Food Sec. (2016) 8:921–937
DOI 10.1007/s12571-016-0607-5

CrossMark

ORIGINAL PAPER

Household food security in the face of climate change in the Hindu-Kush Himalayan region

Abid Hussain[1] · **Golam Rasul**[1] · **Bidhubhusan Mahapatra**[1,2] · **Sabarnee Tuladhar**[1]

Received: 21 February 2016 / Accepted: 25 July 2016 / Published online: 27 September 2016

Abstract This study attempts to understand local people's perceptions of climate change, its impacts on agriculture and household food security, and local adaptation strategies in the Hindu-Kush Himalayan (HKH) region, using data from 8083 households (HHs) from four river sub-basins (SBs), i.e. Upper Indus (Pakistan), Eastern Brahmaputra (India), Koshi (Nepal) and Salween and Mekong (China). The majority of households in SBs, in recent years, have perceived that there have been more frequent incidences of floods, landslides, droughts, livestock diseases and crop pests, and have attributed these to climate change. These changes have led to low agricultural production and income, particularly in Eastern Brahmaputra (EB) where a substantial proportion of HHs reported a decline in the production of almost all staple and cash crops, resulting in very low farm income. Consequently, households' dependency on external food items supplied from plain areas has increased, particularly in the Upper Indus (UI) and EB. After hazards, households face transitory food insecurity owing to damage to their local food systems and livelihood sources, and constrained food supply from other areas. To cope with these, HHs in SBs make changes in their farming practices and livestock management. In EB, 11 % of HHs took on new off-farm activities within the SB and in SM, 23 % of HHs chose out-migration as an adaptation strategy. Lastly, the study proposes policy instruments for attaining sustainable food security, based on agro-ecological potential and opportunities for increasing agricultural resilience and diversity of livelihoods.

✉ Abid Hussain
abid.hussain@icimod.org; abidwaqas670@hotmail.com

1 International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal

2 Present address: Room to Read, New Delhi, India

Keywords Agriculture · Food security · Climate change · Mountains · Adaptation strategies · Hindu-Kush Himalaya region

Introduction

Mountains provide 40 % of global goods and services in the form of water, hydroelectricity, timber, biodiversity and niche products, mineral resources, recreation, and flood control (Huddleston et al. 2003). However, 51 % of the almost 842 million people worldwide facing chronic hunger, are accounted for by six Hindu-Kush Himalayan (HKH) countries, i.e. Bangladesh, China, India, Myanmar, Nepal and Pakistan (FAO 2013). Moreover, recent studies (Giribabu 2013; MoHP-Nepal 2012; FSA 2009; Hussain and Routray 2012) have revealed that severity of food insecurity in mountain areas of HKH countries is significantly higher than in plain areas.

Mountain people, particularly in the HKH region, are highly vulnerable to food insecurity because of their low productivity, subsistence economies, constraints of terrain and climate, poor infrastructure, limited access to markets, physical isolation, vulnerability to natural hazards and high cost of food production and transportation (Rasul 2011; Tiwari and Joshi 2012; Ward et al. 2012, Huddleston et al. 2003, FAO 2008). The natural resource base in the HKH region, particularly soil nutrients, water and biomass, has been steadily depleted over recent years, resulting in a significant decline in food production (Tiwari 2000; Andersen et al. 2005). Increasing impacts of climate change have added to food insecurity, particularly in the Hindu-Kush Himalayan (HKH) region, where people are affected in both upstream and downstream areas (Chatterjee and Khadka 2013; Abbas 2009; World Bank 2009; ICIMOD 2008).

The livelihoods and food security of mountain communities depend heavily on the local resource base at all elevations, although the specific agro-ecological and livelihood potentials vary considerably. Subsistence agriculture, livestock and horticulture are the main sources of livelihoods, with livestock becoming more important than arable farming at higher elevations. Remittances from those who have out-migrated from these communities, small businesses, wage labor, tourism and collection of medicinal plants and other herbs also contribute to livelihoods and food security. However, in recent years, climatic and socioeconomic factors have contributed to depletion of the natural resource base across the HKH region (Rasul et al. 2014). Climatic changes included unprecedented changes in precipitation patterns and hydrological imbalances, rises in temperature, frequent floods and degradation of the forests, rangelands and agricultural land (Nautiyal et al. 2007). Unusually heavy rainfalls, triggering Glacial Lake Outburst Floods. (GLOFs) in the mountain areas (Din et al. 2014), have also been attributed to climate change. In the Upper Indus basin, for instance, the frequency and intensity of GLOF events have increased during recent years, five occurring during 2008–2009 in the Gojal valley of Hunza alone. Analysis of GLOF events showed that they were linked to weather conditions in terms of increased temperature, rainfall and increased occurrence of heat waves. Recently (July 2015), heavy monsoon rains coupled with GLOF affected the Chitral District in Khyber Pakhtunkhwa (KPK) Province (IFRC 2015).

'Too much or too little water' is adding to the vulnerability of mountain agriculture, which is mainly rain-fed. Mountain farmers are experiencing frequent floods and prolonged droughts, resulting in low productivity of agriculture and higher prevalence of food insecurity (Hussain et al. 2016). In Nepal, for instance, the incidence of food poverty in mountain regions is 48 % compared to 18 % in the plain areas (Haslett et al. 2014: p. 28). Likewise, in mountain areas of Pakistan, including FATA, Baluchistan, Gilgit-Baltistan and KPK, nearly 60 % of the people are food insecure (FSA 2009). The past trends and the projected changes in temperature and precipitation in the HKH clearly show that temperature and precipitation patterns are changing faster in this region than neighbouring regions (Dhakal et al. 2010; Government of Nepal 2011). Unusual rainfall patterns, attributed to climate change, are also resulting in the disappearance of some crop species and varieties from local food systems owing to lack of conservation initiatives (FAO-AIPP-IWGIA 2015).

Ensuring food security has become a big challenge in the face of such changes, particularly as subsistence farmers are already facing the constraints of limited arable land, difficult terrain, unfavorable bio-physical conditions, physical isolation and limited market access (Rasul et al. 2014). A further factor is the increasing rate of out-migration, which is causing labor shortages in agriculture, leading to underutilization of agriculture potential. The consequent reduced agricultural production has affected food security and increased the overall vulnerability of mountain people, as they have become more dependent on food from outside and thus exposed to market fluctuations.

Food security in mountain areas usually does not attract much attention from researchers and development planners owing to the physical isolation and higher cost of research and development activities (Rasul and Karki 2007). Therefore there is a dire need to understand the challenges to mountain farming systems, local adaptation strategies and food security in the face of the changing climatic conditions already described. Such understanding may provide novel adaptation strategies that allow mountain people to maintain their food security and livelihoods.

