



Can labour migration help households adapt to climate change? Evidence from four river basins in South Asia

Amina Maharjan , Sabarnee Tuladhar , Abid Hussain , Arabinda Mishra ,
Suruchi Bhadwal , Sultan Ishaq , Basharat Ahmed Saeed , Ishani Sachdeva ,
Bashir Ahmad , Jannatul Ferdous & S. M. Tanvir Hassan

To cite this article: Amina Maharjan , Sabarnee Tuladhar , Abid Hussain , Arabinda Mishra ,
Suruchi Bhadwal , Sultan Ishaq , Basharat Ahmed Saeed , Ishani Sachdeva , Bashir Ahmad ,
Jannatul Ferdous & S. M. Tanvir Hassan (2021): Can labour migration help households adapt to
climate change? Evidence from four river basins in South Asia, Climate and Development, DOI:
[10.1080/17565529.2020.1867044](https://doi.org/10.1080/17565529.2020.1867044)

To link to this article: <https://doi.org/10.1080/17565529.2020.1867044>



© 2021 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group



Published online: 04 Feb 2021.



Submit your article to this journal [↗](#)



Article views: 180



View related articles [↗](#)



View Crossmark data [↗](#)

RESEARCH ARTICLE



Can labour migration help households adapt to climate change? Evidence from four river basins in South Asia

Amina Maharjan^a, Sabarnee Tuladhar^a, Abid Hussain^{id a}, Arabinda Mishra^a, Suruchi Bhadwal^b, Sultan Ishaq^c, Basharat Ahmed Saeed^d, Ishani Sachdeva^e, Bashir Ahmad^c, Jannatul Ferdous^f and S. M. Tanvir Hassan^f

^aInternational Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal; ^bThe Energy and Resources Institute (TERI), New Delhi, India; ^cPakistan Agricultural Research Council (PARC), Islamabad, Pakistan; ^dLeadership for Environment and Development (LEAD), Islamabad, Pakistan; ^eCentre for Ecology Development and Research (CEDAR), Dehradun, India; ^fBangladesh Centre for Advanced Studies (BCAS), Dhaka, Bangladesh

ABSTRACT

The study focuses on four river basins, Gandaki, Indus, Upper Ganga and Teesta, in the Hindu Kush Himalayan (HKH) region in South Asia. The region is considered one of the more environmentally vulnerable areas in the world due to recurrent natural hazards that can be exacerbated by future climate change. The dependence of the population on natural resources based livelihoods makes the region particularly vulnerable to adverse climate change impacts. Labour migration can help household adaptation, particularly when it incurs significant cash investment. The paper analyses the determinants of household adaptation, including migration, in three sectors, namely, agriculture, livestock, and water. It shows that household adaptation to the negative effects of climate change was very poor in the region, with less than a third of the households undertaking adaptation measures. While labour migration showed a positive influence on household adaptation, it was statistically significant only in agriculture. Nevertheless, migration influenced household adaptation indirectly through livelihood diversification, access to services provided by external stakeholders, and changes in household composition. The study identified location, access to climate information, and services provided by external stakeholders as important factors in household adaptation to climate change.

ARTICLE HISTORY

Received 12 March 2020
Accepted 14 December 2020

KEYWORDS

Labour migration; climate change; household adaptation; Hindu Kush Himalayan region; South Asia

1. Introduction

South Asia is highly susceptible to the adverse effects of climate change. In the mountains, the temperature increase is expected to be higher than the global average due to the elevation-dependent warming effect (Pepin et al., 2015). When the global temperature increases by 1.5°C, it will increase by $2.1 \pm 0.1^\circ\text{C}$ in the high mountains of Asia (Kraaijenbrink et al., 2017). This region is already prone to recurrent natural hazards such as glacial-lake outburst floods, storm surges, droughts, river floods and erosion, and heavy and erratic precipitation that can be further exacerbated by future climate change (IOM, 2016; Krishnan et al., 2019). The high dependence of the population on natural-resources-based livelihoods makes the region particularly vulnerable to the adverse impacts of climate change. The study focuses on four river basins – Gandaki, Indus, Upper Ganga and Teesta – that are part of the Hindu Kush Himalayan (HKH) region, which is already considered as one of the more environmentally vulnerable areas in Asia (IPCC, 2014a; Messerli et al., 2004; Wester et al., 2019).

People in the HKH region and those living in the dependent downstream have long adapted to living in a fragile environment, including labour migration to diversify livelihoods and spread risks (Pathak et al., 2017). Consequently, remittance

plays an important role at national as well as household levels in the HKH region. The HKH countries accounted for nearly 19% of the international migrant stock in 2013 and about 29% of the global remittance inflows in 2015 (World Bank, 2017, 2018). Internal migration is even higher which, in the case of India, accounts for about 30% of its total population (Census of India, 2001), in Nepal 14% (CBS, 2012) and in Bangladesh 10% (BBS-GOB, 2015).

There is a growing understanding that migration may serve as an adaptation strategy and/or support the adaptation capacity of households in areas vulnerable to the negative impacts of global environmental change (Bardsley & Hugo, 2010; Black et al., 2011; Jha et al., 2018; Lonergan, 1998; McLeman & Hunter, 2010; McLeman & Smit, 2006). Emerging theoretical and empirical evidence suggests that migration influences household adaptation through remittance, skill transfer, and transnational and translocal ties (Afifi et al., 2016; Mortreux & Barnett, 2009; Scheffran et al., 2011). It can also help households to absorb climate shocks (Gioli et al., 2014; Tebbboth et al., 2019). In climate vulnerable areas, remittance can help in building the adaptive capacities¹ of households, particularly when the adaptation option incurs a significant cash investment by the households (Ng'ang'a

CONTACT Amina Maharjan ✉ amina.maharajan@icimod.org; m_amina24@yahoo.com; www.icimod.org  International Centre for Integrated Mountain Development (ICIMOD), GPO Box 3226, Khumaltar, Lalitpur, Kathmandu, Nepal

© 2021 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

et al., 2016). Migration offers households an opportunity to diversify livelihoods and spread risks in ways that make their households less vulnerable to the impacts of global environmental changes (Greiner & Sakdapolrak, 2013; Hampshire, 2002; Leighton, 2006; Piguet, 2013). One of the benefits of migration is enhancement in transnational or translocal ties (Sakdapolrak et al., 2016) which facilitates better access to information, services and technology for households. But migration also brings about second order changes in the composition and structure of the migrant households that can affect the adaptive capacity of the households (Rao et al., 2019a; Rao et al., 2019b; Singh, 2019a). Most migrants tend to be male which results in an increase in female-headed households (Goodrich et al., 2019; Rao et al., 2019b; Rigg & Salamanca, 2015). There are both positive and negatives outcomes to this. On the one hand, the absence of male household members can increase the workload of the women left behind (Maharjan et al., 2012), resulting in severe time poverty and increased vulnerability (Arora et al., 2017; Bhagat, 2017; Bhatta et al., 2015; Bhattarai et al., 2015; Lawson et al., 2020; Singh, 2019b). On the other hand, it can increase women's decision-making capacity and enhance their agency (Djoudi et al., 2016; Rao, 2019), thereby facilitating household adaptation.

Adaptation studies have focused heavily on assessing vulnerability or adaptive capacity through construction of various outcome indices (Balasubramanian et al., 2007; Gbetibouo et al., 2010; Hahn et al., 2009; Iglesias et al., 2011; Malone & Brenkert, 2008). There are only a few studies that provide empirical evidence of how household decision-making on adaptation is influenced by various household and external factors (e.g. Vincent, 2007; Yohe & Tol, 2002). However, a better understanding of household adaptation decisions, including migration options and the processes resulting in reduced vulnerability or enhanced adaptive capacity, is critical to identify and develop robust policies (Adger & Vincent, 2005; Smit & Wandel, 2006).

The study contributes to the scholarship on migration and climate change adaptation in four ways. Firstly, it identifies the determinants of household adaptation, including the role of migration. Secondly, the study analyses household adaptation in three crucial sectors, namely, agriculture, livestock, and water. To the best of our knowledge, there have not been many studies that categorically analyse multiple sectors simultaneously using surveyed household data. Thirdly, the study covers diverse study areas in terms of the socio-cultural context and climatic stressors, thereby demonstrating the locational specificity of the adaptation behaviour of households. Finally, the study also brings in the mountain perspective by taking into consideration the ecological zones in the study sites in order to show the differential impacts on the mountains and the plains.

2. Theory

The IPCC's Fifth Assessment Report makes a strong case for the capacity of migration outcomes to reduce vulnerability of populations exposed to environmental and climatic hazards and longer-term change (Adger et al., 2014). Studies have

also shown that, in the face of environmental and climatic stress, migration is a strategy aimed at supporting basic needs and livelihoods (Foresight, 2011; Hampshire, 2002; Piguet, 2013). There is an increasing interest among scholars in the potential of migration to contribute to adaptation (Bardsley & Hugo, 2010; Black et al., 2011; McLeman & Smit, 2006). Migration can help the adaptive capacity of households if it helps improve the households' existing resource base to spread risk and reduce vulnerabilities (Gemenne & Blocher, 2017; Tacoli, 2011; Warner & Affi, 2014) or helps expand the asset base. However, there are very few empirical studies exploring the role of migration in shaping household adaptation decisions and processes (Milan et al., 2015).

The New Economics of Labour Migration (NELM) (Stark & Bloom, 1985) is the underlying theory in this study to further investigate the contribution of migration to household adaptation in the specific context of the HKH region. Three major aspects of NELM contribute directly to the analytical framework of the study: (i) the migration decision is taken at the household level; (ii) migration is a household strategy to diversify livelihoods rather than maximize incomes; and (iii) migration helps to overcome other market failures such as capital and insurance markets. Hence, under NELM, migration is considered as a risk management strategy of the households (Robert & Stark, 1985; Stark & Levhari, 1982). Households dependent on the natural resource base for production and consumption often spatially diversify the household income sources by becoming involved in labour migration (Bohra-Mishra et al., 2014; Ramin & McMichael, 2009). Income diversification via migration helps households to reduce risks and relax financial constraints through remittance transfers (Katz & Stark, 1986; Robert & Stark, 1985; Stark & Levhari, 1982; Taylor, 1999). In the absence of formal insurance markets, migration via remittance acts as a household co-insurance strategy.

