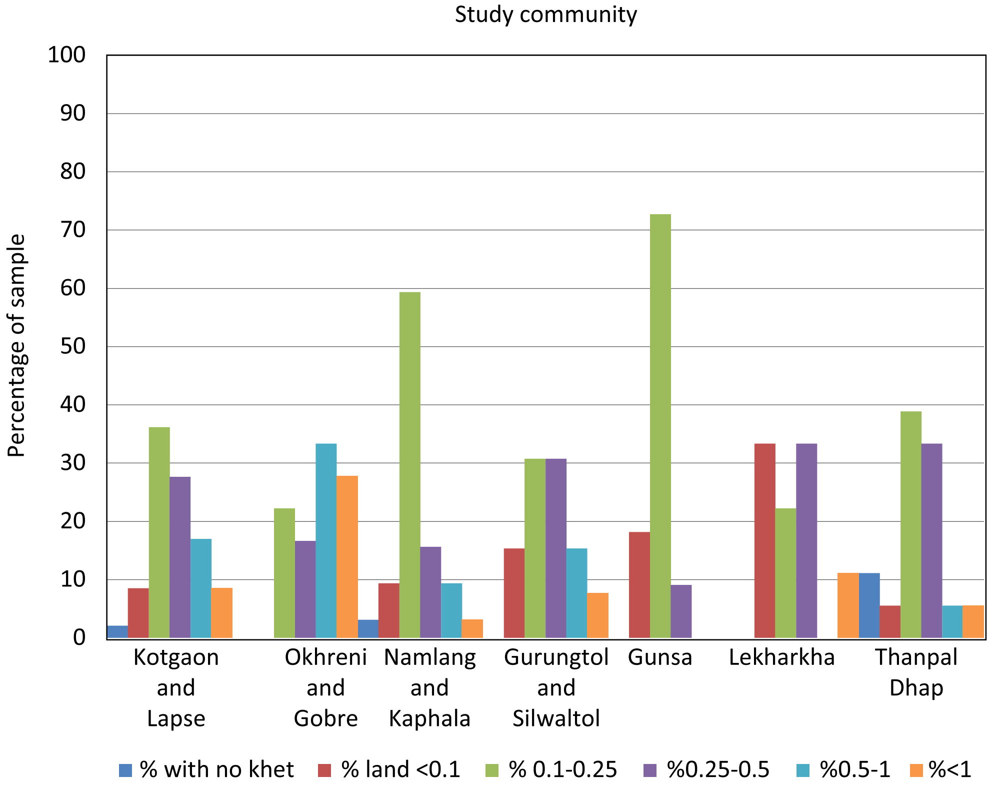


FIGURE 5. Distribution of khet (paddy land)holdings from the sample survey carried out in selected study villages in the Pankhu subbasin (ha).

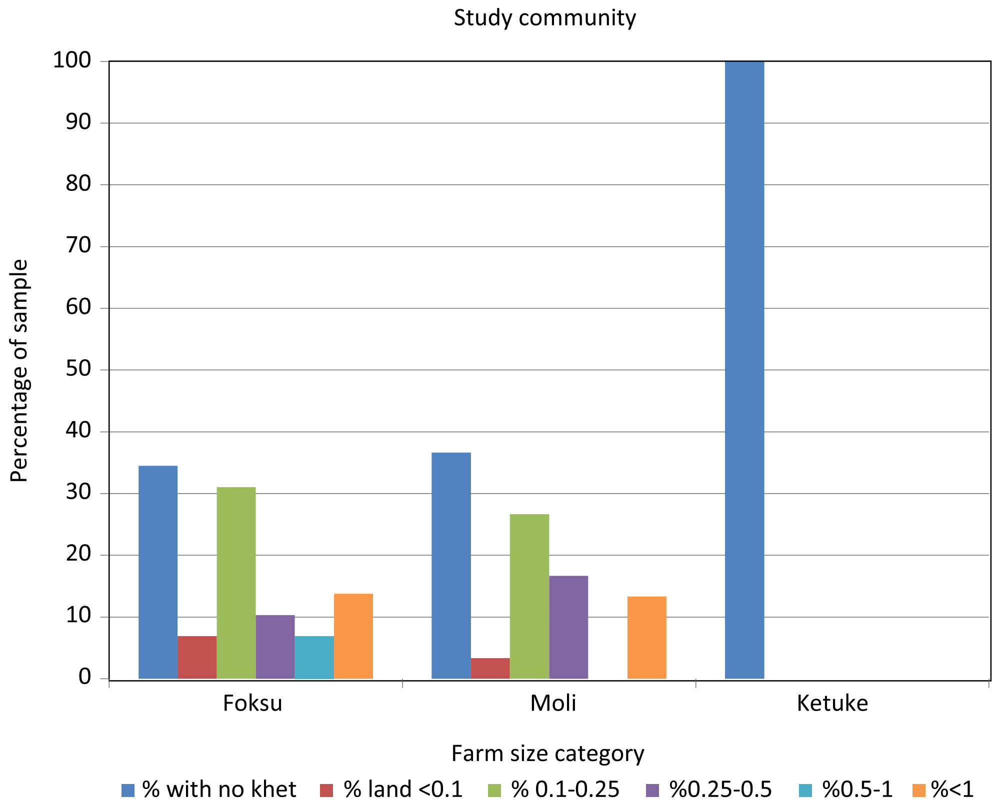


FIGURE 6. Distribution of bari (non-paddy land) holdings from the sample survey carried out in selected study villages in the Pankhu subbasin (ha).