The primary purpose of this study is to understand local people's perception of climate change, its impacts on agriculture and household food security, and local adaptation strategies, using large-scale survey data collected from four river sub-basins, i.e. Upper Indus (Pakistan), Koshi (Nepal), Eastern Brahmaputra (India), and Salween and Mekong (China). It has also identified the opportunities arising out of changing climate for mountain farmers to achieve sustainable food security and livelihoods. This study is descriptive research, which was designed to rely mainly on information provided by local people on the ground. A secondary purpose of the study was to validate the findings of various scientific studies of impacts of climate change in the mountain areas of the HKH region. It is hoped that the study will provide a better understanding of the vulnerability of mountain people to food insecurity under climatic change and their ability to adapt.

Methodology

Research design and study area

This study uses data which was collected through a large scale survey in four river sub-basins, i.e. Upper Indus (Pakistan), Koshi (Nepal), Eastern Brahmaputra (India), and Salween and Mekong (China) of the Hindu-Kush Himalayan region (Fig. 1). This survey tool, named 'Vulnerability and Adaptive Capacity Assessment (VACA)', was developed by the International Centre of Integrated Mountain Development (ICIMOD) in 2011 under the Himalayan Climate Change Adaptation Project (HICAP) to assess the livelihood vulnerability, adaptive capacity and responses to climatic and socioeconomic changes. VACA covers a broad range of aspects with regard to mountain agriculture, food security, livelihoods, ecosystem services, climatic and socioeconomic changes, environmental stability and local adaptation strategies. However, the present study has only used those data that

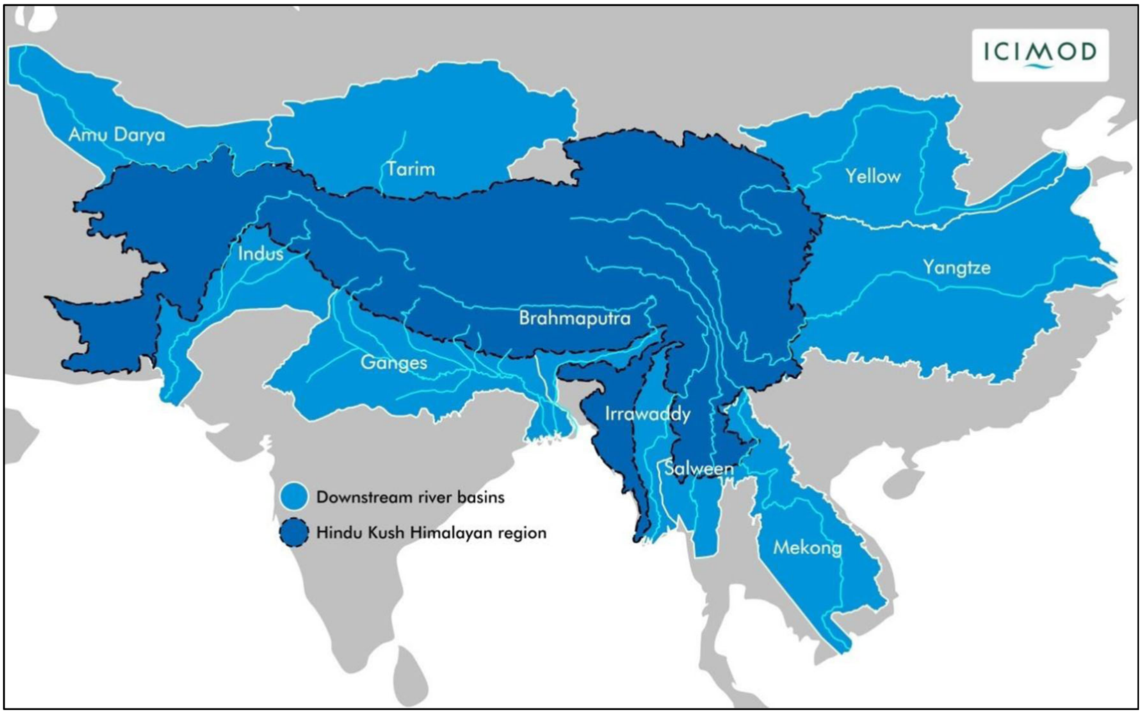


Fig. 1 The Hindu-Kush Himalayan region

were collected to investigate the linkages of climate change with agriculture and food security.

The selected four river sub-basins (SBs) are upstream parts of those large river basins, which are among the largest and the most productive ecosystems in the world. These basins provide water not only for agriculture, but also for forestry and fisheries as well as urban and industrial purposes (Sikka and Ringler 2009). Recent studies (Yu et al. 2013; Rasul & Hussain 2015; Bhatt et al. 2014; Zhen-Feng et al. 2013) have revealed that increased incidences of erratic precipitation, floods, dry spells and landslides, attributed to climate change, have led to decline in agricultural productivity and deterioration of food security. This study investigates whether these scientific findings were mirrored in local people's perception of climate change and its impacts on agriculture and household food security. Projections of climate change modeling suggest that these river basins will also impact future water availabilities in the respective countries through changes in precipitation patterns and decline in water from glaciers.

Sampling design

In India, the study areas selected comprised the states of Arunachal Pradesh (districts: East Siang, Lower Dibang, Lohit) and Assam (districts: Dhemaji, Lakhimpur, Moregaon & Tinsukia). In Nepal, the selected districts were Dolakha, Kavre-Palanchowk, Khotang, Udayapur, Sunsari and Siraha. In Pakistan, the provinces Gilgit Baltistan (districts: Gilgit & Hunzanagar) and Khyber Pakhtunkhwa (district: Chitral) were selected. In China, the counties of Linang, Baosanchan, Dali, Diqing and Nujiang were selected. Within these selected states/districts, random selections of settlements were made followed by a random route procedure to choose the households. Overall, 8083 households were surveyed: 1139, 2647, 2310 and 1987 from Upper Indus, Eastern Brahmaputra, Koshi, and Salween and Mekong, respectively. Data collected for this study may not be a true representative of the sub-basins because districts in the states/provinces were selected purposively in view of their higher vulnerability to climate change impacts rather than following a systematic random sampling technique. Thus, for generalization of results at sub-basin levels, authors clearly caution that sampling design has some limitations.

Type and nature of collected data

For this study, both quantitative and qualitative data were analyzed. Quantitative data included household size, land under different cultivation practices, monthly food and non-food expenditure, agricultural income and working members of households. Qualitative data included households' reporting on cultivation of major staple and cash crops, households' response on ownership of different types of livestock, perception of climate change, reporting on out-migration, perception of climate change impacts on crop production, adaptation strategies and reporting on non-agricultural income sources. Some important points about the nature of the data are clarified below.