The main objective of this study is to analyse the role of migration in influencing the determinants of household adaptation decisions. For this purpose, we supplement the NELM theory with the sustainable livelihoods framework (SLF) developed by Chambers (1989) and later elaborated by Scoones (1998) as well as the conceptual approach of Yohe and Tol (2002). According to Chambers' (1989) theory of vulnerability and adaptation, poor households seek to reduce vulnerability by diversifying their income sources and capital assets. Thus, both NELM and the Chambers' theory postulate that poor people do strategize to reduce risks through livelihood diversification. While both Chambers (1989) and Yohe and Tol (2002) consider household and community level factors in determining adaptation capacities, Yohe and Tol (2002) also consider factors beyond household capital such as access to critical infrastructure, adaptation technology and climate information. The SLF identifies five capital assets: human, natural, financial, social and physical (Scoones, 1998). Yohe and Tol (2002), on the other hand, have listed eight determinants of adaptation: (1) the range of available technological options for adaptation; (2) the availability of resources and their distribution across the population; (3) the structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be

employed; (4) the stock of human capital, including education and personal security; (5) property rights; (6) the system's access to risk-spreading processes; (7) the ability of decision makers to manage information, the processes by which these decision makers determine which information is credible, and the credibility of the decision makers themselves; and (8) the people's perceived attribution of the source of stress and the significance of exposure to its local manifestations. These eight determinants of adaptive capacity include a variety of systems, sectors, and location-specific characteristics. But, as Below et al. (2012) have pointed out, even though these determinants of adaptive capacity are specific enough to explain local adaptation processes, they might not fully explain the processes undergone by poor households to adapt to climatic variability and change. To understand the specific processes leading to reduced vulnerability or enhanced adaptive capacity at household level, especially those triggered by migration, a set of variables drawn from the three theories that can explain household adaptation decision making is needed. The variables that are described in the next section have been identified taking into consideration the HKH context.

3. Material and methods

3.1. Study area

The study area consists of four river basins: Indus, Upper Ganga, Gandaki and Teesta (Figure 1). To ensure that different altitudes from the study area are represented, sites from the up-, mid- and down-stream areas of all rivers basins were included (Table 1). Although all the river basins are largely fed by rainfall, particularly monsoon rains, glacier and snowmelt water also play an important role in basin runoff. An exception is the Indus basin where the glacier and fresh snowmelt contributions to the run-off in the river are comparatively high. But a higher

level of warming is expected across the four river basins under study (Conway et al., 2019). The three sub-areas of the basins show the impacts of climate change in the form of both increased snowmelt and flash floods during the monsoon as well as reduced rainfall especially during the cropping period, leading to drought-like conditions, (Abbasi et al., 2017).

In all four basin sites, the major income sources are agriculture and forest products; livestock and fishing; tourism; rent and business; formal salary or wages; and casual labour. Of these, agriculture remains the primary source of income. Due to topographical and climatic differences, agriculture is more productive in the plains than in the mountains but it is mostly subsistence in nature. For instance, in the Teesta river basin in Bangladesh, about 54% of the population is involved in subsistence agriculture, with 8% of the farmers having less than 1 ha of cultivable land (Syed et al., 2017). With limited opportunities both in farm and non-farm sectors, out-migration has been key in the search for better livelihoods, particularly, in the mountain areas. For instance, in the state of Uttarakhand, India, all the mountain districts in the Upper Ganga basin have recorded less than 5% decadal growth rate in population, including the study areas Rudraprayag and Teri Garhwal. Similarly, the 36 hill and mountain districts in Nepal have recorded a negative decadal growth rate in population, including the study sites Rasuwa and Nuwakot districts (CBS, 2012). Among the resident population, labour migration is an important livelihood strategy.

There is significant diversity in terms of ethnicity, religion and caste among the population in the study sites. This diversity is reflected in the different socio-cultural norms that influence the governance of access to assets among the different ethnic groups residing in the different locations. However, when it comes to gender relations, patriarchy is the norm among most households although the norms are more woman-friendly in mountain areas than in the plains in all

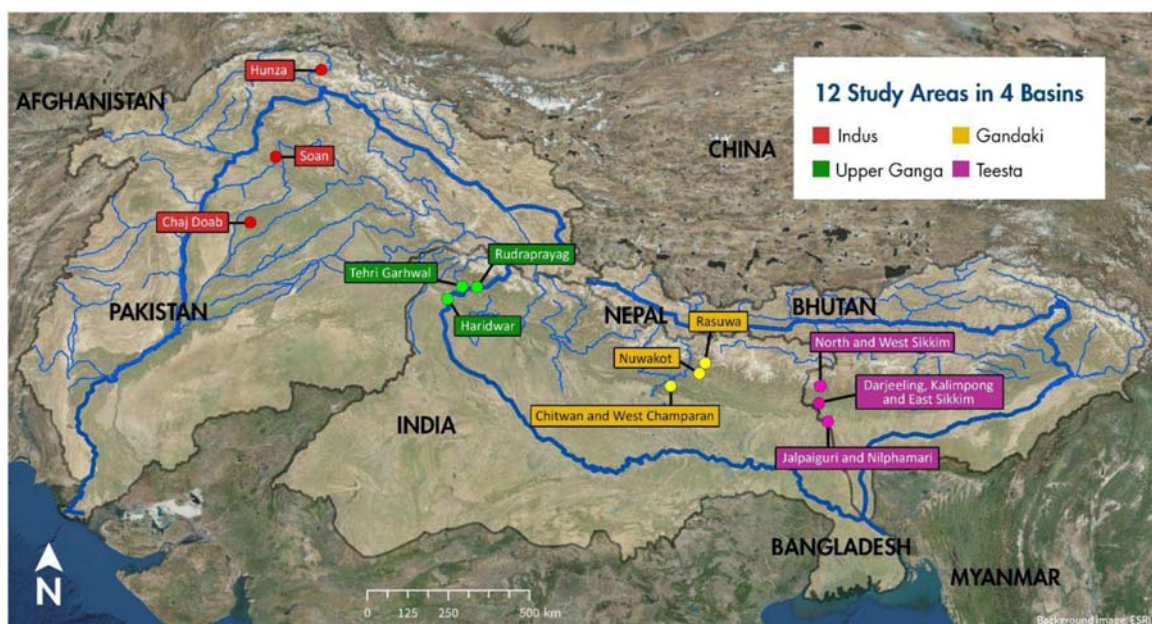


Figure 1. Map of the study sites at up, mid and downstream of Indus, Upper Ganga, Gandaki and Teesta river basins.

Source: Background image from Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Table 1. Study sites in river basins.

River basins	Altitude	Surveyed sample size	Target districts	Selected settlements within districts
Indus (Pakistan)	Upstream	127	Nagar Hunza	Hopper Passu Gircha
	Midstream	131	Chakwal Rawalpindi	Akwaal Saroba Dhok Chawan Gang Chak 7
	Downstream	155	Sargodha	Sada Kamboh
Ganges (India)	Upstream	164	Rudra Prayag	Guptkashi Huddu
	Midstream	159	Tehri Grahwal	Kimkhola Ammi Baghi
	Downstream	161	Haridwar	Hakeempur Badal
Gandaki (Nepal and India)	Upstream	202	Rasuwa (Nepal)	Gatlang
	Midstream	200	Nuwakot (Nepal)	Charghare Khanigaon
	Downstream	201	Chitwan (Nepal)	Gardi Kathar Madikalyanpur
Teesta (India and Bangladesh)	Upstream	84	West Champaran (India) West Sikkim (India)	Shampur Kotraha, Nautan Block Gumpa Dara Simphok
	Midstream	166	West Sikkim (India)	Hee Gaon Martam
	Downstream	237	North Sikkim (India) Rangpur (Bangladesh) Nilphamari (Bangladesh) Chor Dhubni (Bangladesh)	Sudur Panjarbanga Purba-Chatnai Chor Dhubni
Total		1987		

the four river basins under study. But there is significant diversity with regard to ethnicity. For example, in the Teesta basin, the higher elevation villages are inhabited by indigenous groups, the mid-stream villages by mixed Nepali ethnic communities and other scheduled tribes (Bhadwal et al., 2017), and the villages in the downstream floodplains by Bengalis (Syed et al., 2017). A similar diversity is prevalent in relation to religion. While Buddhism and Hinduism are dominant in the Indian part of the Teesta river basin, Islam is the major religion in the Bangladeshi part of the Teesta. As regards caste and other social hierarchies, differences are similarly evident. So, while in the Upper Ganga basin, scheduled castes and tribes constitute the marginalized section of the society, in the plains, the other backward castes (Sainis and Gade Muslims) constitute the marginalized groups. As regards literacy, people in higher elevation sites were generally more literate compared to those in the plains, except for the Gandaki basin. Population density was higher in the plains than in the hills across all four river basins under study.

3.2. Sampling design and data collection

To determine a statistically reliable sample size, Cochran's sample size formula (Cochran, 1977) was used in all four study basins. The formula is presented in Equation (1).

$$n = D \times \left[\frac{Z^2 \times (p) \times (1 - p)}{e^2} \right] \quad (1)$$

In the equation, while sample size is denoted by n , p represents the percentage of households picking a choice

(expressed as decimal = 0.5). Put differently, it is an assumed proportion of household population in the study areas that is likely to have the characteristic of interest. In this study, the characteristic of interest is 'adaptation to climate change induced impacts'. In the equation, $(p) \times (1 - p)$ expresses an estimate of variance. Z represents Z -value (1.96 for 95% confidence interval), e is margin of error (0.06), and D is design effect (1.50).

A stratified sampling design is followed in the study. The design effect has been considered in the sample size formula to compensate for any loss of statistical robustness in the stratification procedure within the river basins (the strata being upstream, midstream and downstream). The design effect is the ratio of the actual variance, under the sampling method actually used, to the variance computed under the assumption of simple random sampling.

Using Equation (1), a sample size of 402 households was determined for each river basin. However, the number of actual surveyed households was higher than the determined sample sizes in all river basins. The researchers contacted a higher number of households than that required for the sample because, through past experience in conducting similar surveys, they knew that there would be a high number of non-responding households and incomplete questionnaires. In total, 1987 households were surveyed in the four river basins. The determined sample in each river basin was unequally distributed across strata using the 'probability proportional to size (PPS)' method. There is one limitation in the sampling design. In each stratum, districts and study settlements within districts were selected purposively in view of their high vulnerability to climate-change-induced impacts. In view of this limitation, the

data and findings of the study may not be a true representative at river basin and strata levels.

A structured questionnaire was prepared to collect data from households. The questionnaire was digitalized in a mobile/tablet-based application called *Akvo-flow*. Predesigned survey forms, which had undergone multiple iterations, were input into the *Akvo-flow* application running on Android-enabled smartphones. This would enable the user to upload the data directly onto a central server from which they could be readily accessed and prevent transcribing mismatches.

The survey enumerators were trained on both the use of *Akvo-flow* and ethics in data collection at a training workshop. In April–May 2017, the questionnaire was pre-tested in all strata to ensure the consistency of questions and for smooth collection of data through electronic devices. The actual survey was administered in the English language from June to September 2017 in all the study sites. In each settlement, households for the survey were selected using the random route procedure. Enumerators were instructed to select the respondents in households based on their age. Respondents who were more than 25 years of age were interviewed because the questionnaire contained many questions relating to perceptions of past events (i.e. recall data of the situation going back 5–10 years).

The questionnaire consisted of information on migration (destination, remittance, migrant profile), climate change perceptions (changes observed and overall impacts), adaptation in the selected three sectors (type of crop/livestock produced and source of water, climate change impacts in these sectors, and measures undertaken to reduce the negative impacts).

3.3. Empirical strategy

This study is mainly based on household level data gathered from the quantitative survey described above. In addition, it also used qualitative data from a different component of the overall project under which this study was conducted. That component, titled ‘social vulnerability to climate change’, used focus group discussions (totalling 111 FGDs), key informant interviews (totalling 68 KIIs) and multi-stakeholder consultations for data collection purposes. The present study used select information from the qualitative data to cross-validate the findings of the household survey.