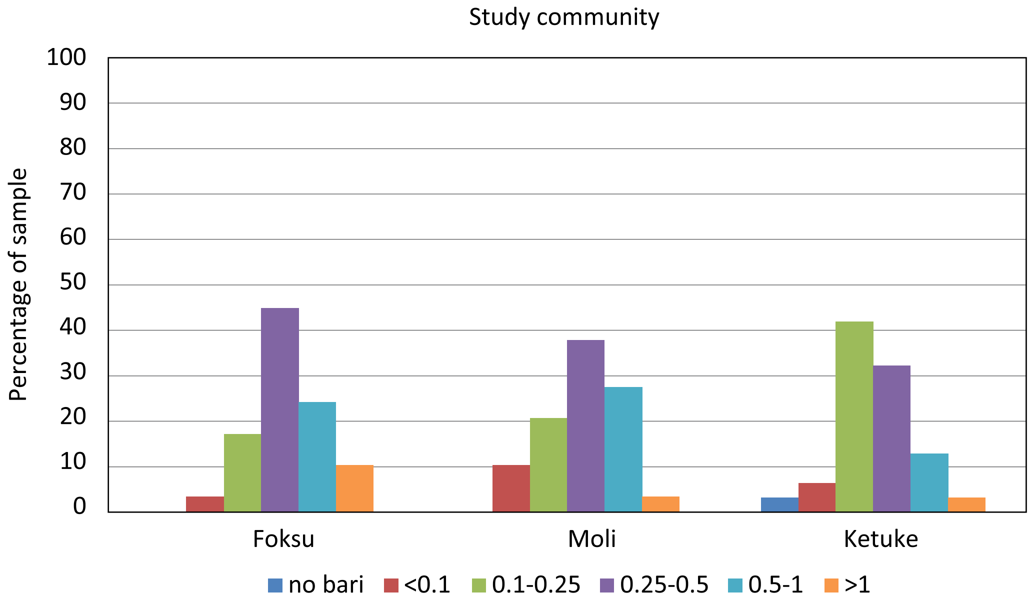
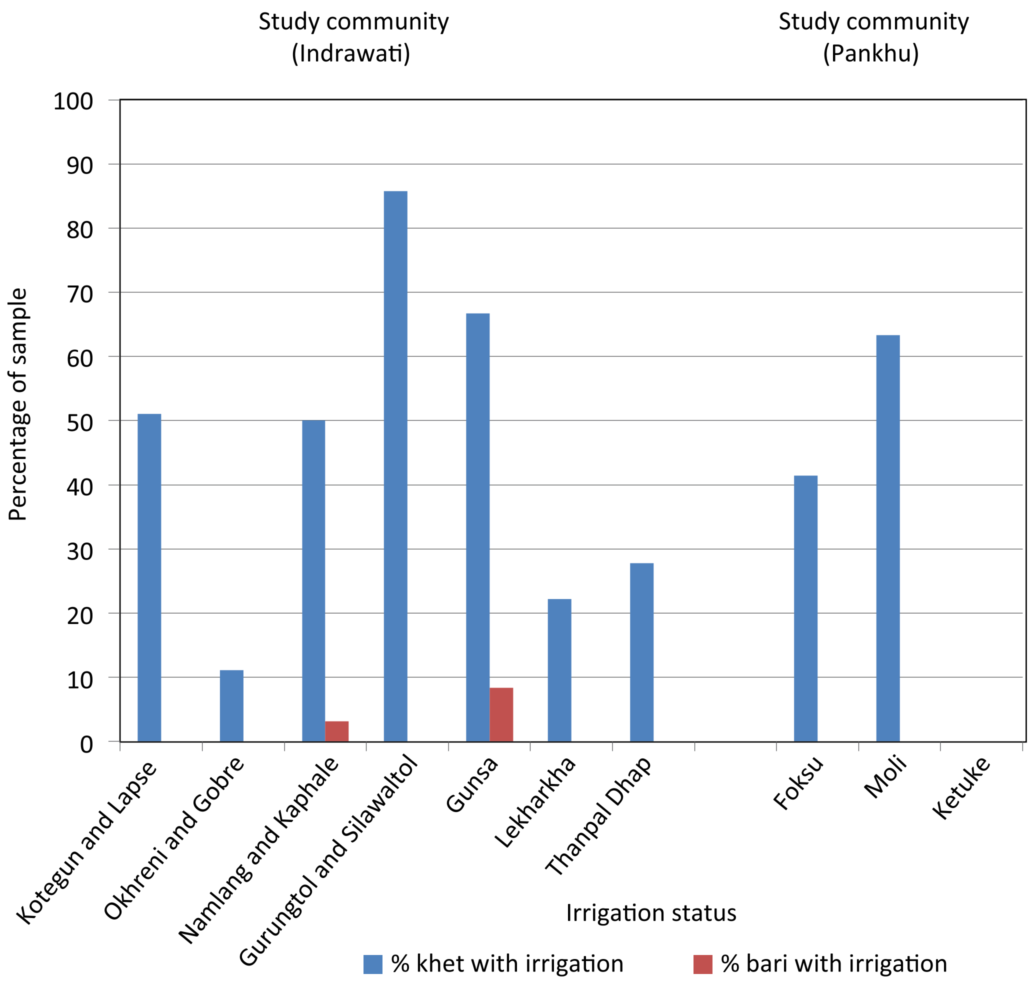


FIGURE 7. Percentage of respondents with and without irrigation in the Indrawati and Pankhu subbasins.



Existing Water Storage Systems in the Study Area

Artificial storage systems can be divided according to size and the nature of the physical infrastructure (see Table 5). The largest artificial storage systems are reservoirs which are built into the terrain to capture water from rivers and streams behind dams for irrigation or power generation (Smakhtin and McCartney 2010). As such infrastructures within the Koshi Basin are limited at present they will not be included in the analysis. The focus of this study is on smaller pond and tank systems. Such infrastructures can be covered or uncovered and designed to capture rainwater or water from streams, which may be small in volume but may be of critical importance for livelihoods (Smakhtin and McCartney 2010). The report will go on to review the existing infrastructure in the two study basins.

Concrete Storage Ponds

These are present in Badegaon of the Indrawati subbasin and Moli and Foksu villages or the Pankhu subbasin and are fed by streams or springs, and capture excess water during periods of high flow, increasing the reliability of irrigation, particularly during the dry season (see Figure 8). One pond stores water which is used for the irrigation of fields for arable crops, while two ponds were used for small-scale irrigation of vegetable plots. All the ponds were built following the initiative of community members with support from the District Agriculture Development Office (DADO), and are fed from springs via pipes or by the canals of an existing irrigation system.[4] Most of the concrete ponds had been built through government programs within the last few decades, usually under the Department of Agriculture.

An on-the-ground survey by irrigation engineers was carried out as part of this project, providing useful insights into the estimated costs of upscaling concrete ponds in study locations where they are not present (NSAE 2013); the relevant data are outlined in Table 6. The estimated up-front cost of a potential 252 m^3 concrete pond in Okhreni, for example, is NPR 979,413. Although this is a significant expenditure, the command area is large, at 25 ha. Since each of most *bari* holdings is less than 1 ha (see Figures 4 and 6) this potentially benefits a large number of households. Nevertheless, in regions with an unreliable source, the costs may be too high to make such systems feasible.[5]

Given that concrete ponds are usually linked to a larger canal network, there is a complex feeding

TABLE 5. Storage systems and their capacity.

Storage system	Characteristic and capacity
a) Small size enclosed storage	• Enclosed tanks used in MUS systems, rainwater harvesting, etc. • Capacity less than 10,000 liters
b) Small size pond storage	• Plastic-lined • Low cost • Less than 20,000 liters
c) Medium sized concrete	• Higher investment • More than 20,000 liters
d) Reservoir storage	• Built within the existing topography • Created by construction of check dams • Large capacity

[4] In the case of Moli, the concrete pond was linked up with a network of plastic ponds.

[5] A much smaller potential pond in Lekharka with a capacity of just 20 m^3 and a command area of only 4 ha costs only slightly less, at NPR 732,526, and the total costs, including the distribution system, almost NPR 2 million or more. This is due to the distance of the source from the community, the unfavorable topography and the limited supply from the spring.

and distribution system to maintain. In Badegaun, all respondents agreed that the process of distribution is not efficient as a lot of water is lost through seepage or leaks, and water passages are easily destroyed. Landslides are also a significant problem. In Foksu, part of the canal gets washed away every year in the monsoon by landslides in a gulley the canal crosses, and community members are expected to work together to repair and bring water to the village in the dry season.

FIGURE 8. Concrete pond in Foksu awaiting repairs to the canal.

Photo: Research team.