1) In this study, reported climatic changes (Figs. 2, 3, 4, 5 and 6) mean 'incidence of extreme events' observed by the households in the last 10 years.
2) Some crops are categorized under both staple and cash crop categories (Tables 3 and 6) because these are being cultivated as both staple and cash crops depending on the farmers' choice in response to market access and prices. Staple crops are those that are cultivated mainly for household food consumption, whereas cash crops are cultivated with the objective of sale to earn income.
3) Changes in crop production attributable to climate change (Table 6) are average changes perceived by the households in the past 10 years.
4) Households' judgement criteria on climate change perception may vary across households but still provide some robust indications about the incidence of extreme events, attributed to climate change, and their impacts on agriculture and food security. Despite some limitations, perception based data are useful for determining if they correspond with the findings of scientific studies, which are down-scaled at least at basin level.

Findings

Socioeconomic characteristics of households

The four river basins differ from each other in terms of socioeconomic characteristics (Tables 1 and 2). Household size is greatest in the Upper Indus (UI) and least in Salween and Mekong (SM) (Table 1), perhaps reflecting China's one-child policy (Riley 2004; Ge et al. 2012). On the other hand, in Pakistan, family planning strategies, due mainly to religious and cultural factors, have not imposed a strict family size (Zulfiqar & Hussain 2014). In all sub-basins, households are mainly headed by male members (Table 1). The proportion of male and female members within households is almost equal. In SM, household heads are mainly literate, conversely in UI, around 46 % household heads are illiterate. Dependency ratio in Koshi and Eastern Brahmaputra (EB) is nearly 60 %. Dependency ratio is highest in UI and least in SM (Table 1). The majority of households in all four sub-basins (SBs) have access to land for agricultural activities. More than 95 % households own agricultural land except those in SM where only 11 % farming households have ownership rights (Table 1) because most of the agriculture land is owned by local government (Keliang and Prosterman 2007). Further background details of the four SBs are given in Table 2.

Farming systems in sub-basins

Farming households in SBs are mainly smallholders who practise mixed farming systems, consisting of crops, fruit and livestock (Tables 3 and 4). In SM and UI, a substantial proportion of agricultural land is under fruit and tree orchards. In UI, more than one-fourth of households' agricultural land has been turned into pasture and grassland, possibly due to frequent agricultural labor shortage (Table 1). It may also be one of the reasons for the 3–5 % fallow agricultural land in Koshi and EB basins, as reported elsewhere (Ghimire and Thakur 2014). In Koshi and EB, around 80 % of the land is under the cultivation of crops. In all four sub-basins, minor plots are transformed into kitchen gardens, e.g. in EB around 10 % of average household land are kitchen gardens. Among the SBs, the UI has the highest percentage (99.9 %) of farm households with access to irrigation systems, whereas EB has the least (16.8 %) (Table 1).

Almost all farming households in UI and Koshi cultivate staple crops including cereals and vegetables (Table 3). Likewise in EB and SM, more than 90 % of farming households cultivate staple crops. In SM, nearly 68 % farming households cultivate cash crops, whereas in the other three SBs, fewer than half of the households cultivate cash crops. Choices of particular crops - both staple and cash - differ across countries owing to differences in agro-ecological potential and market factors (Pan et al. 2010). In UI, among the households who grow staple crops, 55 % grow wheat, which is the main staple crop, not only in the study area but also in other regions of Pakistan (Zulfiqar & Hussain, 2014). Farming households also prefer to cultivate summer potato and other vegetables, apple and summer maize as staple crops. Among those households who grow cash crops in UI, summer potato is the first choice due to suitability of local conditions for its cultivation and its local as well as external demand from downstream areas (Rasul & Hussain 2015). A significant proportion of households also produce fruits such as apple, cherries, apricot and walnut to generate income (Table 3).

In Koshi and EB, paddy is the main staple crop, followed by other cereals in Koshi and vegetables in EB. Similar to UI, summer potato is the main cash crop in Koshi. Instead of fruits, in Koshi vegetables are the next choices of farmers for cash crops. In Koshi, one-quarter of farming households cultivate mustard as a staple crop while one-third of EB households cultivate it as a cash crop. A significant proportion of households also prefer tea, ginger and jute as cash crops (Table 3). In SM, summer maize is the main staple crop, followed by other cereals and vegetables. In this SB, around 40 % of farming households prefer to grow walnut and tea as cash crops. Among other cash crops, garlic, tobacco and

Table 1 Socioeconomic characteristics of households

Variables		Upper Indus (Pakistan) $n = 1139$	Koshi (Nepal) $n = 2310$	Eastern Brahmaputra (India) $n = 2647$	Salween & Mekong (China) $n = 1987$
Household size, Mean (SD)		7.6 (3.4)	5.7 (2.6)	5.6 (2.4)	4.1 (1.6)
% of households headed by male or female	Male	94.5	85.9	91.1	85.8
	Female	5.5	14.1	8.9	14.2
Education of the household heads (%)	Illiterate	46.3	38.1	24.2	7.3
	Attended primary school (class 1–5) or literate but non-formal education	17.6	31.7	19.2	27.7
	Attended middle or high school (class 6–10)	22.0	16.8	36.1	58.6
	Attended college or university (above class 10)	14.2	13.5	20.5	6.4
Sex of household members (%)	Male	49.0	48.6	49.9	50.1
	Female	51.0	51.4	50.1	49.9
Dependency ratio (%)[a]		71.5	57.9	60.5	46.2
Average landholding size (in hectares)		0.63	0.98	1.32	0.76
% HHs who have access to agricultural land		88.2	76.5	66.4	81.2
Proportion of land under different practices (%)[b]	Crop farming	37.7	83.3	77.7	50.9
	Orchard/tree crops	27.3	1.6	8.7	43.0
	Grassland/pasture	27.3	4.1	0.1	3.1
	Kitchen garden	3.1	5.0	10.4	2.4
	Fallow	3.7	5.4	2.5	0.5
	Other use	0.9	0.5	0.6	0.0
% of household who owns agricultural land [b]		99.0	95.9	96.2	10.7
% of household who have irrigated land [b]		99.9	59.5	16.8	62.9
Land ownership [c](%)	Female	2.9	16.2	4.0	36.6
	Male	96.7	81.5	88.5	24.6
	Joint	0.4	1.2	3.7	38.5
Number of HH members working on farm, Mean (SD) [b]		3.4 (1.9)	3.4 (2.0)	3.2 (1.7)	2.3 (1.0)
% household "always" facing labor shortage [b]		69.2	25.6	36.7	37.8
% household involved in transhumance practices in last 12 months [d]		36.5	0.4	0.3	1.4

[a] (HH members below 14 & above 64yrs . of age/Economically active members aged 15 - 64 yrs.) × 100

[b] computed among those who have access to agricultural land

[c] computed among households who own agricultural land; [d] calculated among households who own livestock

Source: ICIMOD Survey 2011–12

sugarcane are also very important income generating choices. Among all SBs, income from the sales of staple and cash crops in SM are significantly higher due to good market connectivity and long-run integration (Park 2008; Laping 2006). Among other SBs, UI is slightly better compared to Koshi and EB in terms of income generated income from crops, whereas EB has the least returns (Table 3).