Survey data were analysed using both descriptive and analytical statistical tools. Descriptive statistical tools were used to understand migration, climate change and adaptation actions. In the case of analytical statistical tools, logistic regression models were used to investigate the determinants of the household adaptation decision. Several studies (Deressa et al., 2009; Gbetibouo, 2009; Gebrehiwot & van der Veen, 2013; Hussain et al., 2018; Kurukulasuriya & Mendelsohn, 2008; Nhemachena & Hassan, 2007; Piya et al., 2013; Seo & Mendelsohn, 2007) have used probability models, including logistic regression, to understand a household’s decision to adapt to climate change induced stresses. In this study, logistic regression is applied to investigate the adaptation decision of households in three sectors, e.g. agriculture, livestock, and water. Adaptation measures taken by households were

classified into sectors, while households taking measures in multiple sectors were included in multiple sectors for purposes of analysis. The Equation (2) of the logistic regression model is given below:

$$P_i = E(Y = 1|X_i) = \frac{1}{1 + e^{-(\alpha + B_i X_i)}} \quad (2)$$

where P_i represents the probability of 1; α is constant; X_i is the vector for independent variables; B_i is the vector for coefficients of independent variables; and e is the base of natural logarithm.

Although the main focus of this study is to examine the effect of migration on a household’s adaptation decision, it is also important to include other relevant variables (control variables) in the regression analysis to ensure the internal validity of estimates. In this regard, the most relevant variables were mainly identified based on the Sustainable Livelihood Framework (SLF) (Scoones, 1998) as well as a set of adaptation determinants identified by Yohe and Tol (2002). All independent variables were classified into five classes of household assets as defined under SLF and the eight determinants of adaptation as proposed by Yohe and Tol (2002). The identified variables together with their expected relation with the dichotomous dependent variable are presented in Table 2.

4. Results

4.1. Migration and remittance status

In the river basins, 29% of all surveyed households reported having at least one migrant member (see Table 3). A migrant, for the purposes of this study, is defined as a member of a household who spends at least 3 months of the year away from home for work purposes. A household with at least one migrant is considered a migrant household. When migration is within a country’s borders, it is called internal migration; when it is beyond the country’s borders, it is called international migration. Most of the migration in the study area is internal (>80%) comprising both seasonal and temporary migration. Gandaki is, however, an exception. It has 53% international migration with the Gulf countries and Malaysia as major destinations. Similar findings of high internal migration in environmentally vulnerable areas have been reported in other studies (Gioli et al., 2014; Rigaud et al., 2018; Warner & Afifi, 2014). Most migrants were male household members although, increasingly, women too are participating in the process. Apart from labour migration, households have also reported temporary displacement as a result of extreme weather events such as floods, extreme rainfall and cloud bursts. Temporary displacement due to extreme events was reported as higher in the Teesta (17%) and Indus (16%) basins than in the other two basins.

Remittance, which is the direct benefit of labour migration, plays an important role in supporting the livelihoods of left-behind household members. Almost 80% of migrant households reported receiving remittances but the remittance amount was low, on average less than 3 USD per day for internal migrants and less than 5 USD per day for international migrants. The annual average remittance amounts differed among the study basins (Table 3). The highest average internal remittance was reported in the Indus basin while the

Table 2. Dependent and independent variables of household adaptation.

Assets category under Sustainable Livelihood Framework	Variables	Description of variables	Yohe and Tol (2002) determinants	Expected sign
<i>Dependent variable</i>	Household adaptation	<i>Dummy variable:</i> If household has undertaken at least one adaptation measure, $D = 1$; Otherwise = 0		–
<i>Independent variables</i>				
Human	Household migration status (variable of interest)	<i>Dummy variable:</i> If household has at least one labour migrant, $D = 1$; households without migrant = 0	No. 6	+
	Age of household head	Age of household head		+/–
	Literacy status of household head	<i>Dummy variable:</i> If household head is literate, $D = 1$; Otherwise = 0	No. 7	+
	Marital status of household head	<i>Dummy variable:</i> If household head is married, $D = 1$; Otherwise = 0	No. 4	+
Financial	Household size	No. of members in a household	No. 4	+/–
	Insurance facility	<i>Dummy variable:</i> If at least one household member has life or health insurance, $D = 1$; Otherwise = 0	No. 6	+
	Livelihood diversity	Number of income sources	No. 2	+
	Outstanding debt	<i>Dummy variable:</i> If household has outstanding debt, $D = 1$; Otherwise = 0	No. 2	+
Social	Sex of household head	<i>Dummy variable:</i> If household head is male, $D = 1$; Otherwise = 0	No. 5	+
	Membership in community group	<i>Dummy variable:</i> If household is member of any community groups such as cooperative/CFUG/Mother group, $D = 1$; Otherwise = 0	No. 5	+
	Access to government services	<i>Dummy variable:</i> If household is visited by the government service providers, $D = 1$; Otherwise = 0	No. 7	+
	Access to services of NGOs	<i>Dummy variable:</i> If household is covered by the services of NGOs, $D = 1$; Otherwise = 0	No. 7	+
Natural	Landlessness	<i>Dummy variable:</i> If household does not have any agricultural land, $D = 1$; Otherwise = 0	No. 2	–
Physical	Distance to road	Distance to nearest motorable road in km	No. 3	–
	Access to climate related information	<i>Dummy variable:</i> If household has access to climate related information, $D = 1$; Otherwise = 0	No. 1	+

Note: Barring ‘household migration status’, all other independent variables are included as control variables.

corresponding international remittance was reported in the Upper Ganga basin. About 18% of surveyed households reported using remittance incomes to cope with household food and non-food needs during extreme events, with the highest such use reported in the Teesta basin (29%), a finding similar to those of Le De et al. (2015) and Suleri and Savage (2006).

4.2. Climate change and its impacts

Almost 90% of surveyed households have perceived some changes in the climate during the last decade (2007–2017) and there was no noticeable difference in perception between migrant and non-migrant households (Table 4). A large majority of households across the river basins perceived an increase in annual and summer temperatures and a decrease in precipitation and snowfall.

Table 3. Migration and remittance status among households with at least one labour migrant.

River basins	Migration destination	% migrant households	% of migrant households receiving remittances	Average annual remittance (USD per migrant)**	Average cost of migration (USD per migrant)***
Gandaki	Total	27 ^a	78 ^a		
	Internal	37 ^b	52 ^d	643	205
	International	65 ^c	87 ^e	1402	1603
Indus	Total	31 ^a	74 ^a		
	Internal	85 ^b	71 ^d	1082	255
	International	15 ^c	91 ^e	1576	2699
Teesta	Total	20 ^a	76 ^a		
	Internal	99 ^b	76 ^d	542	118
	International	1 ^c	100 ^e	–	–
Upper Ganga	Total	32 ^a	84 ^a		
	Internal	95 ^b	83 ^d	142	30
	International	9 ^c	67 ^e	1793	297
Overall	Total	28 ^a	78 ^a		
	Internal	76 ^b	73 ^d	557	319
	International	26 ^c	85 ^e	1426	1611

*Percentage of surveyed household with at least one labour migrant in particular river basin.

**Calculated only for remittance receiving households.

***Calculated for all migrant households.

^aPercentage of migrant households receiving remittance.

^bPercentage of migrant households with internal migrant.

^cPercentage of migrant households with international migrant.

^dPercentage of internal migrant households receiving remittance.

^ePercentage of international migrant households receiving remittance.

Table 4. Perceptions of households about changes in climatic variables (%).

Climatic variables	% reporting households						
	River basin				Migration status		Overall
	Gandaki	Indus	Teesta	Upper Ganga	Migrant household	Non –migrant household	
Increased annual average temperature	85	96	66	79	81	81	81
Increased summer average temperature	86	96	63	83	83	81	81
Increased winter average temperature	59	61	46	58	59	55	56
Increase in erratic rainfall	63	62	80	90	77	72	73
Decrease in average rainfall	70	46	48	60	64	55	57
Decrease in snowfall	32	30	15	44	30	31	30
Increase in hailstorms	32	27	32	58	35	38	37

However, there was a difference in response to various climatic variables across the four basins reflecting the local climatic context.

A large portion of households also perceived a change in the incidence of extreme events such as floods, droughts, extreme rainfall, landslides and heat waves. There was only a slight difference in response between migrant and non-migrant households in this regard. However, the nature of extreme events differed across the four basins. While drought was reported as a major concern in the Gandaki basin, it was heat waves in the Indus, floods in Teesta, and extreme rainfall in the Upper Ganga.

Studies based on climatic data also indicate that climatic changes are already happening in the Indus, Ganges and Brahmaputra river basins. Some of the main changes observed in the recent decades include increasing temperature trends, erratic rainfall patterns, and alterations in climatic extremes (Nepal & Shrestha, 2015; Wijngaard et al., 2017). A study by Nepal and Shrestha (2015), which took the same four river basins as their sample, reported an increase in temperature across the basins although precipitation patterns and trends varied among the basins based on seasons and locations. Karki et al. (2017) also reported erratic and extreme precipitation in one of the river basins that forms part of our study.

A large number of households reported impacts of climate change on all three sectors—agriculture, livestock and water (Table 5). Some of the impacts reported were increased water scarcity, drying up of freshwater sources, decrease in crop and livestock productivity, increase in disease/pest incidence in crops and livestock, and degradation of pasture land and forests. There was no difference in perception between migrant and non-migrant households except with regard to drying up of freshwater sources and degradation of pasture land and forest.

4.3. Adaptation situation of the households

The results of the survey show that more than 90% of households perceived some changes in climate but less than one third of the households reported undertaking adaptation measures to reduce the negative impacts of such change (Table 6). An adaptation measure is defined as a measure that the households have undertaken to reduce the negative impacts of climate change. Most adaptation measures are reported in the agriculture and water sectors.

A comparison between migrant and non-migrant households in terms of adaptation measures reveal that, overall, a

Table 5. Household perception of climate change impacts.

Perceived impacts of climate change (compared with 10 years before situation)	% of reporting households*						
	River basin				Migration status		Overall
	Gandaki	Indus	Teesta	Upper Ganga	Migrant households	Non migrant households	
Increased water scarcity for domestic use	30	21	27	33	30	27	28
Increased water scarcity for crops and animals	39	27	24	18	31	27	28
Drying up of freshwater sources	57	27	42	73	63	49	53
Decrease in crop productivity	35	30	30	53	44	41	42
Increased incidence of diseases/pests in crops	75	69	56	61	68	64	65
Decrease in livestock productivity	18	42	7	36	24	24	36
Increased incidence of livestock diseases	37	62	23	41	39	40	40
Degradation of pasture land and forests	8	43	6	31	32	16	21

*Calculated among the total surveyed households.

Table 6. Proportion of households reporting adaptation by sector and migration status.

River Basin	Adapting* households by sector			Adapting households by migration status		Overall
	Agriculture	Livestock**	Water	Migrant households	Non-migrant households	
Gandaki	47	11	21	35	27	29
Indus	32	30	43	15	15	15
Teesta	18	10	23	9	7	7
Upper Ganga	16	13	58	36	35	35
Total	29	15	35	24	21	22

*Adapting households are those that have taken at least one adaptation action to cope with climate change impacts.