TABLE 6. Cost estimates of potential new storage infrastructure projects based upon irrigation engineers' survey in selected study sites.

Source	Max/Min discharge of source (l/s)	Intake chamber to storage	Storage	Distribution	Estimated annual discharge (l/s)	Command area	Estimated cost of storage (NPR)	Cost per ha of storage	Estimated cost of whole system (NPR)
Spring	38/2	90 mm pipe	252 m^3 concrete pond	90 mm pipes	5	25 ha	979,413	39,176	4,897,900
Spring	27/1	50 mm pipe	20 m^3 concrete pond	40-25 mm pipe	1.5	4 ha	732,526	183,131	6,904,400
Excess water from taps	NA	Free flow	21 X 33 m^3 plastic ponds	50 drip system with 500 l tank	NA	2.5 ha (0.12 per pond)	3,520,496 (167,642 per pond)	1,397,022	4,481,500
Rainwater	NA	Direct to pond	20 X 50 m^3 plastic ponds	20 drip systems, each with 500 l tank	NA	1.04 ha (0.052 per pond)	3,532,875 (176,643 for each pond)	3,396,980	4,667,200

Note: NA - Data not available.

Plastic Ponds

These small-sized ponds are lined with plastic to reduce seepage (Ngigi et al. 2005) (see Figure 9). These are low-cost, and are an effective way to capture and store overflow from domestic water sources, or water from streams or springs. Two of the study areas, Moli and Foksu, in the Pankhu subbasin, used plastic-lined ponds to store water for irrigation, while in Taranamlang, one plastic pond was under construction. They are filled by collecting excess water from the spring which supplies drinking water, with the water being distributed to individual ponds through pipes. Each plastic pond would serve the same small group of households that share a drinking water tap. Such ponds have a much smaller command area than the larger concrete systems, and are designed for areas where there is a more limited supply of water, unlike the concrete ponds which are designed to be refilled continuously by canals or pipes. The water yield is thus insufficient to irrigate arable land, and they are used entirely for vegetable gardens which can be irrigated through more efficient sprinkler systems and similar technologies.

In Moli, both seasonal and off-season vegetables are grown using water from these ponds, and the income is valuable for food security, being used to buy nutritious food such as dairy and meat products. Some households would also directly consume the vegetables, a contrast from the earlier days when they had to travel to Okhaldunga (3 to 4 hours' walk and 1 hour in a vehicle) to buy vegetables during the dry months.

The engineer's scoping report developed a cost estimate for developing plastic pond systems in the study villages, Ketuke and Kotgaun, where they are not present, including systems fed both by rainwater and overflow from the drinking water system (NSAE 2013). Table 6 shows that the estimated cost of a single plastic pond varies from just NPR 167,642 in Kotgaun to NPR 176,643 in Ketuke. However, it also shows that the estimated command area is significantly lower, at just 0.12 ha for a proposed tap-fed pond in Kotgaun to 0.052 ha for the rain-fed pond in Ketuke. As a result, the cost per ha is significantly higher. However, this is not because these ponds cannot store more water but because of the poorer water supply in communities where this is a feasible option for water storage. The slow rate of refill

FIGURE 9. Plastic pond in Moli with irrigated vegetable fields in the background.

Photo: Research team.

means that a larger concrete pond with a larger distribution system would not be feasible.

A technical disadvantage of such systems when compared to plastic ponds is that they have a high loss from evaporation and are thus highly vulnerable to reduced flow from feeder streams. They also require regular maintenance, particularly due to the growth of wild plants, whose roots would damage the pond. Nevertheless, the use of low-cost and easily available materials means maintenance is easier than in the case of concrete ponds.

Closed Storage

The smallest-scale storage systems include enclosed tanks which are present across Nepal and the Himalayan regions (Adhikari 2007). These are generally of low capacity, often less than 10,000 liters, and are fed by springs or through rainwater harvesting. The advantages of closed storage systems are that there is low water loss from evaporation, and as they are enclosed they are suitable for storing drinking water. It is increasingly common for drinking water storage tanks to be combined with small-scale irrigation through Multiple-Use Systems (MUSs). In these systems, overflow from the drinking water tank is stored in a separate tank to be used for irrigation purposes (Adhikari 2007; Mikhail and Yoder 2008). In Nepal, MUS and other micro-scale systems oriented to vegetable cultivation are particularly suitable in settlements high above perennial streams with no other source of irrigation for conventional crop production (Mikhail and Yoder 2008). Most of the investigated villages in the Pankhu and Indrawati subbasins have some form of closed water tanks used for drinking water, with water being collected from springs, and then fed to standpipes. The one exception is a rainwater harvesting system in Ketuke Village, which collects water from the roof of a school building (see Figure 10).

A challenge for these small-scale enclosed storage systems is the high demand, particularly in ridge-top settlements such as Ketuke where reliable all-year supplies are scarce, meaning that multiple uses for both household and irrigation purposes become difficult. Such communities are far from water sources; ridge lines have long been important transport routes in Nepal, and as these are converted to roads, bazaars develop as more shops and hotels are built, and demand

FIGURE 10. Rainwater harvesting tank in Ketuke.

Photo: Research team.

for water for household use increases further. In Ketuke there is a good source of drinking water 100 m below the bazaar area to which some women travel to fetch water when the tanks in the community dry up. If one wanted to use closed tanks for irrigation, one would require technology to lift water, given that many of the fields are above the source.