Similar to other mountain regions, households in the study SBs raise livestock to support their food security and livelihoods. In UI and Koshi, more than 80 % households own livestock. Also in EB and SM, a substantial proportion of households raise livestock (Table 4). Among the livestock raising households, a substantial proportion of the households in UI, Koshi and EB raise cattle and goats, whereas in SM most of the households prefer to raise pigs. In Koshi more than half of the households raise buffalo, whereas in other SBs, only a small proportion of households prefer to do this. In UI, more than half of livestock raising households raise sheep (Table 4), which is in line with the higher transhumant activities in this SB (Table 1). Moreover, sheep are more resilient to water and fodder/forage-stress but can have negative long-term environmental impacts on pastures and rangelands (Shafiq & Kakar 2007). In all SBs, households also raise poultry, ducks and pigeons for home consumption as well as sale. However, bird raising is significantly higher in EB and SM. Fish catching and farming practices are prominent only in EB compared to other SBs.

Table 2 Supplementary fact sheet of river basins

Indicators	Upper Indus (Pakistan)	Koshi (Nepal)	Eastern Brahmaputra (India)	Salween & Mekong (China)
Topography	Mountainous	Mountainous	Mountainous & Plains	Mountainous
Land ownership	Mainly private	Mainly private	Mainly private	Mainly government
Gini Coefficient (%)	30.4	24.0	28.4	31.1
[a]Monthly per capita food expenditure (USD)	40.4	29.0	23.9	87.3
% households having access to electricity from national grid	98	88	65	100
Primary source of fuel for cooking	Wood (99 % HHs)	Wood (81 % HHs)	Wood (73 % HHs)	Electricity (61 % HHs)
% HHs having enclosed pit/flush toilet	91	57	65	86
% HHs in debt	36	69	51	43
% HHs who received help to deal with environmental shocks in the last 12 months	59	94	80	83

[a] Adjusted for adult equivalent

Source ICIMOD Survey 2011–12

Households' perception of climate change

The majority of households in all four SBs perceived that climate has been changing over the last 10 years (Fig. 2). In UI, among those households who perceived changes in climate, the majority reported the greater frequency of floods in their area. A significant proportion of the households also reported that they observed certain changes in rainfall patterns and temperature. Moreover, one-fifth of households faced landslides and erosion triggered by heavy rainfall and floods (Fig. 3). Manzoor et al. (2013) also revealed that after 2000–01, frequency and magnitude of floods in UI has increased due to intense rainfall in the Indus catchments and are occasionally increased by snowmelt.

Table 3 Major staple and cash crops cultivated in last 12 months

Variables	Upper Indus (Pakistan)	Koshi (Nepal)	Eastern Brahmaputra (India)	Salween & Mekong (China)
% HHs who cultivated staple crops in last 12 months	99.5	97.8	95.2	91.5
% HHs who cultivated both staple & cash crops in last 12 months	48.7	45.4	47.7	68.5
Top five staple crops grown in last 12 month [a]	Wheat (55.4)	Main Paddy (75.7)	Main Paddy (87.0)	Summer Maize (64.4)
	Summer Potato (49.8)	Wheat (65.2)	Winter Vegetables (33.4)	Main Paddy (56.8)
	Summer Vegetables (44.0)	Summer Maize (63.6)	Winter Potato (17.7)	Wheat (9.7)
	Apple (38.9)	Millet (39.3)	Early Paddy (17.3)	Winter/Spring Maize (9.0)
	Summer Maize (36.1)	Mustard (25.1)	Summer Vegetables (17.1)	Summer Vegetables (7.7)
Total income in USD from sale of staple crops [b]	160.58	106.92	75.56	317.72
Top five cash crops grown in last 12 months [c]	Summer Potato (73.4)	Summer Potato (44.1)	Mustard (33.1)	Walnut (43.0)
	Apple (26.8)	Onions (32.6)	Tea (24.4)	Tea (39.6)
	Cherries (18.8)	Garlic (30.3)	Ginger (21.5)	Garlic (15.7)
	Apricot (13.1)	Winter Vegetables (22.8)	Other Cash Crops (18.2)	Tobacco (12.3)
	Walnut (8.5)	Summer Vegetables (21.9)	Jute (8.2)	Sugarcane (9.0)
Total income in USD from sale of cash crops [d]	252.34	237.60	198.35	953.16

Figures in parenthesis are % of HHs who reported the cultivation of the particular crop

[a] computed among HHs who cultivated staple crops in last 12 months

[b] computed among HHs who sold staple crops in last 12 months

[c] computed among HHs who cultivated cash crops in last 12 months

[d] computed among HHs who sold cash crops in last 12 months

Source: ICIMOD Survey 2011–12

Table 4 Livestock and fisheries

Variables		Upper Indus (Pakistan) $n = 1139$	Koshi (Nepal) $n = 2310$	Eastern Brahmaputra (India) $n = 2647$	Salween & Mekong (China) $n = 1987$
% HHs who own any livestock		83.1	83.2	69.1	75.5
% HHs with different types of livestock (computed among those HHs who own any livestock)	Cattle	92.6 (2.7)	72.8 (2.7)	80.0 (4.8)	22.7(2.4)
	Buffalos	1.0 (2.7)	53.0 (2.0)	2.0 (5.4)	14.5 (1.6)
	Goats	61.1 (9.8)	74.4 (4.5)	41.6 (4.1)	4.9 (13.8)
	Sheep	53.0 (5.7)	0.4 (3.8)	0.3 (5.8)	0.3 (9.3)
	Pigs	0.0 (0.0)	9.1 (2.0)	39.5 (2.8)	70.0 (5.5)
	Poultry/ducks/pigeons	39.9 (4.7)	53.8 (8.4)	70.8 (9.2)	80.3 (14.2)
Livestock heads per household (Median)		8	8	10	12
Fisheries & fish catching		0.2	2.6	20.5	1.0

Note: Figures in parenthesis are 'average number of animals owned by households'