**Livestock sector also includes the forest sector.

slightly higher proportion of migrant households reported undertaking adaptation measures in the agriculture sector (Table 6). However, in other sectors, there is negligible difference between migrant and non-migrant households.

The most common adaptation measures in the agriculture sector were the use of pesticides/insecticides; introduction of new crop varieties; adjustment of timing; improved irrigation; and use of organic fertilizer. The top five adaptation measures in the livestock sector were improvements in animal sheds and ponds; investments in disease control through medicines and vaccines; switching to native breeds; switching to new breeds; and support from external stakeholders. The top five adaptation measures in the water sector were switching to an alternative water supply, mostly a piped water supply; maintenance of water sources; construction of water storage units; improved recharge systems; and construction of a resilient water supply. Some differences between the migrant and non-migrant households were noted with regard to the preferred adaptation measures.

4.4. Factors influencing household adaptation decision

The descriptive analysis indicates that, in general, a higher proportion of migrant households reported undertaking adaptive measures to reduce the negative effects of climate change, particularly in the agriculture sector. In order to identify the key factors that influence household adaptation decisions, the logistic regression models are used. Table 7 presents the descriptive statistics of the explanatory variables used in the regression analysis.

The Table shows that differences between migrant and non-migrant households with regard to the selected variables is generally low barring a few variables such as education of household head, average age of household head, and households with insurance and group membership. The regression analysis results, according to sectors, are given in Table 8 below.

Table 7. Descriptive statistics of variables by migration status.

Variables	Non-migrant household	Migrant household
Sex of household head (% female)	16.3	16.4
Education of household head (% literate)	66.8	62.0
Average age of household head (in yrs.)	47.1	51.1
Marital status of household head (% married)	89.3	85.9
Average household size	4.2	4.6
Households with insurance (% of households)	15.4	29.3
Livelihood diversity (average number of income sources)	1.2	1.1
Access to climate information (% of households)	51.5	52.6
Outstanding debt (% of households with loans)	33.1	34.2
Group membership (% of households)	39.5	44.5
Access to government services (% of households)	17.9	15.2
Access to NGO services (% of households)	11.7	12.3
Average distance to motorable road (in km)	1.9	2.3
Landlessness (% of landless households)	45.9	45.4

4.4.1. Any adaptation measure

Before analysing the relationship between migration and adaptation measures in the three key sectors, a regression model was run to examine the relationship of migration and other variables to overall adaptation measures in any one of the sectors. It revealed that migration did not have a statistically significant relationship with aggregated adaptation measures. It also revealed that households headed by males had a 30% less chance of taking adaptation measures compared to female headed households (Table 8). However, the addition of one income sources was likely to increase the chances of adaptation by 72%. Likewise, access to climate information, group membership and access to NGO services were likely to increase the likelihood of adaptation by 88%, 71% and 39%, respectively. But an increase in distance to a motorable road by one kilometre was likely to result in a decline in adaptation chances by 3%. Similarly, landlessness was likely to result in a decline in the chances of taking adaptation measure by 38% (Table 8). Moreover, the likelihood of taking adaptation measures was less in the Indus and Teesta than in the Upper Ganga. The likelihood of adaptation was lower in the upstream and midstream areas than in the downstream areas.

4.4.2. Agriculture sector

The regression results showed that migration status had a highly significant positive influence on household adaptation decisions. Households with at least one labour migrant were 1.5 times more likely to undertake at least one adaptation measure as compared to non-migrant households. Among the household human and natural capital variables, education and age of household head showed a highly significant positive influence on the adaptation decision. Having a literate household head increased household adaptation by 1.5 times. However, having a woman as household head was likely to decrease adaptation by 72%. Similarly, landless households were 32% less likely to undertake adaptive measures than households with land ownership. Households with diverse sources of income were much more likely to adapt than those depending on fewer sources of income. The addition of one more local income source was likely to double household adaptation.

Household adaptation decisions were also highly influenced by access to external stakeholders and information. Households with access to climate related information were twice as likely to adapt than households without access to such information. Similarly, being part of community groups and having access to non-governmental services increased household adaptation by almost 1.5 times. Locational variability was also observed among the river basins as well as the up, mid and down streams within a basin. As compared to the Upper Ganga basin, households in the other three basins were much more likely to adapt and the difference was statistically significant for the Gandaki and Indus basins. Households in the Gandaki basin were 6 times and those in the Indus basin were almost 3 times more likely to adapt than households in the Upper Ganga basin. As compared to the down-stream flood plains, households in both the upstream and mid-streams were less likely to adapt.

Table 8. Results of logistic regression analysis.

Variables	Adaptation measure in any sector	Odds ratios		
		Agriculture	Livestock ^a	Water
Household migration status	1.1754 (0.1334)	1.4638*** (0.1836)	1.0864 (0.1683)	0.9146 (0.1084)
Household size	1.0186 (0.0246)	0.9706 (0.0259)	1.0984*** (0.0314)	1.0279 (0.0252)
Sex of HH	0.6986** (0.1086)	0.7242* (0.1267)	0.4205*** (0.1069)	0.6021*** (0.0989)
Education of HH	0.8816 (0.1057)	1.5131*** (0.2067)	0.6595*** (0.1042)	0.6742*** (0.0837)
Age of HH	1.0016 (0.0039)	1.0120*** (0.0044)	1.0051 (0.0055)	0.9991 (0.0040)
Marital status of HH	0.9498 (0.1571)	0.7553 (0.1404)	0.8939 (0.2164)	0.8507 (0.1480)
Household member has insurance	0.976 (0.1307)	0.8905 (0.1344)	0.7278* (0.1331)	0.9071 (0.1209)
Livelihood diversity	1.7176*** (0.1586)	1.9794*** (0.1961)	1.2517* (0.1463)	1.5841*** (0.1436)
Access to climate information	1.8752*** (0.2201)	2.1924*** (0.3466)	2.7318*** (0.4554)	1.6642*** (0.2623)
Outstanding debt	1.0219 (0.1217)	1.1682 (0.1513)	1.1958 (0.1922)	1.2687* (0.1584)
Group membership	1.7124*** (0.1970)	1.7979*** (0.2321)	2.1563*** (0.3683)	1.6195*** (0.2027)
Access to government services	1.1000 (0.1642)	0.9729 (0.1525)	1.1891 (0.2284)	1.6105*** (0.2312)
Access to NGO services	1.3927** (0.2265)	1.5868*** (0.2741)	1.7288*** (0.3445)	1.3917** (0.2284)
Distance to motorable road	0.9732* (0.0138)	1.0011 (0.0153)	1.0029 (0.0179)	0.9271*** (0.0159)
Landlessness	0.6243*** (0.0735)	0.3209*** (0.0450)	0.6186*** (0.1013)	1.0430 (0.1244)
Gandaki basin	0.7507 (0.1424)	5.8107*** (1.2696)	0.6805 (0.1897)	0.1602*** (0.0315)
Indus basin	0.6186** (0.1229)	2.8830*** (0.6516)	1.847** (0.4519)	0.5263*** (0.1024)
Teesta basin	0.1831*** (0.0315)	1.2877 (0.2642)	0.5443** (0.1316)	0.1339*** (0.0235)
Up-stream dummy	0.2919*** (0.0391)	0.3196*** (0.0497)	0.3748*** (0.0694)	0.5935*** (0.0810)
Mid-stream dummy	0.4930*** (0.0640)	0.7450** (0.1036)	0.3378*** (0.0602)	0.8496 (0.1142)
Constant	1.5165 (0.5402)	0.0737*** (0.0159)	0.842*** (0.0403)	0.9117 (0.3481)
Pseudo R ²	0.14	0.19	0.16	0.14
LR Chi ²	371.95***	460.81***	281.3***	360.98***

Note: Figures in parentheses are respective standard errors.

^aThe livestock sector also includes 'forest' based on the strong linkage between the two due to the use of fodder plants from and grazing in forests.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.4.3. Livestock sector

The household migration status had a positive influence on the household adaptation decision in the livestock sector but it was

not statistically significant. The gender and age of the household head showed a significant influence on household adaptation. Women-headed households were 42% less likely to adapt than households headed by men. Households with literate household heads were 66% less likely to adapt than households with illiterate heads. Large households were more likely to adapt than small households. Households with diverse livelihood income sources were 1.2 times more likely to adapt than those without them. Similarly, households with insurance were 72% less likely to adapt than those without insurance. Landless households were 60% less likely to adapt than households with land ownership.

Among the external factors, group membership, access to non-government services, and access to climate information were likely to increase household adaptation by 2.1, 1.7 and 2.7 times, respectively. There were statistically significant variations observed in adaptation decisions among the river basins and streams of the study. Compared to the Upper Ganga basin, households in the Gandaki and Teesta basins were more than 50% less likely to adapt whereas households in the Indus basin were 1.8 times more likely to adapt. As was the case with the agriculture sector, compared to households in the down-stream, households in both the up-stream and mid-stream were more than 30% less likely to adapt.

4.4.4. Water sector

Unlike in the case of the agriculture and livestock sectors, the household migration status seemed to exert a negative influence on adaptation decisions in the water sector but it was not statistically significant. The age and sex of household head, household livelihood diversification and debt showed a statistically significant relation with the household adaptation decision. Women-headed households were 60% less likely to adapt than male-headed households while a literate household head was 67% less likely to adapt than a literate household head. An addition of one more household income source was likely to increase adaptation by 1.5 times. Households with outstanding debt, a proxy variable for households' access to finance, were 1.2 times more likely to adapt.

Once again, the influence of external stakeholders was found to be highly significant on the household adaptation decision. Variables such as access to climate information, group membership and access to government services increased household adaptation by 1.6 times. Access to non-government services was likely to increase adaptation by 1.3 times. An increase in distance by one kilometre to a motorable road was likely to decrease household adaptation by 92%.

Compared to households in the Upper Ganga basin, households in the other three basins were less likely to adapt and it was statistically highly significant. Again, compared to the down-stream, households in the up and mid-streams were less likely to adapt though it was statistically significant only in the case of the up-stream.

5. Discussion

In the study sites, migration was an important livelihood strategy undertaken by nearly one third of the surveyed households although most migration was internal. The study showed how

migration affects household adaptation in both direct and indirect ways. By simultaneously analysing the results overall and, separately, in the three sectors, the study was able to show the differential effect of migration on the different sectors.

However, while the regression analysis showed that migration had a positive influence on the household adaptation decision, both overall and in relation to the agriculture and livestock sectors, it was statistically significant only in the case of the agriculture sector. In the agriculture sector, having a family member as migrant was likely to increase the households' adaptation by 1.4 times. The results show that households were more likely to invest the limited remittances on agriculture and livestock, both of which are private enterprises. The literature on migration and development scholarship support our finding that remittances are often invested in small enterprises (Black et al.,). In rural areas where farming is the only economic sector or where farming is still competitive, it thus leads to investment in farming (Gartaula et al., 2014; Milan et al., 2015; Sunam & McCarthy, 2016; Yang & Choi, 2007). In contrast, migration had a negative effect on adaptation in the water sector. A likely explanation is that access to drinking or irrigation water is either provided by the government through a piped water supply or through collective action such as maintenance of water sources or construction of a resilient water supply rather than through individual effort. Although the roles of the government and the private sector are diverse when it comes to provisioning water for drinking and irrigation purposes, water is still mostly considered a collective good or common property resource by people in the study sites (Ahmed & Araral, 2019).