Political Economic Context and Challenges to Upscaling Storage Infrastructure

Agrarian Stress and Out-migration

Political-economic context

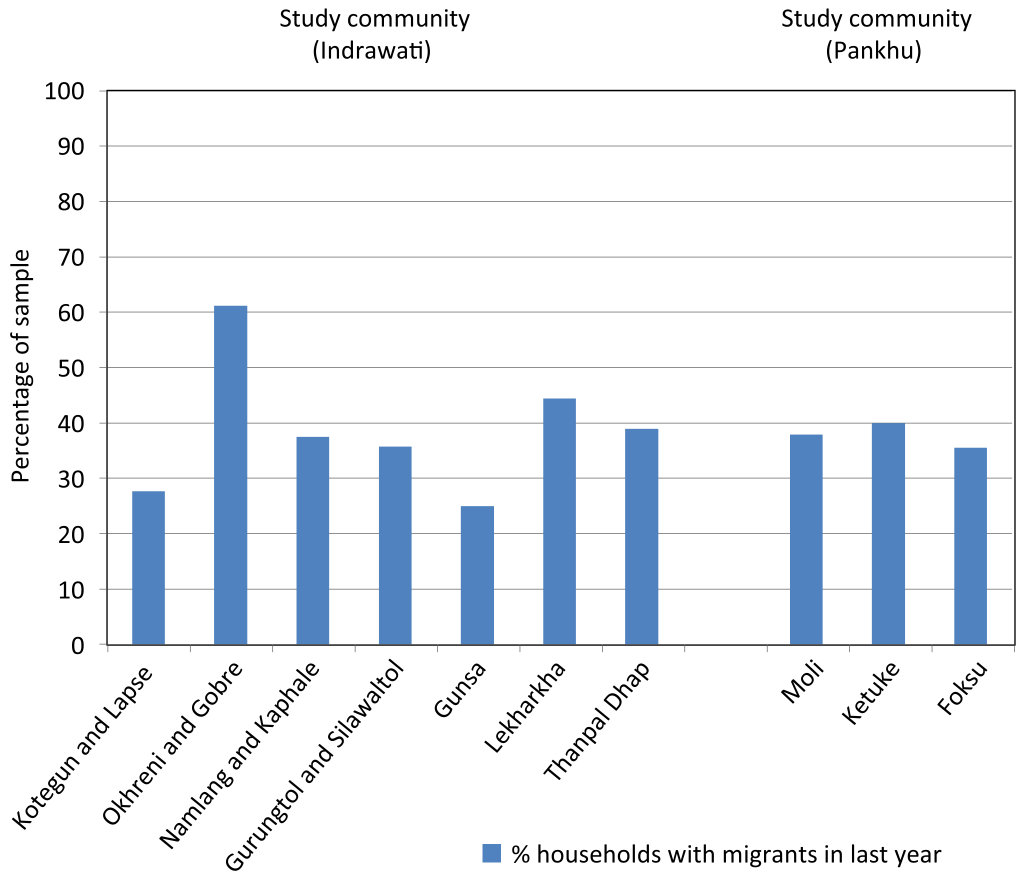
It is clear that there are significant opportunities to expand the network of small-scale storage infrastructure in the Koshi Basin. From a technical perspective, concrete ponds have a larger command area, and can be integrated into existing canal networks to reduce seasonal shortages, although they are expensive to build and maintain, and are financially viable only if there is a regular water supply. Smaller plastic ponds, in contrast, are cheap and easy to construct, can be built in any location, and yet have a limited command area. Enclosed storage tanks can also be built anywhere, and are effective when water is scarce, although their scope for irrigation is more limited. However, in order to make concrete recommendations regarding the upscaling of such storage infrastructure in the middle hills of Nepal, it is necessary to consider technical feasibility in conjunction with the broader political-economic context. This involves understanding the patterns of change at a macroscale, which complement climate stress, and the social, political and economic relations within communities.

Migration and adaptation to climate and non-climatic stress

One of the biggest challenges by far to the successful development of water storage infrastructure is out-migration. For generations, agriculture in the middle hills has failed to fully support the subsistence needs of its population and, in this context, there has been a long-established pattern whereby the peasant economy of the hills articulates with the urban capitalist economy of the lowlands, Kathmandu and India, with the former supplying labor to the latter. This migrant labor has been historically seasonal in character, with migrants returning to communities during the harvest time. Oral histories claimed however, that this pattern has changed over the last generation, and permanent or long-term migration has become more widespread.

Since the 1990s, there has been a boom in long-term overseas migration with the emergence of new labor opportunities in the Gulf and Malaysia. Seeing its potential to facilitate economic and political ‘stability,’ the government has actively encouraged this process (Graner and Gurung 2003). Figure 11 shows that 30-40% of every household has experienced the migration of at least one family member over the last year. In villages such as Okhreni, with limited agricultural potential, this proportion is as high as 62%. Migration was predominantly of young adult men. This included both longer-term migration to Gulf countries and Malaysia, and also the traditional seasonal migration patterns to India and within Nepal for labor. A large proportion of the respondents interviewed received some financial support through remittances. Figure 12 shows that a large portion of the average monthly income for sampled households in each of the basins is from remittances from family members living outside. This is far higher than what was earned from local nonfarm labor or crop sales.

FIGURE 11. Percentage of households with migrant family members over the last year.



What is important to observe is that migration is itself a form of adaptation due, at least in part, to climate change. Unreliable harvests and declining yields were considered as one reason to migrate, changes which could be linked to climate change. Farmers felt the risk of a failed harvest to be too high when balanced out against the opportunities for labor outside the community. This applies, in particular, to dry-season rain-fed cultivation, where the risks are highest. As a result, this is a key time for seasonal migration. This perception of risk was found to be particularly acute in Ketuke Village. While the levels of migration according to Figure 11 are not much higher than in the other villages in the Pankhu subbasin, the higher elevation and lack of irrigation mean households appeared to be far more dependent upon migrant remittances than their neighbors lower down. Added to this may be a long tradition of labor migration amongst the Tamang community who are the majority there. Despite the hardships and high loans[6] necessary, the young people aspire to migrate overseas because they feel it brings them a more stable income for a set period of time, particularly once debts have been repaid. Lekharkha and Okhreni, both of which face water scarcity, also displayed high dependence on money brought from outside.

This raises the question as to whether the development of water storage infrastructure, by reducing ‘risk,’ will actually encourage greater investment in agriculture and reduce out-migration. Discussions in the villages suggested this could

[6] Households incur debts in the range of USD 1,000 to USD 1,500, usually from private money lenders, to send money to a family member living overseas.

be a problematic assumption, as climate was just one among several stresses on agriculture. First, the expanding cost of inputs such as fertilizer has put considerable strain on agriculture. The price for diesel increased by 352% between 1995/96 and 2009/10, in turn impacting the price of fertilizer (Pant 2011). Second, inflation means that marginal farmers and landless households once dependent in part on agricultural or other local labor are no longer able to subsist on the local farm wages that some households depended upon in the past, driving them to seek work outside of agriculture in greater numbers than before. Prices of grain staples and vegetables in Nepal have nearly doubled between 2000 and 2010[7] (Pant 2011). This is linked again to high oil prices, diversion of farmland to commercial and residential purposes, hoarding by traders, and climate change itself which have contributed to reduced harvests.

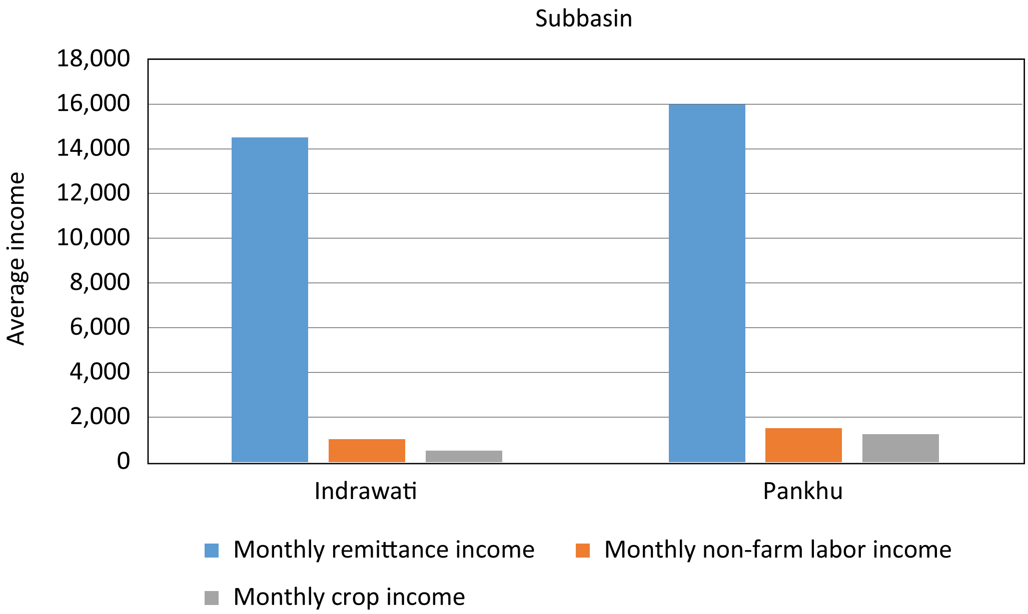
Another compounding factor is population pressure and fragmentation of holdings. The division of holdings amongst sons was said to have made it increasingly more difficult for the current generation to meet its subsistence needs when compared to the past. Added to this is an increasingly monetized economy with greater demand for manufactured commodities and 'luxury' goods, raising cash needs and encouraging out-migration.