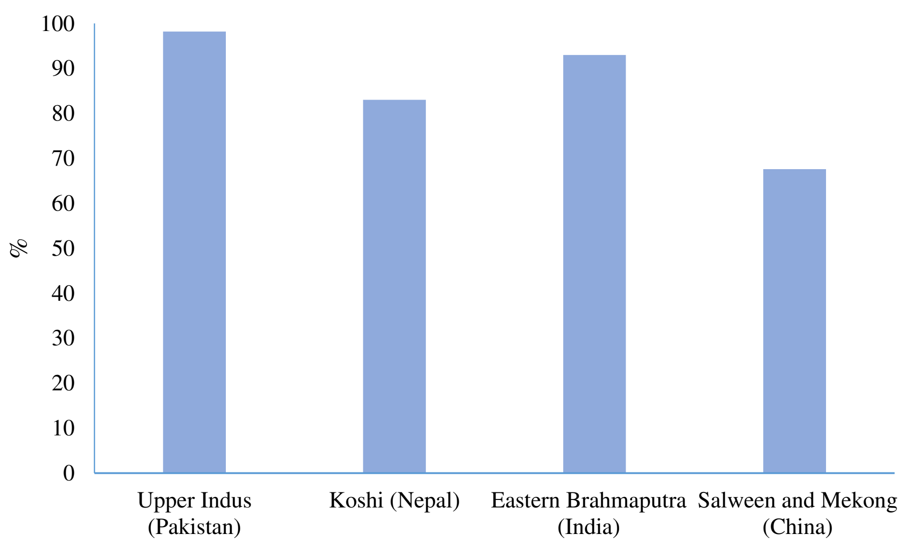
Source: ICIMOD Survey 2011–12

In Koshi, changes in rainfall patterns were reported by more than half of the surveyed households. In this SB, households perceived that decrease in annual rainfall has resulted in prolonged dry spells and droughts. In addition, they also perceived an increase in temperature and incidence of livestock diseases over time (Fig. 4). Bharati et al. (2012) projected a 0.79–0.86 °C rise in temperature in the 2030s for the Koshi Basin compared to a baseline average over 1976–2005. Increased temperature leads to greater evaporation and thus surface drying, increasing the intensity and duration of drought (Devkota and Gyawali 2015).

In the EB, incidence of drought, flood and erratic rainfall have increased, and the majority of households also observed a rise in temperature (Fig. 5). More than 55 % households reported that incidence of livestock diseases had also increased in their areas. This is consistent with other studies (Sirohi and Michaelowa 2007; Singh et al. 2000; Basu and Bandhyopadhyay 2004) where changes in temperature, rainfall patterns and humidity were directly related to increased incidences of livestock diseases.

Similar to other SBs, in SM around 47 % households reported that they observed frequent dry spells and droughts in their areas (Fig. 6). A significant proportion of households also observed a rise in the incidence of erratic rainfall, temperature rise and crop pests. SM is the only SB where households have reported an increase in crop pests over time, which was attributed to climate change (Fig. 6). This is understandable because changes in temperature, timings of seasons and rainfall patterns may lead to increased populations of weeds in grasslands, and incidences of pests and diseases of grasses and crops (Sirohi and Michaelowa 2007).

Fig. 2 Households (%) who perceived an increase in climate induced extreme events in the last 10 years



Note: Climate induced extreme events include flood, erratic rainfall, high and low temperature extremes, landslides/erosions, dry spells, droughts, livestock diseases and crop pests.

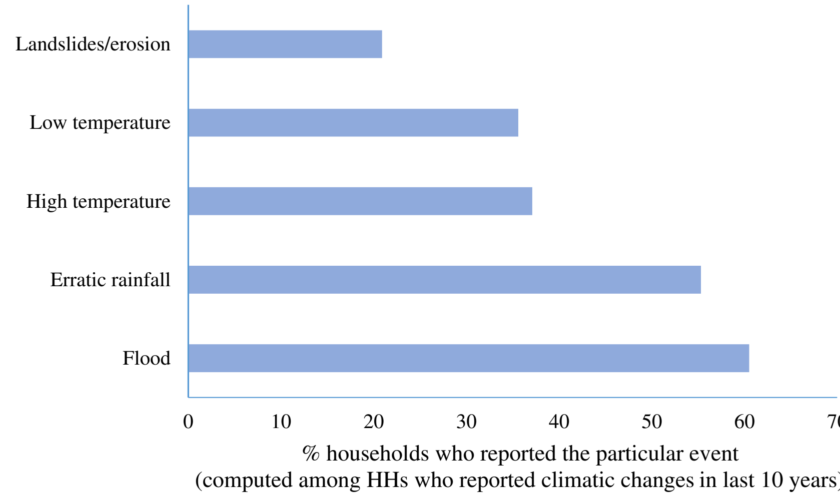


Fig. 3 Households' perception: Top five climate induced events in the Upper Indus, sub-basin (Pakistan)

In addition to climate change, outmigration is the most prominent socioeconomic change observed in all four SBs. Outmigration from EB is relatively low compared to other SBs (Table 5). In UI and SM, migration to other parts of the country is higher than the overseas migration. However, in Koshi, overseas migration is higher than within country migration. Among the migrant sending households in Koshi, more than 74 % of households receive remittances, whereas in UI and EB, 55 % and 58 % households receive remittances, respectively. Despite the higher outmigration (40 %) in SM, only one-fifth of migrant sending households receive remittances (Table 5) due possibly to reasonable income from agriculture (Table 3), lessening the need for them.

Impacts of changes in agricultural production

In SBs, farmers' timely and adequate access to water has become a challenge. Irregular precipitation patterns, attributed to climate change, have caused severe impacts on livelihoods of millions of vulnerable people (Chen et al. 2013). Rural communities in hills and mountains are experiencing substantial impacts on water resources due to prolonged dry seasons. UI has experienced erratic rainfalls and floods (Fig. 2), whereas in the other three SBs, temperature rise, frequent dry spells and droughts have been observed (Figs. 3, 4 and 5). Irregular changes in rainfall patterns may have impacts on water availability, particularly in EB where over 80 % of agricultural land is rain-fed (Table 1).

Despite advances in agricultural technology and inputs, a significant proportion of households reported a decline in the production of their crops over the last 10 years. This decline in production may be attributed to climate change. In UI, the majority of crop growing households reported that production of main staple crops such as wheat and summer potato has decreased over time (Table 6). In Koshi, the majority of households reported that the production of summer maize, millet and mustard has decreased. In EB, changes in climatic events have caused relatively more severe impacts on production. Households perceived that production of all staple crops and most cash crops had declined (Table 6). In SM, as perceived