Conceptually, the indirect influence of migration on household adaptation can be assessed via the following household characteristics: livelihood diversification, female headship of households, translocal/transnational ties, . In the present study, the empirical results showed diversified livelihoods to have a positive influence on household adaptation. The livelihood diversification effect is statistically significant both overall and separately in all the three sectors. According to studies, migration is often leveraged by households in areas facing severe climate change impacts as a critical livelihood diversifying strategy (Adger et al., 2015; Singh & Basu, 2019). In our sample, a majority of households reported a single source of local income irrespective of migration status (Table 7). Thus, the addition of remittances increases the diversity of income sources for migrant households. Hence, in addition to the direct effect of migration on household adaptation, it could affect household adaptation through spatial livelihood diversification as postulated by the New Economics of Labour Migration theory. Livelihood diversification due to migration has been reported in several other studies as well (Afifi et al., 2016; Mortreux & Barnett, 2009; Oudry et al., 2016).

The results also show the importance of external stakeholders in influencing household adaptation decisions. A growing body of empirical studies have shown how migration expands the local social network to incorporate transnational (Glick Schiller et al., 1992; Levitt et al., 2006) and translocal networks (Sakdapolrak et al., 2016) to establish links between the migrant and the left-behind family and between the host

and the home community of migrants. This spatially extended social network is made possible by expansion in information technology, such as mobile phones, internet and cable networks (Horst, 2006; Hunter, 2015; Madianou, 2012). In the study sites, mobile phones and internet access have become indispensable for migrant households to maintain communications between the migrant and the left-behind family. At first glance, there was no obvious relationship between the household access to external services and their migration status (see Table 7). But the field observations suggested a nuanced linkage between migration and household access to weather related information (see Box 1). A higher proportion of migrant households than non-migrant households, moreover, reported having insurance (health, life and livestock insurance), which indicates their connection with external stakeholders facilitated by translocal/transnational ties.

Box 1: Access to climate app in Huddu village, Uttarakhand.

In this study site, it was observed that the locals were using a certain mobile-based app that updated them about the weather conditions. Though traditional ways of understanding changes in wind patterns and likelihood of rains were still being maintained, the use of the app gave them further information that would strengthen decision making related to protection of their backyard crops, fodder and harvested crops. On further inquiry, it was revealed that local youth working in the cities came to know about this app and disseminated this information to their families in the village.

Migration can also indirectly influence household adaptation outcomes through the emergence of female-headed households due to migration. However, there was not much difference between migrant and non-migrant households with regard to the percentage of female-headed households, which was roughly 16% for both.

Household adaptation was also influenced by household human and natural capacities such as gender and education of the household head and land ownership. The study findings highlight the importance of gender equality and education for improving household adaptation. A female household head was likely to decrease household adaptation both overall and separately in all the three sectors. The findings reveal that, as regards marital status, 65% of female heads of households were married while 30% were either widowed or divorced. The impact of gender on household adaptation is supported by other empirical studies by Below et al. (2012), Deressa et al. (2009), Goulden et al. (2009), Iglesias et al. (2011) and Jost et al. (2016). Studies have established that the gender differentiated impacts of climate change is due to constraints on women's access to land, credit and other resources (Rao et al., 2019a) although climate adaptation and mitigation policies still remain gender blind (Goodrich et al., 2019). Thus the study adds to the existing empirical work on the importance of gender integration in adaptation policies and actions.

The education of the household head showed mixed results as regards household adaptation. Having a literate household head was likely to increase household adaptation by 1.5 times in the case of the agriculture sector but it was likely to reduce adaptation by about 66% in the case of the livestock and water sectors. A similar positive relation in the agriculture sector was reported by Shah et al. (2019) and Gebrehiwot and

van der Veen (2013) although Below et al. (2012) reported a negative relation. The negative effect of education on the livestock sector is understandable as subsistence livestock predominates in this region, which requires high family labour (particularly child labour) that is difficult to be substituted by hired labour. With aspirations of better education for their children, households are, therefore, increasingly opting to reduce or give up livestock keeping. However, the negative effect of education of household head, in the case of the water sector, is counter-intuitive. Logically, an educated household head would be expected to prioritize adapting to water stress. One reason could be that educated households are better equipped to choose more cost-effective response measures and the water-related response measures might be costlier than other measures. However, this finding needs further investigation.

The regression analysis showed that access to services provided by external stakeholders showed a much stronger influence on household adaptation than household characteristics. Hence, having access to climate information was likely to double household adaptation in all three sectors as well as overall adaptation. Exposure to climate information could generate awareness regarding climate change impacts and thus facilitate adaptation (Deressa et al., 2009; Keil et al., 2008; Kibue et al., 2016; Lutz et al., 2014). When a household is a member of a local community group (such as a savings and credit group or forest group) and has access to NGO services, it increases the likelihood of household adaptation in all three sectors. Having access to government services were particularly important for adaptation in the water sector. Thus, the study findings add to the large body of empirical evidence on the importance of access to information and service provision from external stakeholders for adaptation to climate change impacts (e.g. Abdullah Al-Amin et al., 2019; Bailey et al., 2019; Cooper et al., 2008; Defesta & Rapera, 2014; Khanal et al., 2019; Mutabazi et al., 2015; Nhemachena & Hassan, 2007).

A recent assessment report in the HKH region has shown that although identification and verification of autonomous local adaptation practices is important, they alone might not be sufficient to manage the new risks and extreme changes arising from climate change effects, both now and in the future (Mishra et al., 2019). Our results highlight the important role that external stakeholders play, particularly the state and collective actions, as compared to individual efforts in adapting to climate change effects.

The study also showed significant variability in household adaptation across the four river basins under study and between the mountains (up- and mid-streams) and the plains (down-stream) within a river basin. Households in the mountainous areas were significantly less likely to adapt in all sectors. This finding shows that household adaptation is equally influenced by external critical infrastructure such as motorized roads and the topography of the location. The absence of critical infrastructure such as a road is a major factor behind lower adaptation in mountainous areas as compared to the plains. The need for investment in critical infrastructure (such as good roads) for better adaptation to climate change has also been reported by Halsnaes and Traerup (2009) and Nelson et al. (2010).

In comparison with the Upper Ganga basin, the other three basins were likely to have lower household adaptation in the water sector. Similarly, in the livestock sector, household adaptation was likely to be lower in the Gandaki and Teesta basins but higher in the Indus basin. But, in the agriculture sector, household adaptation is likely to be higher by as much as 5.8 times in the Gandaki and 2.8 times in the Indus basin than in the Upper Ganga basin. This finding confirms the general understanding that adaptation is a complex and nuanced process that is highly location-specific and necessitates focusing on a local level analysis to gain a better understanding of the adaptation processes, capacities and planning (IPCC, 2007; Mano & Nhemachena, 2007; Smit & Wandel, 2006).

6. Conclusions

The analysis of household survey data from four river basins in the HKH region has generated some interesting insights on the role of labour migration in household adaptation to climate change impacts in key livelihood-related sectors such as agriculture, livestock and water. Among the limited number (less than a third) of surveyed households who were undertaking adaptation measures, labour migration showed a direct and positive influence on household adaptation decisions, especially in the agriculture sector, with migrant households prioritizing the investment of their remittances on private enterprise such as agriculture and livestock. Overall, the study shows that although both household assets (as posited by SLF) and external factors (as proposed by Yohe & Tol, 2002) contribute to better adaptation, the influence of external factors is comparatively stronger. Thus, emphasizing the role of household characteristics alone will only serve to undermine the role of external stakeholders, including government and critical infrastructure, in enabling rural households to adapt to the negative impacts of climate change.

The study adds to the existing evidence which highlights the responsibility of governments and other stakeholders to address the adaptation needs of vulnerable population groups situated in hazard prone and economically deprived circumstances. It is they who often face the compulsion to migrate for livelihood purposes. In addition to providing critical infrastructure, government policy measures could ensure household access to a range of knowledges and technological means – including the option of safe migration – for better preparedness and adaptation to climate change impacts. Moreover, national policy-making on climate change needs to take into account the potential of labour migration to augment the household economy. This would enable migrant households to utilize remittances for better adaptation. A shift in the discourse is needed from migration-as-adaptation to migration-for-adaptation. It would help mobilize private investment for skill-building, entrepreneurship and livelihood diversification in rural areas. Further research and evidence generation on household choices with regard to migration and adaptation, locational differences in such choices, and associated gender and equity issues will serve to strengthen the new direction that the discourse should take.

Note

1. In the context of climate change, adaptation is defined as the process of adjustment to actual or expected climate and its effects, which seeks to minimize harm or exploit beneficial opportunities (IPCC, 2014b) while adaptive capacity refers to the ability of people, system, or society to transform structure, function or organization to manage better their response to weather hazards and other negative changes (IPCC, 2012, p. 72).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was carried out by the Himalayan Adaptation, Water and Resilience (HIAWARE) consortium under the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAS) with financial support from the UK Government's Department for International Development and the International Development Research Centre, Ottawa, Canada.

Disclaimer

The views expressed in this work are those of the authors and do not necessarily represent those of the UK Government's Department for International Development, the International Development Research Centre, Canada or its Board of Governors.

Notes on contributors

Dr. Amina Maharjan works as senior livelihood and migration specialist at ICIMOD. She leads the group working on resources, capabilities and institutions within ICIMOD's Livelihood theme. She works in broad area of human mobility and migration, including migration and agrarian change, migration and climate change adaptation; gendered impacts of migration.

Sabarnee Tuladhar is currently working as Statistical Research Associate under Livelihoods Theme at ICIMOD. Her works focuses on data collection and analysis on mountain livelihood, food and nutrition security, migration, gender, climate change, and resilience. She has around 7 years of experience in this field.

Dr. Abid Hussain is currently working as Food Security Economist at ICIMOD. He supervises a group on socioeconomics and research methods within ICIMOD's Livelihoods Theme. His research and policy work focuses on mountain agriculture, food and nutrition security, agrobiodiversity, rural credit, and climate change adaptation. He has around 16 years of experience in research, development, and policy processes.

Dr. Arabinda Mishra is a trained economist presently leading Livelihoods Theme at ICIMOD with 30 years of experience in teaching, research and academic leadership. His core competencies include community resilience building, engaging with stakeholders for knowledge co-creation, and building capacity on climate change adaptation. He has steered experts' groups engaged in preparation of India's climate change action plans, led the team that developed a roadmap for regional cooperation among South Asian countries, and managed an international collaboration of scientists that investigated the links between ecosystems and poverty in South Asia.

Suruchi Bhadwal is a senior fellow with The Energy and Resources Institute (TERI) with a background on environmental sciences working on research projects and consultancies on climate change impacts, vulnerability, and adaptation for the last two decades.

Sultan Ishaq worked as climate change adaptation specialist at National Agricultural Research Centre (NARC), Pakistan Agricultural Research Council.