Migration and incentives to invest

Although increased migration has offered a more stable source of income for many households, it has had lasting impacts on the social dynamics of communities, with implications for the efficient functioning, management and future upscaling of water storage infrastructure. One of the most striking impacts of migration was that it was reducing interest in agriculture, particularly amongst the younger generation. As one respondent remarked: *"parisramgarepanifaalnapaune [literally, hard work does not give any good result and people will be disappointed and frustrated]."* In many households, agriculture is not considered a profitable investment.

This may make it more difficult to mobilize community members in the future to invest

FIGURE 12. Mean remittance income, non-farm labor income and crop sales income (NPR [Nepalese Rupees]).



[7] Pant notes that although the fact that the price of food has nearly doubled every decade for the last 40 years, per capita GDP has only risen at a modest rate, from USD 157 in 1981/82 to USD 559 in 2009/10.

resources or time in water-storage development. Across the different communities, there was a perception that young people aspire to move abroad and have little interest in learning new agricultural techniques or investing on the land when they are older. Elders in particular were concerned as they felt young people see migration as a 'fashion.' As one Tamang elder in Ketuke remarked: *"...if one person does something all will follow. It is the same with the migration; a few Tamang persons went abroad and now all feel that they have to go abroad to get a better life."* With reference to out-migration, another community member used a local saying, *"Nepali kobhedajastobuddhihuncha (meaning, there is a tendency for Nepali people to follow others like a sheep).* It was felt that they are dependent on a source of income that is not sustainable, and they did not bring any benefits to the community.

Community members complained that young migrants waste a lot of money on household goods and newfangled items. When they come back to the village it was felt that they give the impression that going abroad is high status and they show off their new clothes and technology. As one elder respondent in Ketuke complained about young migrants: *"if they have NPR 10,000 in their pocket, they boast they have more and have expenses of NPR 20,000."* This causes even more young people to aspire to migrate. When they return to the village, they see agriculture as a nonprestigious work, and have reduced interest to invest the money in any productive assets on the farm.

In Badegaun the falling interest in agriculture and the large number of landowners living outside have meant landowners are often unwilling to contribute funds or labor for joint repairs. Residents had seen successful plastic ponds and Multiple Use Systems projects in other villages. However, there was no community drive to invest. Some respondents had looked into the possibilities of rainwater harvesting but due to lack of community cohesion it was not possible. Similarly, in Ketuke, an offer for plastic ponds by an external organization was refused. The organization required the locals to contribute labor but community members feared losing their daily wages which they rely on to feed their family and they were only willing to work for cash.

In this context, it is clear that it will become increasingly difficult to encourage young people to take a lead in developing water storage infrastructure when their aspirations are to leave the community. However, there were significant differences between villages. Ironically, the perception of water scarcity in some villages is reportedly one of the reasons that young people do not see any future in agriculture. This is an important consideration if these villages are to become the target for water storage development. In the context of Ketuke, for example, one of the villages with the most severe water crises, limited water sources for agriculture, along with lack of local employment, was listed in interviews as a primary cause for migration. However, out-migration was also reducing any incentives amongst the young to actually improve agricultural production or invest on the land. Down the valley in Moli and Foksu on the other hand, although migration was also high, the overall agricultural productivity in these communities was much higher, and during interviews and focus groups, the interest in improving irrigation was much higher. Those who had stayed behind were very active in managing the canal and pond infrastructure.

This raises the important point that not all community members were losing interest in agriculture due to out-migration, and even in areas of high migration there was an incentive amongst some community members living outside to invest in development activities at home. In Okhreni for example, people have never been able to subsist on agriculture alone due to lack of irrigation, and out-migration has been a feature of lives for generations (see Figure 11). The primary crop is rain-fed potatoes with a 9-month cycle, and they have no other income source. Respondents in the focus group however, expressed a strong interest to come back to their village *if* they had an opportunity and access to water. There was interest in establishing a rainwater harvesting system, and respondents said they would like to start a large-scale apple plantation, use herbs grown in community forests to make herbal medicine, not to mention other nonagricultural activities such as establishing *thanka* or carpet-weaving industries. However, the Sherpa residents of Okhreni with high literacy rates were organized and held strong community bonds. The high levels of community mobilization were evident during one visit when all the men who had migrated to Kathmandu had returned for a day in the village to meet the Chief District Officer to request him to bring electricity to the community. However, the same drive to return to the village was not evident in the poorer community of Ketuke.

Feminization of agriculture and out-migration

Out-migration of males has also had a significant impact on gender relations, a fact which is likely to impact the potential success of future storage systems. As males seek work outside, women have been facing an increased workload both within the house and in the field, in tasks that would at one time be shared with men. If the household is receiving good financial support which is enough to pay for labor then households with an absent male member will hire people to work on their fields. However, in most cases, the remittances are not sufficient. Often, they are lower than expected due to exploitation by *dalals* (middlemen), and the high interest on loans which are taken to go abroad.

In this context, women said they are much more actively involved in farming, even in tasks long considered the 'male' domain such as plowing. This undermines their capacity to actively participate in the management of new water storage systems, or benefit from them by taking up new opportunities such as vegetable cultivation. In fact, for many households, the land is left fallow during the dry season due to a lack of labor, particularly when family members migrate seasonally. A movement out of dry-season agriculture means that it may be increasingly difficult to mobilize community members to expand the development of water storage infrastructure.

A further problem is that it is traditionally men who take a lead in maintaining and managing irrigation systems and storage ponds. Female participants in Badegaun expressed that people remaining in the village lacked a sense of future direction on how to improve the irrigation system. Second, migration is also putting increased financial stress on those who are left behind, especially when remittances are low or irregular. This is particularly difficult for female-headed households. In a focus group in Badegaun, women said that despite the financial support, they preferred if people did not migrate from the village. Aside from the increased workload, income is often erratic with money only being sent every 3 to 4 months.

On one level this highlights the continued importance of developing irrigation and storage facilities to boost the income of women farmers. However, lack of regular income can also limit the capacity for households to make the financial contributions which are often necessary to maintain systems. A number of women also felt they lacked skills to get involved in new income-generating agricultural activities which would emerge with improved irrigation. While there was some involvement of women in vegetable cultivation in Moli, female respondents still felt the need for a more active involvement of women from diverse backgrounds, and enhanced training so they could better benefit from the schemes.