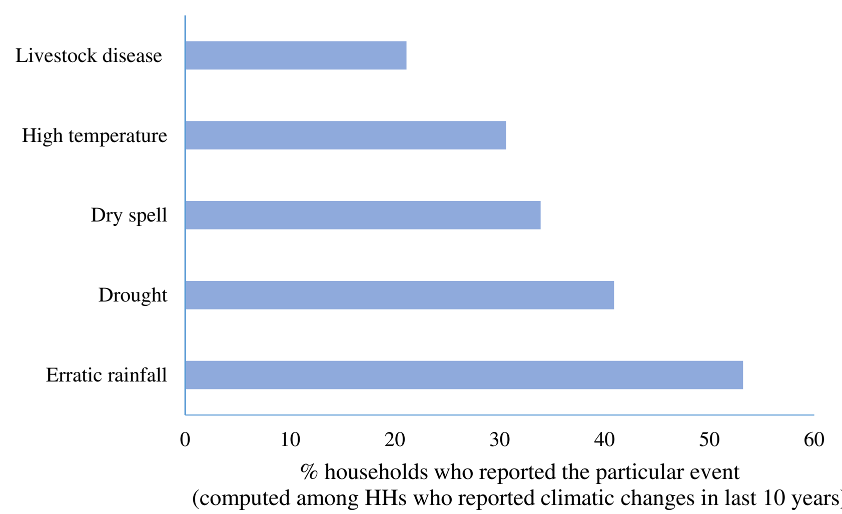


Fig. 4 Households' perception: Top five climate induced events in Koshi, sub-basin (Nepal)

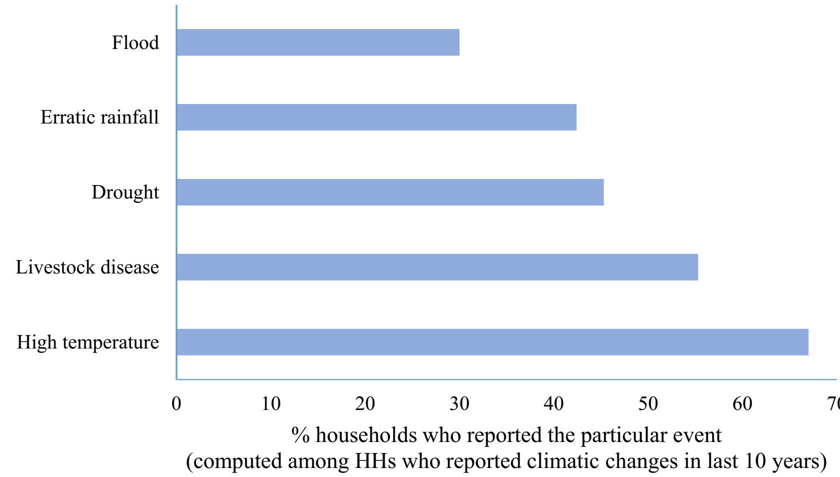


Fig. 5 Households' perception: Top five climate induced events in Eastern Brahmaputra, sub-basin (India)

by the majority of particular crop growers, production of some staples, i.e. wheat and maize has decreased in the last 10 years. Some opportunities are also arising for farming households. For instance, in UI, a substantial proportion of households reported an increase in the production of summer vegetables and fruits such as apple, cherries, apricots and walnuts. Likewise, a significant proportion of households reported an increase in the production of summer potato, onion and vegetables in Koshi, tea in EB, and walnut, tea, garlic, tobacco and sugarcane in SM.

Inflow of remittances from out-migrants is undoubtedly a potential source for improving local food security and livelihoods through enhancing local small businesses, transferring new technologies, and creating job opportunities for local skilled and unskilled labor. But outmigration has also added to the challenges in mountain areas. Increased outmigration and decreased interest of the youth in farming also add to the low production in agriculture (Rasul et al. 2014). Households in all four SBs face frequent labor shortages, which together with water shortages is leading to increased amounts of fallow agricultural land (Table 1).

Adaptation to climate change

For adaptation to climate change, households have adopted various practices, which improve their resilience. Those households which perceived changes in climate were asked to report their adaptation practices during the survey. In UI, almost one-fifth of households changed their farming practices and introduced new crops (Table 7). Changes in farming practices include water conservation methods, change in sowing time and introduction of new crops, such as fruits and nuts, which are relatively more resilient to water-stress and have higher market value (IFAD 2015). Some areas such as *Broghil* top in *Chitral* and *Deo Sai* in Gilgit-Baltistan, which were not suitable for crop cultivation due to their harsh climates, are now under vegetable cultivation. During summer months, these areas do not have snow cover anymore. Therefore, local communities have started growing winter vegetables (i.e. potato, peas etc.) during the summer (Rasul et al. 2014). More than 16 % households gave up the rearing of certain livestock (Table 7). In UI, climate change has resulted in significant degradation of pastures and rangelands,

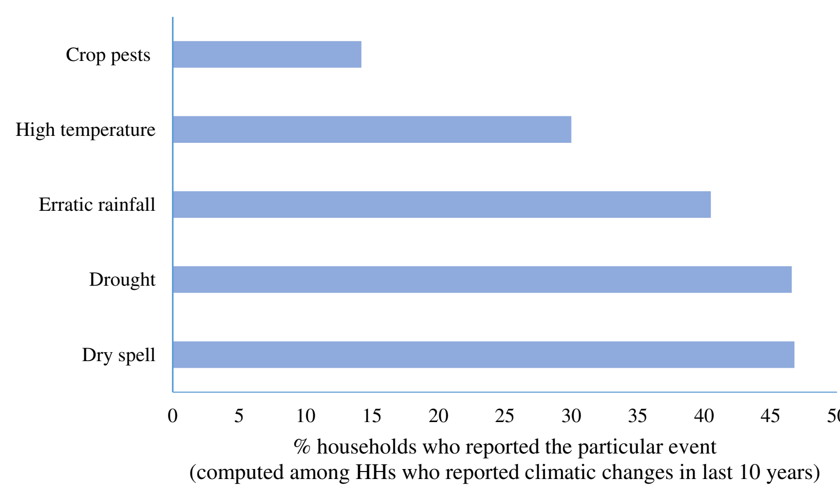


Fig. 6 Households' perception: Top five climate induced events in Salween and Mekong, sub-basin (China)

Table 5 Outmigration from mountains

Variables	Upper Indus (Pakistan)	Koshi (Nepal)	Eastern Brahmaputra (India)	Salween & Mekong (China)
% HHs with no migrants	59.0	61.4	89.9	59.7
% HHs with migrants	41.0	38.6	10.1	40.3
% HHs with migrants within country only	35.3	15.5	9.7	39.8
% HHs with migrants outside country only	2.1	20.0	0.3	0.2
% HHs with migrants within and outside country	3.7	3.0	0.1	0.3
% HHs who received remittances from migrants [a]	54.7	74.2	58.4	21.1

[a] calculated among migrant sending households

Source: ICIMOD Survey 2011–12

which are free sources of grazing for almost 80 % of livestock in the SBs (Khan et al. 2013). Since sheep and the larger animals consume more fodder and water, as a coping strategy, livestock owners are more likely to reduce the number of the larger animals and sheep, and increase the number of local goats (Table 4). Local breeds of goats are more resilient to water and fodder/forage-stress, as revealed by a study done in Balochistan province of Paksitan (Shafiq & Kakar 2007). In