Basharat Ahmed Saeed, presently a water resources specialist at the World Bank, focuses on political economy and policy issues related to irrigation, water supply and sanitation, and climate change adaptation. Most recently, he co-authored a water security diagnostic report titled, *Pakistan: Getting More from Water* (World Bank 2019).

Ishani Sachdeva works as network coordinator - clean air collective at Asar Social Impact Advisors Pvt. Ltd. India. Earlier she worked as research associate at Centre for Ecology, Development and Research (CEDAR) and was involved in various social-ecological research.

Dr. Bashir Ahmad is the director of Climate, Energy and Water Research Institute (CEWRI), Pakistan Agricultural Research Council (PARC). He specializes in climate change and hydrology and has published numerous article in this topic.

Jannatul Ferdous is currently engaged with International Federation of Red Cross and Red Crescent (IFRC), Bangladesh Delegation as Protection, Gender and Inclusion Officer. Before that, she had been working with Bangladesh Centre for Advanced studies (BCAS) since 2016 to 2018 as senior research officer. She was responsible for supervising the social research particularly focus on gender and diversity, social inequality, marginality, migration, climate change adaptation issues. She has around 10 years of experience in social research, development, and policy processes.

S. M. Tanvir Hassan presently works as Programme Coordinator - IWRM at Swiss Red Cross delegation in Bangladesh, is a practitioner and researcher in water and climate. He has contributed to more than 20 peer reviewed publications, many policy briefs and project reports.

ORCID

Abid Hussain  <http://orcid.org/0000-0001-8703-4681>

References

- Abbasi, S. S., Ahmad, B., Ali, M., Anwar, M. Z., Dahri, Z. H., Habib, N., Hussain, A., Iqbal, B., Ishaq, S., Mustafa, N., Naz, R., Virk, Z. T., & Wester, P. (2017). *The Indus basin: A glacier-fed lifeline for Pakistan*. HI-AWARE Working Paper 11. HI-AWARE. <https://lib.icimod.org/record/32783>
- Abdullah Al-Amin, A. K. M., Akhter, T., Islam, A. H. M. S., Jahan, H., Hossain, M. J., Prodhan, M. M. H., Mainuddin, M., & Kirby, M. (2019). An intra-household analysis of farmers' perceptions of and adaptation to climate change impacts: Empirical evidence from drought prone zones of Bangladesh. *Climate Change*, <https://doi.org/10.1007/s10584-019-02511-9>
- Adger, W. N., Arnell, N., Black, R., Dercon, S., Geddes, A., & Thomas, D. (2015). Focus on environmental risks and migration: Causes and consequences. *Environmental Research Letter*, 10(6), 60201. <https://doi.org/10.1088/1748-9326/10/6/060201>
- Adger, W. N., Pulhin, J. M., Barnett, J., Dabelko, G. D., Hovelsrud, G. K., Levy, M., Oswald Spring, U., & Vogel, C. H. (2014). Human security. In *Climate change 2014: Impacts, adaptation, and vulnerability* (pp. 755–791). Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.
- Adger, W. N., & Vincent, K. (2005). Uncertainty in adaptive capacity. *Comptes Rendus Geoscience*, 337(4), 399–410. <https://doi.org/10.1016/j.crte.2004.11.004>
- Affi, T., Milan, A., Etzold, B., Schraven, B., Rademacher-Schulz, C., Sakdapolrak, P., Reiff, A., van der Geest, K., Warner, K. (2016). Human mobility in response to rainfall variability: Opportunities for migration as a successful adaptation strategy in eight case studies. *Migration and Development*, 5(2), 254–274. <https://doi.org/10.1080/21632324.2015.1022974>

- Ahmed, M., & Araral, E. (2019). Water governance in India: Evidence on water law, policy, and administration from eight Indian states. *Water*, 11(10), 2071. <https://doi.org/10.3390/w11102071>
- Arora, D., Arongo, J., Burkart, S., Chirinda, N., & Twyman, J. (2017). *Gender (im)balance in productive and reproductive labor among livestock producers in Colombia: Implications for climate change responses*. CCAFS Info Note.
- Bailey, K. M., McCleery, R. A., & Barnes, G. (2019). The role of capital in drought adaptation among rural communities in Eswatini. *Ecology and Society*, 24(3), 8. <https://doi.org/10.5751/ES-10981-240308>
- Balasubramanian, T. N., Nambi, A. A., & Paul, D. (2007). A suggested index for assessment of vulnerability of a location to climate change. *Journal of Agrometeorology*, 9(2), 129–137.
- Bardsley, D. K., & Hugo, G. J. (2010). Migration and climate change: Examining thresholds of change to guide effective adaptation decision-making. *Population and Environment*, 32(2), 238–262. <https://doi.org/10.1007/s11111-010-0126-9>
- BBS-GOB. (2015). *Population & housing census 2011: Socio-economic and demographic national report, volume 4*. Bangladesh Bureau of Statistics, Ministry of Planning, Government of Bangladesh. Retrieved July 23, 2017, from https://203.112.218.66/WebTestApplication/userfiles/Image/BBS/Socio_Economic.pdf
- Below, T. B., Mutabazi, K. D., Kirschke, D., Franke, C., Sieber, S., Siebert, R., & Tscherning, K. (2012). Can farmers' adaptation to climate change be explained by socio-economic household-level variables? *Global Environmental Change*, 22(1), 223–235. <https://doi.org/10.1016/j.gloenvcha.2011.11.012>
- Bhadwal, S., Ghosh, S., Gorti, G., Govindan, M., Mohan, D., Singh, P., Singh, S., & Yogya, Y. (2017). *The upper Ganga Basin – will drying springs and rising floods affect agriculture?* HI-AWARE Working Paper 8, HI-AWARE.
- Bhagat, R. (2017). Migration, gender and right to the city. *Economic and Political Weekly*, LII, 35–40.
- Bhatta, G. D., Aggarwal, P. K., Poudel, S., & Belgrave, D. A. (2015). Climate-induced migration in South Asia: Migration decisions and the gender dimensions of adverse climatic events. *Journal of Rural and Community Development*, 10, 1–23.
- Bhattarai, B., Beilin, R., & Ford, R. (2015). Gender, agrobiodiversity, and climate change: A study of adaptation practices in the Nepal Himalayas. *World Development*, 70, 122–132. <https://doi.org/10.1016/j.worlddev.2015.01.003>
- Black, R., Bennett, S. R. G., Thomas, S. M., & Beddington, J. R. (2011). Climate change: Migration as adaptation. *Nature*, 478(7370), 447–449. <https://doi.org/10.1038/478477a>
- Bohra-Mishra, P., Oppenheimer, M., & Hsiang, S. M. (2014). Nonlinear permanent migration response to climatic variations but minimal response to disasters. *Proceedings of the National Academy of Sciences*, 111(27), 9780–9785. <https://doi.org/10.1073/pnas.1317166111>
- CBS. (2012). *National population and housing census 2011: National report*. Central Bureau of Statistics, Government of Nepal. Retrieved January 22, 2018, from <https://unstats.un.org/unsd/demographic-social/census/documents/Nepal/Nepal-Census-2011-Vol1.pdf>
- Census of India. (2001). *Migration*. Office of the Registrar General & Census Commissioner, Ministry of Home Affairs, Government of India. Retrieved January 30, 2018, from https://censusindia.gov.in/Census_And_You/migrations.aspx
- Chambers, R. (1989). Editorial introduction: Vulnerability, coping and policy. *IDS Bulletin*, 20(2), 1–7. <https://doi.org/10.1111/j.1759-5436.1989.mp20002001.x>
- Cochran, W. G. (1977). *Sampling Techniques* (3rd ed.). John Wiley & Sons.
- Conway, D., Nicholls, R. J., Brown, S., Tebboth, M. G. L., Adger, N. W., Ahmad, B., Biemans, H., Crick, F., Lutz, A. F., Safrá De Campos, R., Said, M., Singh, C., Zaroug, M. A. H., Ludi, E., New, M., & Wester, P. (2019). The need for bottom-up assessments of climate risks and adaptation in climate-sensitive regions. *Nature Climate Change*, 9(7), 503–511. <https://doi.org/10.1038/s41558-019-0502-0>
- Cooper, P. J. M., Dimes, J., Rao, K. P. C., Shapiro, B., Shiferaw, B., & Twomlow, S. (2008). Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change. *Agriculture, Ecosystems and Environment*, 126(1–2), 24–35. <https://doi.org/10.1016/j.agee.2008.01.007>
- Defesta, G., & Rapera, C. L. (2014). Measuring adaptive capacity of farmers to climate change and variability: Application of a composite index to an agricultural community in the Philippines. *Journal of Environmental Science and Management*, 17(2), 48–62.
- Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile basin of Ethiopia. *Global Environmental Change*, 19(2), 248–255. <https://doi.org/10.1016/j.gloenvcha.2009.01.002>
- Djoudi, H., Locatelli, B., Vaast, C., Asher, K., Brockhaus, M., & Sijapati, B. (2016). Beyond dichotomies: Gender and intersecting inequalities in climate change studies. *Ambio*, 45(3), S248–S262. <https://doi.org/10.1007/s13280-016-0825-2>
- Foresight. (2011). *Migration and global environmental change: Final project report*. The Government Office for Science.
- Gartaula, H. N., Chaudhary, P., & Khadka, K. (2014). Land redistribution and reutilization in the context of migration in rural Nepal. *Land*, 3(3), 541–556. <https://doi.org/10.3390/land3030541>
- Gbetibouo, G. A. (2009). *Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa*. Environment and Production Technology Division, International Food Policy Research Institute. Retrieved July 8, 2018, from <https://www.ifpri.org/publication/understanding-farmers-perceptions-and-adaptations-climate-change-and-variability>
- Gbetibouo, G. A., Ringler, C., & Hassan, R. (2010). Vulnerability of the South African farming sector to climate change and variability: An indicator approach. *Natural Resources Forum*, 34(3), 175–187. <https://doi.org/10.1111/j.1477-8947.2010.01302.x>
- Gebrehiwot, T., & van der Veen, A. (2013). Farm level adaptation to climate change: The case of farmer's in the Ethiopian Highlands. *Environmental Management*, 52(1), 29–44. <https://doi.org/10.1007/s00267-013-0039-3>
- Gemenne, F., & Blocher, J. (2017). How can migration serve adaptation to climate change? Challenges to fleshing out a policy ideal. *The Geographical Journal*, 183(4), 336–347. <https://doi.org/10.1111/geoj.12205>
- Gioli, G., Khan, T., Bisht, S., & Scheffran, J. (2014). Migration as an adaptation strategy and its gendered implications: A case study from the Upper Indus basin. *Mountain Research and Development*, 34(3), 255–265. <https://doi.org/10.1659/MRD-JOURNAL-D-13-00089.1>
- Glick Schiller, N. G., Basch, L., & Blanc-szanton, C. (1992). Transnationalism: A new analytic framework for understanding migration. In N. Glick Schiller, L. Basch, & C. Blanc-szanton (Eds.), *Towards a transnational perspective on migration: Race, class, ethnicity, and nationalism reconsidered* (pp. 1–24). New York Academy of Sciences.
- Goodrich, C. G., Prakash, A., & Udas, P. B. (2019). Gendered vulnerability and adaptation in Hindu-Kush Himalayas: Research insights. *Environmental Development*, 31, 1–8. <https://doi.org/10.1016/j.envdev.2019.01.001>
- Goulden, M., Naess, L. O., Vincent, K., & Adger, W. N. (2009). Accessing diversification, networks and traditional resource management as adaptations to climate extremes. In W. N. Adger, I. Lorenzoni, & K. O'Brien (Eds.), *Adapting to climate change: Thresholds, values, governance* (pp. 448–464). University of Cambridge.
- Greiner, C., & Sakdapolrak, P. (2013). Rural-urban migration, agrarian change, and the environment in Kenya: A critical review of the literature. *Population and Environment*, 34(4), 524–553. <https://doi.org/10.1007/s11111-012-0178-0>
- Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The livelihood vulnerability Index: A pragmatic approach to assessing risks from climate variability and change – a case study in Mozambique. *Global Environmental Change*, 19(1), 74–88. <https://doi.org/10.1016/j.gloenvcha.2008.11.002>
- Halsnaes, K., & Traerup, S. (2009). Development and climate change: A mainstreaming approach for assessing economic, social, and environmental impacts of adaptation measures. *Environmental Management*, 43(5), 765–778. <https://doi.org/10.1007/s00267-009-9273-0>
- Hampshire, K. (2002). Fulani on the move: Seasonal economic migration in the Sahel as a social process. *The Journal of Development Studies*, 38(5), 15–36. <https://doi.org/10.1080/00220380412331322491>