Another challenge relates to the limited involvement of women thus far in the management of existing irrigation infrastructure. Across the study communities, a recurring trend was for women to be actively involved in household work and decision making *within* the household but to have a very limited role in the public sphere. In Moli, the role of women in the earlier plastic pond project planning was reported by female respondents to have been limited. There was evidence in the focus groups that men, rather than women, had most of the knowledge about the usage of the system and its technical specifications. A similar scenario was evident with regard to the concrete pond under construction in Badegaun, where the women's group members had very little information on who is in the user committee, how it will be managed and who the beneficiaries are.

Women in Moli lamented their limited role in management activities, noting that even in their own *amasamuha* (mother's group) there were two male members who did the accounting. In a focus group with women in Thanpal Dhap it was highlighted that women had limited awareness of larger plans for community development. Their role in the village was perceived as very much defined by men and is limited to household work and work in the field, causing much resentment amongst female respondents. One respondent in Taranamlang quoted her husband as saying: *"you are good to do household work, look after children and cattle and work in the field; if you do these tasks we will work in the community."* In the interview with a male respondent for one storage system, it was claimed that female participation in the committee was passive, and due to lower levels of literacy they lack the information and confidence to actively participate. Also due to the time burden of other household responsibilities they cannot regularly attend the meetings. It is clear that women's participation in storage systems must be significantly increased if storage infrastructure is going to be expanded in the Nepal hills.

Migration and institutions to manage storage infrastructure

Another outcome of increased migration was that it was becoming even more difficult for community members to maintain existing canals and storage ponds. An important observation was that despite the fact that the ponds were built through external interventions, the operation, management and maintenance of existing storage systems were not done through formal agency-established user committees, but through mutual support. As is noted by Venot et al. (2012) with regard to small-scale reservoirs for storage in sub-Saharan Africa, the presence of a formal water user association is by no means a perquisite for effective management. Externally imposed user groups are described as an "institutional fix" by development agencies, and this in itself is seen as a measure of performance (Venot et al. 2012:19). In Badegaun and Moli, it was revealed in focus groups that committees were normally formed as it was a prerequisite to securing the grant, only to be dissolved soon after the construction was completed as they were perceived to serve little purpose.

Collective mobilization of labor in agriculture has been a long-standing feature of the social formation in the middle hills and it is nothing new for farmers to work cooperatively for the maintenance of irrigation systems without a formal committee, and there is an extensive literature on the topic (Lam 1998; Ostrom 2002; Pradhan 2006). Beneficiaries in the study area have a verbal agreement to work together if there is a need for any repairs, and these are negotiated during informal meetings. They also have made an agreement with the community to fine anyone who is seen performing any activities that will damage ponds. Respondents work together to clean the pond frequently, while performing small repairs. Only one pond which was researched had a 'formal' committee which was registered with local government bodies, yet this was linked to the canal system.

Despite the capacity of informal institutions, these are coming under increased stress due to out-migration and the greater dependence on nonfarm labor. First, given that periodic repairs are carried out by mobilizing labor locally, a shortage of labor can make maintenance difficult. Second, it was felt that migration had precipitated a breakdown in community relations. Interviews in Ketuke highlighted that out-migration, combined with rapid economic change following the completion of the road and expansion of the bazaar, has created problems of theft and lack of respect toward the elders, and a breakdown in community spirit and cooperation. This breakdown in community relations is also evident with regard to ties of mutual support in agriculture. For example, the *parma* system of collective labor is common in the rice transplanting season, yet it has declined due to out-migration and a lack of local labor, in turn undermining irrigation management. Under this system, groups of laborers from a set of households would irrigate and labor on one household's field collectively, and then would move on to the next person's field. By the end, each laborer's own fields would have been transplanted. In Badegaun, respondents noted that this prevented conflicts over the allocation of water. However, in the areas where people no longer follow the *parma* system, people would often try to irrigate their land first, leading to arguments, showing that a breakdown of indigenous community institutions can have a detrimental effect on other forms of collective action. Some elders suggested that they needed a stronger village leadership, as one recalled: *"Even with a good tailor you need to be able to tell the tailor what you want otherwise you will not get the clothes you want."*

The breakdown or absence of management institutions is, in some contexts, worsening a culture of aid dependency, which future water storage projects could perpetuate. In Badegaun, the community was not willing to invest in repairing a damaged concrete pond due to high repair cost. The community members remarked that they were relying on the hope that an external organization would financially support the repair cost. This challenge is particularly applicable for concrete ponds as repairs cannot be easily made using local resources. Following major damage, financial investment is often required to bring in materials and/or skilled workers from outside. In these circumstances, it is often difficult to mobilize community members to contribute funds. An equally significant and related challenge of concrete ponds is that they require technical knowledge to be repaired and maintained. This issue was raised in all villages when discussing the merits of concrete-storage ponds. Community members are dependent on the skills of experts from outside the village.

Although the plastic ponds consist of low technology, sustainability remains an issue. Even in Moli, a village with strong community cohesion, there was a perception that if the plastic ponds ceased functioning they would simply request assistance from the government or NGOs to maintain them rather than mobilizing community members to contribute labor or funds. No plans were found to be in place in the event of a financial investment being required to maintain and repair the system. They said they lacked the knowledge and skills to repair the system, which was of concern given that these ponds were much more easily damaged than their concrete equivalents. For example, the Foksu pond was not functioning at the time of research due to damage by children throwing in stones, yet no initiative had been taken by beneficiaries to repair it.

It is important to note that there were some positive examples of successful institutions managing irrigation infrastructure, even in the context of out-migration, such as in Foksu. This community held strong aspirations and bonds with one another, and the canals were maintained relatively well without any formal committees in place. The research team observed the community working together to reconstruct the canal destroyed by monsoonal floods. People from all ages and genders participated in the work, although most were adolescents and women. Interestingly, even some migrants who were back for their holidays had participated in this exercise. The community shared hope that they will be able to reconstruct the canal and bring water to the village for dry-season vegetable cultivation. However, there was a fear that with fewer productive workers in the community, in the future, it may be more difficult to mobilize collective labor as is done at present, and that they may need a formal committee whereby a fee is paid to employ laborers.[8]

Inequality and Power Relations

Landownership and property rights

Another persisting challenge to successful upscaling of water storage interventions, which is intricately connected to the broader socioeconomic context, is the unequal landownership structure