Table 6 Households' perception of changes in production of crops

Major staple crops	% HHs who perceived decrease in production over last 10 years	% HHs who perceived increase in production over last 10 years	Crop growing HHs (number)	Major cash crops	% HHs who perceived decrease in production over last 10 years	% HHs who perceived increase in production over last 10 years	Crop growing HHs (number)
Upper Indus (Pakistan)							
Wheat	39.9	37.7	596	Summer Potato	53.3	36.6	396
Summer Potato	61.8	27.1	492	Apple	26.8	51.6	141
Summer Vegetable	23.0	51.4	588	Cherries	13.8	73.8	104
Apple	32.8	39.8	382	Apricot	16.0	55.8	63
Summer Maize	31.2	47.3	330	Walnut	6.5	89.8	23
Koshi (Nepal)							
Main Paddy	36.8	45.2	1290	Summer Potato	25.4	63.3	269
Wheat	36.8	45.2	1290	Onions	19.4	65.6	137
Summer Maize	43.2	32.5	1287	Garlic	22.3	43.1	129
Millet	46.7	31.1	875	Winter Vegetables	36.7	50.2	113
Mustard	44.9	30.8	400	Summer Vegetable	33.5	56.1	103
Eastern Brahmaputra (India)							
Main Paddy	67.1	15.8	1635	Mustard	62.8	22.1	428
Winter Vegetables	42.4	12.3	434	Tea	18.8	65.1	123
Winter Potato	62.0	16.5	345	Ginger	40.4	41.7	430
Early Paddy	51.7	29.5	463	Other Cash Crops	65.4	19.9	86
Summer Vegetable	28.2	8.2	175	Jute	76.9	19.0	77
Salween & Mekong (China)							
Summer Maize	20.0	40.4	1240	Walnut	15.5	44.5	403
Main Paddy	19.7	31.1	655	Tea	16.3	40.9	342
Wheat	37.8	23.9	272	Garlic	5.8	32.3	95
Winter/Spring Maize	59.8	10.1	196	Tobacco	23.5	34.7	180
Summer Vegetables	2.2	33.7	121	Sugarcane	22.5	37.9	111

Changes in crop production are average trends perceived by households in last 10 years

Source: ICIMOD Survey 2011–12

addition to adaptation practices in crops and livestock, 10 % of households also invested in disaster preparedness practices, e.g. construction of sheds and shelter for livestock and family members.

In Koshi, around 18 % of households gave up planting crops which were highly vulnerable to water stress (e.g. paddy). Around 15 % households introduced new crops on their farms (Table 7). In Nepal, farmers are shifting their cropping patterns from highly water consumptive crops (i.e. paddy) to fruits and vegetables which are high value crops (Gurung and Bhandari 2009; GWP-JVS 2014: p.21, Dixit et al. 2009). A small proportion of households also changed their farming practices (Table 7). These changes included slight shifts in timing of crop cultivation, exploring improved varieties of seed and use of different agriculture practices requiring less water (Bhatta et al. 2015). Around 8–9 % of households either gave up rearing certain livestock or changed their grazing practices (Table 7). Compared to other SBs, in EB fewer households adopted new farming practices to cope with the impacts of climate change. Rather over 10 % of them started new off-farm income activities to support their food security and livelihoods (Table 7) because of high vulnerability to floods and low agricultural production (Saikia 2012; Sarkar et al. 2012). Only 5–10 % households changed their farming practices and cropping choices, whereas almost 7 % invested in some disaster preparedness practices (Table 7).

In SM, more than one-fifth of households were those who sent at least one member of the family to work either in other parts of the country or overseas as a coping strategy (Table 7). In addition to changes in farming practices and crop choices, investments in advanced irrigation technology have been made by 11–12 % households. The Chinese government is also promoting investment in the construction of water collection and utilization engineering in hill and mountain areas (GoPRC 2007).

Agricultural income and household food consumption

Traditionally, agriculture is assumed to contribute to the food security and livelihoods of households in the mountains through providing diverse foods and contributing to household income. However, due to increasing climatic vulnerabilities and market uncertainties, the contribution of agriculture to household income has significantly decreased over time (ISET 2008). In all SBs, the majority of households reported that agriculture and livestock were sources of their income. However, they are main sources of income for only a small proportion of households (Table 8) due mainly to declining productivity resulting from climatic hazards and labor shortages.

Although farm production contributes to household food consumption, yet the local people have to buy several other

Table 7 Adaptation to climate change

Ranking of adaptation practices based on number of HHs by which they are performed	Upper Indus (Pakistan)	Koshi (Nepal)	Eastern Brahmaputra (India)	Salween and Mekong (China)
Practice 1	Changed farming practices (22.4)	Given up planting certain crops (18.1)	Taken on new off-farm activities (11.1)	Migrated for work (23.3)
Practice 2	Introduced new crops (21.4)	Introduced new crops (15.2)	Given up planting certain crops (9.9)	Changed farming practices (16.9)
Practice 3	Given up planting certain crops (20.1)	Changed farming practices (12.5)	Invested in disaster preparedness (7.4)	Introduced new crops (13.9)
Practice 4	Given up rearing certain livestock (16.1)	Given up rearing certain livestock (9.1)	Changed farming practices (6.6)	Community jointly invested in irrigation (12.2)
Practice 5	Invested in disaster preparedness (11.2)	Changed grazing practices (7.6)	Introduced new crops (4.9)	Household invested in irrigation (11.6)

Figures in parenthesis are % HHs computed among those households who reported climate changes in last 10 years

Source: ICIMOD Survey 2011–12

Table 8 Household's income sources

	Income Sources	Upper Indus (Pakistan)	Koshi (Nepal)	Eastern Brahmaputra (India)	Salween & Mekong (China)
% of households who reported that agriculture and livestock are source of their income	Agriculture	49.4	49.6	43.8	55.7
	Livestock	31.3	41.8	41.7	41.9
% households who reported that agriculture & livestock are still their main sources of income	Agriculture	4.9	12.8	9.8	4.9
	Livestock	4.3	4.7	2.6	4.3
% households whose main portion of income comes from non-agricultural sources	Daily wage	20.6	18.6	27.2	32.5
	Salaried employment	21.5	16.8	24.7	7.4
	Other business/trade income	15.4	13.1	21.3	12.4
	Remittances	15.6	16.2	1.9	5.6
	No one major source	11.2	10.0	7.1	6.4

Source ICIMOD Survey 2011–12

food items from the market due to declining productivity and diversity in mountain agriculture. In Koshi, farm production is the main source of food for almost half of the households (Fig. 7). In EB and SM, home production is the main contributor to food consumption for 23 % and 38 % households, respectively. In the UI, only 10 % households reported that home production is the main source of their food requirements (Fig. 7). In all four SBs, households are heavily dependent on external sources of food such as stores and markets where food items are mostly supplied from downstream plain areas. It is also evident from food expenditure data in three SBs, i.e. UI, Koshi and EB, more than half of household monthly expenditure was spent on food items, whereas in SM, the share of food expenditure was 40 % (Fig. 8). The supply of food items from downstream areas is likely to be limited, particularly after hazards such as landslides blocking roads (Andersen et al. 2005; MoHP-Nepal 2012).