- Horst, H. A. (2006). The blessings and burdens of communication: Cell phones in Jamaican transnational social fields. *Global Networks*, 6(2), 143–159. <https://doi.org/10.1111/j.1471-0374.2006.00138.x>
- Hunter, A. (2015). Empowering or impeding return migration? ICT, mobile phones, and older migrants'. *communications with Home. Global Network*, 15(4), 485–502. <https://doi.org/10.1111/glob.12091>
- Hussain, A., Rasul, G., Mahapatra, B., Wahid, S., & Tuladhar, S. (2018). Climate change-induced hazards and local adaptations in agriculture: A study from Koshi river basin, Nepal. *Natural Hazards*, 91(3), 1365–1383. <https://doi.org/10.1007/s11069-018-3187-1>
- Iglesias, A., Quiroga, S., & Diz, A. (2011). Looking into the future of agriculture in a changing climate. *European Review of Agricultural Economics*, 38(3), 427–447. <https://doi.org/10.1093/erae/jbr037>
- IOM. (2016). *Assessing the climate change environmental degradation and migration nexus in South Asia*. International Organization for Migration. Retrieved February 19, 2018, from <https://publications.iom.int/books/assessing-climate-change-environmental-degradation-and-migration-nexus-south-asia>
- IPCC. (2007). *Climate change 2007: Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on climate change*. Cambridge University Press.
- IPCC. (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation: A special report of working groups I and II of the Intergovernmental Panel on climate change*. Cambridge University Press.
- IPCC. (2014a). *Climate change 2014: Impacts, adaptation and vulnerability. Part A: Global and sectoral aspects. Contribution of working group II to the Fifth assessment report of the Intergovernmental Panel on climate change*. Cambridge University Press.
- IPCC. (2014b). *Climate change 2014. Synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the Intergovernmental Panel on climate change*.
- Jha, C. K., Gupta, V., Chattopadhyay, U., & Sreeraman, B. A. (2018). Migration as adaptation strategy to cope with climate change: A study of farmers' migration in rural India. *International Journal of Climate Change Strategies and Management*, 10(1), 121–141. <https://doi.org/10.1108/IJCCSM-03-2017-0059>
- Jost, C., Kyazze, F., Naab, J., Neelormi, S., Kinyangi, J., Zougmore, R., Aggarwal, P., Bhatta, G., Chaudhury, M., Tapio-Bistrom, M. L., Nelson, S., & Kristjanson, P. (2016). Understanding gender dimensions of agriculture and climate change in smallholder farming communities. *Climate and Development*, 8(2), 133–144. <https://doi.org/10.1080/17565529.2015.1050978>
- Karki, R., Schickhoff, U., Scholten, T., & Böhner, J. (2017). Rising precipitation extremes across Nepal. *Climate*, 5(1), 4. <https://doi.org/10.3390/cli5010004>
- Katz, E., & Stark, O. (1986). Labour migration and risk aversion in less developed countries. *Journal of Labour Economics*, 4(1), 134–149. <https://doi.org/10.1086/298097>
- Keil, A., Zeller, M., Wida, A., Sanim, B., & Birner, R. (2008). What determines farmers' resilience towards ENSO-related drought? An empirical assessment in central Sulawesi, Indonesia. *Climatic Change*, 86(3–4), 291–307. <https://doi.org/10.1007/s10584-007-9326-4>
- Khanal, U., Wilson, C., Hoang, V.N., & Lee, B. (2019). The impact of community-based organizations on climate change adaptation in agriculture: Empirical evidence from Nepal. *Environment, Development and Sustainability*, 21 (2), 621–653. <https://doi.org/10.1007/s10668-017-0050-6>
- Kibue, G. W., Liu, X., Zheng, J., Zhang, X., Pan, G., Li, L., & Han, X. (2016). Farmers' perceptions of climate variability and factors influencing adaptation: Evidence from Anhui and Jiangsu, China. *Environmental Management*, 57(5), 976–986. <https://doi.org/10.1007/s00267-016-0661-y>
- Kraaijenbrink, P. D. A., Bierkens, M. F. P., Lutz, A. F., & Immerzeel, W. W. (2017). Impact of a global temperature rise of 1.5 degrees Celsius on Asia's glaciers. *Nature*, 549(7671), 257–260. <https://doi.org/10.1038/nature23878>
- Krishnan, R., Shrestha, A. B., Ren, G., Rajbhandari, R., Saeed, S., Sanjay, J., Syed, A. S., Vellore, R., Xu, Y., You, Q., & Ren, Y. (2019). Unravelling climate change in The Hindu Kush Himalaya: Rapid warming in the mountains and increasing extremes. In P. Wester, A. Mishra, A. Mukherji, & A. B. Shrestha (Eds.), *The Hindu Kush Himalaya assessment—mountains, climate change, Sustainability and people* (pp. 57–97). Springer.
- Kurukulasuriya, P., & Mendelsohn, R. (2008). Crop switching as a strategy for adapting to climate change. *African Journal of Agricultural and Resource Economics*, 2(1), 105–126. <https://doi.org/10.22004/ag.econ.56970>
- Lawson, E.T., Alare, R.S., Salifu, A.R.Z., & Thompson-Hall, M. (2020). Dealing with climate change in semi-arid Ghana: Understanding inter-sectional perceptions and adaptation strategies of women farmers. *Geo Journal*, 85, 439–452. <https://doi.org/10.1007/s10708-019-09974-4>
- Le De, L., Gaillard, J. C., & Friesen, W. (2015). Remittances and disaster: Policy implications for disaster risk management, migration, environment and climate change. *Policy Brief Series*, 1(2).
- Leighton, M. (2006). Desertification and migration. In P. M. Johnson, K. Mayrand, & M. Paquin (Eds.), *Governing global desertification: Linking environmental degradation, poverty and participation* (pp. 43–58). Routledge.
- Levitt, P., DeWind, J., & Vortovec, S. (2006). International perspective on transnational migration: An introduction. *International Migration Review*, 37(3), 565–575. <https://doi.org/10.1111/j.1747-7379.2003.tb00150.x>
- Loneragan, S. (1998). *The role of environmental degradation in population displacement*. Environmental Change and Security Project Research Report, Issue 4, Retrieved August 8, 2018, from <https://www.oceanfdn.org/sites/default/files/The%20Role%20of%20Environmental%20Degradation%20in%20Population%20Displacement.pdf>
- Lutz, W., Muttarak, R., & Striessnig, E. (2014). Universal education is key to enhanced climate adaptation. *Science*, 346(6213), 1061–1062. <https://doi.org/10.1126/science.1257975>
- Madianou, M. (2012). Migration and the accentuated ambivalence of motherhood: The role of ICTs in Filipino transnational families. *Global Networks*, 12(3), 277–295. <https://doi.org/10.1111/j.1471-0374.2012.00352.x>
- Maharjan, A., Bauer, S., & Knerr, B. (2012). Do rural women who stay behind benefit from male out-migration? A case study in the hills of Nepal. *Gender, Technology and Development*, 16(1), 95–123. <https://doi.org/10.1177/097185241101600105>
- Malone, E. L., & Brenkert, A. L. (2008). Uncertainty in resilience to climate change in India and Indian states. *Climatic Change*, 91(3), 451–476. <https://doi.org/10.1007/s10584-008-9472-3>
- Mano, R., & Nhemachena, C. (2007). *Assessment of the economic impacts of climate change on agriculture in Zimbabwe: A Ricardian approach*. Policy Research Working Paper 4292, Development Research Group, Sustainable Rural and Urban Development Team, The World Bank. Retrieved January 31, 2018, from <https://documents.worldbank.org/curated/en/584431468168844535/pdf/Wps4292.pdf>
- McLeman, R. A., & Hunter, L. M. (2010). Migration in the context of vulnerability and adaptation to climate change: Insights from analogues. *Wiley Interdisciplinary Reviews: Climate Change*, 1(3), 450–461. <https://doi.org/10.1002/wcc.51>
- McLeman, R. A., & Smit, B. (2006). Migration as an adaptation to climate change. *Climatic Change*, 76(1), 31–53. <https://doi.org/10.1007/s10584-005-9000-7>
- Messerli, B., Viviroli, D., & Weingartner, R. (2004). Mountains of the world: Vulnerable water towers for the 21 century. *Ambio*, 13(sp13), 29–34. <https://doi.org/10.1007/0044-7447-33.sp13.29>
- Milan, A., Gioli, G., & Afifi, T. (2015). Migration and global environmental change: Methodological lessons from mountain areas of the global South. *Earth System Dynamics*, 6(1), 375–388. <https://doi.org/10.5194/esd-6-375-2015>
- Mishra, A., Appadurai, A. N., Choudhury, D., Regmi, B. R., Kelkar, U., Alam, M., Chaudhary, P., Mu, S. S., Ahmed, A. U., Lotia, H., Fu, C., Namgyel, T., & Sharma, U. (2019). Adaptation to climate change: Stronger action urgently needed. In P. Wester, A. Mishra, A. Mukherji, & A. B. Shrestha (Eds.), *The Hindu Kush Himalaya assessment—mountains, climate change, Sustainability and people* (pp. 457–490). Springer.