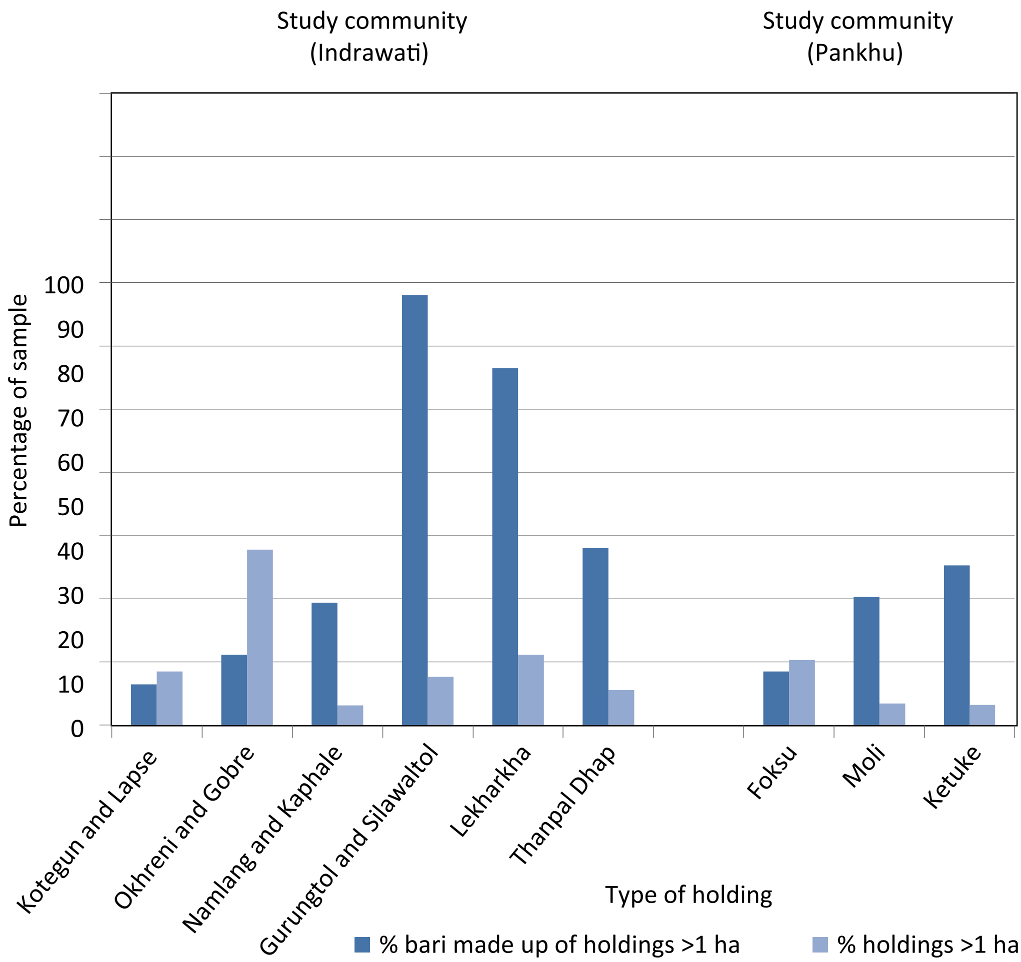
[8] A key role of the committee in Foksu was to ensure that all members contribute labor for maintenance. Users are expected to give one laborer to work for free for as long as it takes to complete the work. Noncompliance results in a fine of NPR 200 per day which can be used to hire laborers from outside. This offers some flexibility for househlods whose family members have migrated causing a labor shortage.

and class inequalities. As with many irrigation interventions, there is always a risk that larger landowners will benefit more. With regard to *bari* lands which are most likely to benefit from improved storage development, distribution appears heavily skewed (Figure 13). In clusters such as Gurungtol and Silwaltol, 68% of the *bari* lands were owned by just 8% of the sample with each holding above 1 ha. However, despite these inequalities, all households are expected to contribute an equal amount of labor to canal maintenance.

There were also inequalities in the distribution of water. In Foksu and Moli, water was given for a fixed period of time according to availability. This meant that larger farmers could only water a small part of their land. In Badegaun, on the other hand, water was allocated according to landownership, with a set of rules over which people had mixed feelings. There was some unhappiness in Badegaun that larger farmers would receive water for a longer period, making other farmers wait. Future storage development could potentially worsen community tensions and reinforce inequalities in villages where there are more concentrated landholdings.

There were also challenges relating to the ownership of the source. In Badegaun, the source for the concrete pond is owned by a single farming household, although through mutual understanding they let other farmers use it. The source owner generally takes priority and irrigates his own land first, meaning that only the excess water from the source is collected in the pond. In contexts such as this, the community did not have a sense of ownership for the storage system resulting in a lack of interest in maintaining it or making a financial contribution to repair it. In a one-to-one interview with a private source owner, he expressed his dissatisfaction over

FIGURE 13. Bari land concentration in selected study villages in the Indrawati and Pankhu subbasins.



the participation of the community. He noted that the water source was good and therefore wanted to increase the height of the pond so that more water could be stored for the dry season, yet community members showed no interest in supporting the plan or making any financial contribution.

Other tensions related to the ownership of land by absentee landlords, a trend which was increasing due to out-migration. Respondents showed dissatisfaction over the lack of initiative and investment from landowners living outside the village. They complained that landlords have given their land on an *adhiya* sharecropping basis to poorer farmers, and are happy to reap a share of production but do not want to invest in anything to improve the fields. At the same time, those who farm the land as tenants are less likely to make any significant investment on land which does not belong to them – posing significant challenges for future water storage development.

Unequal power relations in management

While it is clear there was inequality in the village with respect to ownership of productive assets and class divisions, these power relations also permeate the management of interventions. In Ketuke, it was noted in the focus group that customary authority was very prevalent in the community, with only a few wealthy people from within the community holding authority and taking decisions on matters such as negotiating development interventions. For example, it appeared that the decision to reject the offer of plastic ponds in the community was made not through community consensus, but through the agreement of some 'leaders.'

There were also more direct forms of elite capture. In one community, it was claimed by one respondent that the dominant ethnic group had priority over water usage. The concrete pond supposedly only served half of the community, leaving the rest of the community with no access to stored water. These farmers were dependent on an unreliable supply of water from a spring source directed through a canal. The village was reportedly deeply divided along ethnic lines and respondents expressed that the minority caste faced unequal treatment in access to various facilities in the village, and this shaped who had priority in accessing water. Respondents lamented that most of the time there is no point arguing and they avoided confrontation and possible violence.

Class and 'development priorities'

Finally, an important consideration when considering new storage interventions in light of these deeply entrenched inequalities is the different priorities for people in different class or caste positions. In poorer villages such as Ketuke, the limited interest in developing storage infrastructure which was displayed in interviews may be linked in part not only to the more limited potential for agriculture, but to the lower economic status of respondents when compared to the lower-altitude villages. What appeared as a higher priority was the provision of improved drinking water, regardless of whether it contained storage. This is backed up by a choice experiment carried out as a separate component of this project, data for which were collected during the survey used for this study (Price et al. Forthcoming). The experiment suggested that younger, wealthier and better-educated participants displayed a preference for storage systems focused on irrigation. More marginal farmers and older households were more inclined towards storage projects with an emphasis on the provision of drinking water, and the quality of water was more important than the quantity. This is understandable when one considers that poorer households are more dependent on migrant remittances, and thus safe water for the women and older family members left behind takes priority over improved irrigation. The fact that the people interested in investing in storage systems for irrigation may be those who are already practicing more profitable agriculture should be taken into account seriously when planning new interventions.