- Mortreux, C., & Barnett, J. (2009). Climate change, migration and adaptation in Funafuti, Tuvalu. *Global Environmental Change*, 19(1), 105–112. <https://doi.org/10.1016/j.gloenvcha.2008.09.006>
- Mutabazi, K. D., Amjath-Babu, T. S., & Sieber, S. (2015). Influence of livelihood resources on adaptive strategies to enhance climatic resilience of farm households in Morogoro, Tanzania: An indicator-based analysis. *Regional Environmental Change*, 15(7), 1259–1268. <https://doi.org/10.1007/s10113-015-0800-7>
- Nelson, G. C., Rosegrant, M. W., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M., Valmonte-Santos, R., Ewing, M., & Lee, D. (2010). *The costs of agricultural adaptation to climate change*. World Bank Discussion Paper Number 4. World Bank. Retrieved July 9, 2018 from <https://documents.worldbank.org/curated/en/973551468165538882/pdf/566620NWP0D1CC10Box353730B01PUBLIC1.pdf>
- Nepal, S., & Shrestha, A. B. (2015). Impact of climate change on the hydrological regime of the Indus, Ganges and Brahmaputra river basins: A review of the literature. *International Journal of Water Resources Development*, 31(2), 201–218. <https://doi.org/10.1080/07900627.2015.1030494>
- Ng'ang'a, S. K., Bulte, E. H., Giller, K. E., McIntire, J. M., & Rufino, M. C. (2016). Migration and self-protection against climate change: A case study of Samburu County, Kenya. *World Development*, 84, 55–68. <https://doi.org/10.1016/j.worlddev.2016.04.002>
- Nhemachena, C., & Hassan, R. (2007). *Micro-level analysis of farmers' adaptation to climate change in Southern Africa*. International Food Policy Research Institute (IFPRI). Retrieved January 31, 2018, from <https://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/39726>
- Oudry, G., Pak, C., & Chea, C. (2016). *Assessing vulnerabilities and Responses to environmental changes in Cambodia*. International Organization for Migration (IOM).
- Pathak, S., Pant, L., & Maharjan, A. (2017). *De-population trends, patterns and effects in Uttarakhand, India – a gateway to Kailash Mansarovar*. ICIMOD Working Paper 2017/22, ICIMOD.
- Pepin, N., Bradley, R. S., Diaz, H. F., Baraer, F., Caceres, E. B., Forsythe, N., Fowler, H., Greenwood, G., Hashmi, M. Z., Liu, X. D., Miller, J. R., Ning, L., Ohmura, A., Palazzi, E., Rangwala, I., Schöner, W., Severskiy, I., Shahgedanova, M., Wang, M. B., ... Yang, D. Q. (2015). Elevation-dependent warming in mountain regions of the world. *Nature Climate Change*, 5(5), 424–430. <https://doi.org/10.1038/nclimate2563>
- Piguet, E. (2013). From “primitive migration” to “climate refugees”: The curious fate of the natural environment in migration studies. *Annals of the Association of American Geographers*, 103(1), 148–162. <https://doi.org/10.1080/00045608.2012.696233>
- Piya, L., Maharjan, K. L., & Joshi, N. P. (2013). Determinants of adaptation practices to climate change by Chepang households in the rural Mid-hills of Nepal. *Regional Environmental Change*, 13(2), 437–447. <https://doi.org/10.1007/s10113-012-0359-5>
- Ramin, B. M., & McMichael, A. J. (2009). Climate change and health in sub-Saharan Africa: A case-based perspective. *EcoHealth*, 6(1), 52. <https://doi.org/10.1007/s10393-009-0222-4>
- Rao, N. (2019). From abandonment to autonomy: Gendered strategies for coping with climate change, Isiolo County, Kenya. *Geoforum; Journal of Physical, Human, and Regional Geosciences*, 102, 27–37. <https://doi.org/10.1016/j.geoforum.2019.03.017>
- Rao, N., Lawson, E. T., Raditloaneng, W. N., Solomon, D., & Angula, M. A. (2019a). Gendered vulnerabilities to climate change: Insights from the semi-arid regions of Africa and Asia. *Climate and Development*, 11(1), 14–26. <https://doi.org/10.1080/17565529.2017.1372266>
- Rao, N., Singh, C., Solomon, D., Camfield, L., Sidiki, R., Angula, M., Poonacha, P., Sidibe, A., & Lawson, E. T. (2019b). Managing risk, changing aspirations and household dynamics: Implications from well-being and adaptation in semi-arid Africa and India. *World Development*, 125, <https://doi.org/10.1016/j.worlddev.2019.104667>
- Rigaud, K. K., de Sherbinin, A., Jones, B., Bergmann, J., Clement, V., Ober, K., Schewe, J., Adamo, S., McCusker, B., Heuser, S., & Midgley, A. (2018). *Groundswell: Preparing for internal climate migration*. World Bank. <https://openknowledge.worldbank.org/handle/10986/29461>
- Rigg, J., & Salamanca, A. (2015). The devil in the details: Interpreting livelihood turbulence from a 25-year panel study from Thailand. *Area*, 47(3), 296–304. <https://doi.org/10.1111/area.12188>
- Robert, E. B. L., & Stark, O. (1985). Motivations to remit: Evidence from Botswana. *Journal of Political Economy*, 93(5), 901–918. <https://doi.org/10.1086/261341>
- Sakdapolrak, P., Naruchaikusol, S., Ober, K., Peth, S., Porst, L., Rockenbach, T., & Tolo, V. (2016). Migration in a changing climate: Towards a translocal social resilience approach. *Die Erde: Journal of the Geographical Society of Berlin*, 147(2), 81–94. <https://doi.org/10.12854/erde-147-6>
- Scheffran, J., Marmer, E., & Sow, P. (2011). Migration as a contribution to resilience and innovation in climate adaptation: Social networks and co-development in Northwest Africa. *Applied Geography*, 33, 119–127. <https://doi.org/10.1016/j.apgeog.2011.10.002>
- Scoones, I. (1998). *Sustainable rural livelihoods: A framework for analysis*. IDS Working Paper 72. Institute of Development Studies. Retrieved February 1, 2018, from <https://www.ids.ac.uk/publication/sustainable-rural-livelihoods-a-framework-for-analysis>
- Seo, S. N., & Mendelsohn, R. (2007). *Climate change adaptation in Africa: A microeconomic analysis of livestock choice*. Policy Research Working Paper no. WPS 4277, The World Bank Group. Retrieved July 8, 2018, from <https://openknowledge.worldbank.org/handle/10986/7462>
- Shah, S. H., Wagner, C. H., Sanga, U., Park, H., Demange, L. H. M. L., Gueiros, C., & Niles, M. T. (2019). Does household capital mediate the uptake of agricultural land, crop, and livestock adaptations? *Evidence from the Indo-Gangetic Plains (India)*. *Frontiers in Sustainable Food Systems*, 3, 1. <https://doi.org/10.3389/fsufs.2019.00001>
- Singh, C. (2019a). Migration as a driver of changing household structures: Implications for local livelihoods and adaptation. *Migration and Development*, 8(3), 301–319. <https://doi.org/10.1080/21632324.2019.1589073>
- Singh, C. (2019b). Of borewells and bicycles: The gendered nature of water access and its implications on local adaptive capacity. In A. Hans, N. Rao, A. Prakash, & A. Patel (Eds.), *En-gendering climate change: Learnings from South Asia*. Routledge.
- Singh, C., & Basu, R. (2019). Moving in and out of vulnerability: Interrogating migration as an adaptation strategy along a rural urban continuum in India. *The Geographical Journal*, <https://doi.org/10.1111/geoj.12328>
- Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, 16(3), 282–292. <https://doi.org/10.1016/j.gloenvcha.2006.03.008>
- Stark, O., & Bloom, D. E. (1985). The new economics of labour migration. *The American Economic Review*, 75(2), 173–178.
- Stark, O., & Levhari, D. (1982). On migration and risk in LDCs. *Economic Development and Cultural Change*, 31(1), 191–196. <https://doi.org/10.1086/451312>
- Suleri, A. Q., & Savage, K. (2006). *Remittances in crises: A case study from Pakistan*. A Humanitarian Policy Group Background Paper, Overseas Development Institute.
- Sunam, R. K., & McCarthy, J. F. (2016). Reconsidering the links between poverty, international labour migration, and agrarian change: Critical insights from Nepal. *Journal of Peasant Studies*, 43(1), 39–63. <https://doi.org/10.1080/03066150.2015.1041520>
- Syed, A., Haq, A., Uzzaman, A., Goodrich, C. G., Mallick, D., Mini, G., Sharma, G., Nyima, K., Mamnun, N., Varma, N., Singh, P., Ghate, R., Triwedi, S., Sen, S., Bhadwal, S., Hassan, T., Dilshad, T., Gulati, V., & Naznin, Z. (2017). *The Teesta Basin: Enough water for power and agriculture for all?* HI-AWARE Working Paper 12, HI-AWARE.
- Tacoli, C. (2011). *Not only climate change: Mobility, vulnerability and socio-economic transformations in environmentally fragile areas in Bolivia, Senegal and Tanzania*. Human Settlements Working Paper 28, International Institute for Environment and Development, UK. Retrieved January 31, 2018, from <https://pubs.iied.org/pdfs/10590IIED.pdf>
- Taylor, E. J. (1999). The new economics of labour migration and the role of remittances in the migration process. *International Migration*, 37(1), 63–88. <https://doi.org/10.1111/1468-2435.00066>

- Tebboth, M. G. L., Conway, D., & Adger, W. N. (2019). Mobility endowment and entitlements mediate resilience in rural livelihood systems. *Global Environmental Change*, 54, 172–183. <https://doi.org/10.1016/j.gloenvcha.2018.12.002>
- Vincent, K. (2007). Uncertainty in adaptive capacity and the importance of scale. *Global Environmental Change*, 17(1), 12–24. <https://doi.org/10.1016/j.gloenvcha.2006.11.009>
- Warner, K., & Afifi, T. (2014). Where the rain falls: Evidence from 8 countries on how vulnerable households use migration to manage the risk of rainfall variability and food insecurity. *Climate and Development*, 6(1), 1–17. <https://doi.org/10.1080/17565529.2013.835707>
- Wester, P., Mishra, A., Mukherji, A., & Shrestha, A. B. (Eds.). (2019). *The Hindu Kush Himalaya assessment—mountains, climate change, Sustainability and people*. Springer.
- Wijngaard, R. R., Lutz, A. F., Nepal, S., Khanal, S., Pradhananga, S., Shrestha, A. B., & Immerzeel, W. W. (2017). Future changes in hydro-climatic extremes in the Upper Indus, Ganges, and Brahmaputra River basins. *PloS ONE*, 12(12), e0190224. <https://doi.org/10.1371/journal.pone.0190224>
- World Bank. (2017). *Migration and remittances data*. Retrieved January 30, 2018, from <https://www.worldbank.org/en/topic/migrationremittancesdiasporaissues/brief/migration-remittances-data>
- World Bank. (2018). *Migration remittances data*. Retrieved June 1, 2018, from <https://www.worldbank.org/en/topic/migrationremittancesdiasporaissues/brief/migration-remittances-data>
- Yang, D., & Choi, H. J. (2007). Are remittances insurance? Evidence from rainfall shocks in the Philippines. *The World Bank Economic Review*, 21(2), 219–248. <https://doi.org/10.1093/wber/lhm003>
- Yohe, G., & Tol, R. S. J. (2002). Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. *Global Environmental Change*, 12(1), 25–40. [https://doi.org/10.1016/S0959-3780\(01\)00026-7](https://doi.org/10.1016/S0959-3780(01)00026-7)