Conclusions

Water Storage, and Agrarian and Social Change

It has been shown that climatic stress is putting farmers under increased stress in the hills of the Koshi Basin, primarily due to the rising variability - a fact backed up by the SWAT models and farmer testimonies. A number of storage systems offer technical solutions which can be tailored to different agricultural or ecological domains. However, storage systems are unlikely to reach their full potential if it is not acknowledged that climate is only one of several drivers of change. Broader patterns of agrarian stress such as rising costs of living and poor terms of trade for agriculture, when combined with climate change, are driving out-migration from the middle hills, resulting in a reduced interest in farming. This, in turn, is affecting the aspirations of the younger generation who increasingly foresee a future outside of agriculture. The analysis of existing storage and irrigation systems identified how out-migration and changing priorities were undermining the management of these systems, and reducing the incentives to invest in their maintenance. This change has also affected community relations and institutions which are necessary for collective management of systems – often worsening aid dependency.

Aside from these drivers of change, there are also complex social relations which must be taken into account if one is to successfully upscale water storage in the middle hills of Nepal. These include the distribution of land, water and labor, which can affect the distributional benefits for different groups. Unequal power relations in management can also have negative consequences given differential needs.

It is important to note however that, despite the challenges, interest in developing water storage systems amongst community members remains high, and the levels of out-migration, changed aspirations and inequality vary from community to community. Participants were keen to explore opportunities to more efficiently use the existing systems, expand their capacity, and introduce new systems. Community members were very positive that the water storage system would support the community to increase production, decrease dependency on rain-fed crops, open opportunities to plant cash crops, and bring new income sources to the family. The priority therefore should be to tailor storage systems in a way which addresses the multiple social constraints outlined above. In sum, what conclusions and policy recommendations can be raised from this study?

Engage with Youth

It is important to note that even in the context of out-migration improved irrigation could potentially offer incentives for young people to stay in the community, or at least offer migrants a greater interest in investing in their land at home. Speaking to adolescents, many were interested in continuing with agriculture if they had access to water all year-round, and access to technology that would increase production and offer agricultural-based income-generation opportunities. For this they had been keen to learn and study more about agriculture in school. However, usually the drive to migrate was higher.

It is therefore crucial for new interventions to proactively engage with the young male population which is the backbone of the migrant economy, and let them see the benefits of new agricultural techniques. As one respondent in Foksu noted: *"the younger generations are forgetting that after getting education also you can continue with agriculture; we need people with new skills and technology in the agricultural field."* This can be achieved through external development agencies seeking to directly target young and potential migrant households. By proactively seeking their involvement in planning and user committees, they can gain a sense of ownership to the interventions, while also learning about the potential livelihood opportunities which could lie in agriculture once water issues are addressed. At a broader level, national agricultural policies should also make the involvement of youth a priority, with a greater engagement with agriculture and irrigation issues in educational curricula.

However, while targeting communities for support through both government and external schemes, it is also important to note the different community dynamics. In Ketuke, it would be easy to assume there is a 'demand' for irrigation due to its marginal location on a ridge-top. However, it is perhaps for this reason that households have diversified their livelihoods and are much more dependent on the migration of young people and small businesses. It is therefore crucial for rigorous pre-project research to identify livelihood aspirations and trends, so that alternatives can be considered, for example, water storage to improve drinking water provision for those who stay behind. There are also other opportunities locally beyond agriculture, with which young people are interested in, and should be supported by development agencies. For example, in Ketuke, a number of respondents were more interested in learning how to make products from locally available wild herbs. They expressed an interest in establishing a local factory to make herbal products. Similarly, respondents in Badegaun said that due to dissatisfaction with agriculture, many people in the village now are keeping livestock and selling milk, facilitated by a community collection center and committee.

Engage with Women Farmers and Elders

Even while engaging with young people, male out-migration is a complex process, and will always continue. In this context, it is becoming even more important to actively involve women in the management of new water-storage interventions. Involving them as 'token' members of a committee is not sufficient, as they need to be actively engaged in decision making. After all, those who would be most dependent on new infrastructure are women, producing food for the family, while male family members are outside. In Ketuke, it was a group of senior male community members who had actively rejected the opportunity to construct plastic ponds due to potential technical shortcomings. Had women had a say there could have been a different outcome. Agriculture is likely to become increasingly important for female-headed households and the elder generation. With the rising cost of foodstuffs it will become increasingly difficult to purchase food with what is sent through remittances.

It is also important to engage with other, often overlooked, groups, such as elder community members whose sons and daughters are living outside, who often receive little income, and who are dependent on the land.

Understand and Build Upon Local Institutions

It is important that agencies considering new interventions consider the strength of local informal institutions which can be built upon. For example, Foksu already has a well-functioning committee for their irrigation canal. This does not mean that informal institutions should be left to manage affairs entirely, but it is important to build upon and improve existing institutions rather than establishing new ones. Many respondents felt that there was a need to formalize some of the rules and responsibilities, particularly as out-migration upsets traditional community dynamics. For example, with regard to managing the plastic ponds in Moli, respondents need to formalize some responsibilities to ensure the system is managed and maintained well. It was suggested that groups collect a membership fee to bring some financial income to the committee which will be used to manage and maintain the system.

It is also important to understand property rights to sources and springs when developing new water storage options. In Badegaun, property rights over the spring had undermined the success of the past storage project. It is important to ask if source owners fully back the project. Are there ways in which source owners could be compensated to maintain and protect the source through financial contributions by downstream users? This is particularly important if sources appear to be drying up.

Match Scale with Community Needs

While concrete ponds have a much larger command area, the smaller plastic ponds are cheaper, can be maintained locally, and do not face the same management challenges. Such interventions may be more suitable in regions with high out-migration with labor shortages. Furthermore, with the traditional role of women farmers in small-scale vegetable cultivation, such interventions may be more suitable for female-headed households. However, even for low technology interventions such as plastic ponds, a culture of dependency was still observed in villages such as Moli, suggesting that external agencies need to do more to build the capacity and skills of community members to maintain the infrastructure. Larger-scale interventions are still suitable if there are strong local institutions to manage them, such as in Foksu, and sufficient labor to contribute to maintenance. However, long-term effective monitoring and evaluation are necessary to ensure longer-term efficient management.

Better Integrate Storage Development with Agricultural Extension

For storage systems to be effective, it is crucial to link them with the development of new agricultural technologies, particularly through encouraging active interest amongst youth and women. Agricultural production should be seen to provide economic benefits for young people if it is to encourage their participation. Part of this will also involve identifying possible market chains to link urban centers to rural communities.

Integrate Small-scale Storage Development with Source Protection and Water Storage at a Larger Scale

It is clear that investing in small-scale storage will be fruitless if sources dry up over the medium and long term. While small-scale storage may be crucial from a livelihoods perspective, it is unlikely to have a significant impact on water balance at a broader basin, and subbasin scale, and with climate change, the risk of sources declining is increasingly likely. Indeed this has already been shown to be occurring in the Indrawati and Pankhu subbasins. It is therefore necessary for programs developing storage to be part of larger programs for integrated watershed management, including initiatives to improve land cover, and maintain soil moisture, and facilitate aquifer recharge.

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ISSN: 1026-0862
ISBN: 978-92-9090-792-3