Food security strategies in the time of environmental shocks

While agriculture remains an important contributor to household food security in mountainous areas, non-agriculture sources such as daily wage, salaried employment, small businesses and remittances, are becoming increasingly important to sustaining livelihoods, especially for households with small landholdings (Rasul et al. 2014; Bhandari and Grant 2007). When environmental shocks occur such as floods, prolonged dry spells, drought or erratic rainfall, most farming households in the SBs face transitory food insecurity due to damage to their farming systems and other livelihood sources. In the UI and SM, 86 % and 91 %

Fig. 7 Households' food sources

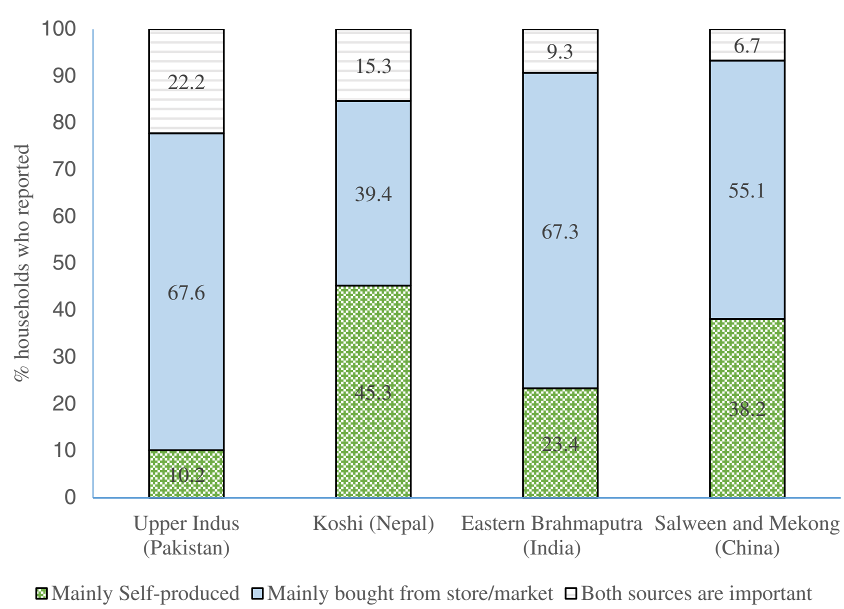


Fig. 8 Monthly food and non-food expenditures

households, respectively, reported that they had faced at least one shock in the 12 months prior to the survey, whereas in Koshi and EB, almost all households faced this situation (Table 9). Households adopt various strategies to reduce the impact of shocks on household food security. In the UI, one-fifth of households reported that they replaced expensive food items with the cheaper ones and about the same proportion borrowed money from relatives. Almost 14 % of households reduced their spending on clothing, whereas 10 % made changes in their farming practices, growing crops which take less time to harvest.

In Koshi and EB four out of five and three out of five strategies, respectively, to combat shocks threatening food supply involved borrowing money from different sources (Table 9). Those who did not borrow money bought food on credit from local shopkeepers or stores, sold livestock or reduced spending on clothing. Incurring debts as a coping strategy to obtain food or non-food items may be effective in the short term but debts may increase in the long term, negatively affecting community resilience and sustainable food security (Milbert 2009). In the SM, in addition to borrowing money, 21 % sought work outside the community, 18 % within the community, 19 % of adults restricted their consumption and 16 % spent savings on food.

Conclusions

In four river sub-basins (SBs) of the Hindu-Kush Himalayan region (HKH), i.e. Upper Indus (UI), Koshi, Eastern Brahmaputra (EB), and Salween and Mekong (SM), households perceived that increased incidences of natural hazards such as floods, droughts, landslides, livestock diseases, crop pests, erratic rainfall and temperature extremes, attributed to climate change, were significantly influencing agricultural production, income and household food security. Increased rates of out-migration have also resulted in labor shortages in agriculture, possibly adding to a decline in productivity, food availability and farm income. Traditionally, agriculture is assumed to contribute to the food security and livelihoods of households in the mountains through providing diverse food and contributing to household income. However, due to increasing vulnerabilities, the contribution of agriculture in household food consumption and household income has significantly decreased over time. Particularly in EB, the majority of farm households reported a notable decline in the production of almost all staple and cash crops, resulting in the least farm income compared to other SBs. Due to decreased food production, households' dependency on external food items supplied from downstream plain areas is increasing. Although agriculture and livestock are contributing to the income of a substantial proportion of households in SBs, yet these are no longer the main sources of income for the majority of households. Generally, in SBs, households have to rely on non-agricultural income sources to buy expensive food and non-food items, supplied from plain areas.

To cope with the climate change risks, households have adopted various strategies. These include changes in farming practices such as the introduction of new resilient crops, abandoning certain highly water consuming crops and giving up rearing certain livestock, which are vulnerable to water and fodder stress. In addition, households in UI and EB invested in preparedness for hazards such as floods and landslides, and in Koshi they made changes in livestock grazing practices to avoid excessive degradation of pastures and rangelands. In EB, a notable proportion of households took on new off-farm activities due to the increased vulnerability of agriculture. One-fourth of households in SM decided to migrate as an adaptation measure, either to other areas of China or overseas to find off-farm income opportunities. Households in this SB also invested in irrigation to cope with water stress.

Table 9 Food security strategies in the time of environmental shocks

		Upper Indus (Pakistan)	Koshi (Nepal)	Eastern Brahmaputra (India)	Salween & Mekong (China)
% HHs who faced problems in last 12 months		86	99	97	91
Coping strategies of HHs when faced shocks in last 12 months	Strategy 1	Relied on less expensive food (21.1)	Borrowed money from relatives (33.6)	Bought food on credit (39.4)	Borrowed money from relatives (25.2)
	Strategy 2	Borrowed money from relatives (18.4)	Borrowed money from money lenders (21.8)	Borrowed money from relatives (38.3)	Sought work elsewhere (21)
	Strategy 3	Reduced spending on clothes (13.5)	Borrowed money from friends (20.2)	Borrowed money from friends (34.8)	Restricted consumption of adults (19)
	Strategy 4	Changed farming practices (10.4)	Borrowed money from cooperative (18.7)	Sold livestock (28.6)	Sought employment in same community (17.8)
	Strategy 5	Relied on relief assistance (9.2)	Bought food on credit (14.4)	Reduced spending on clothes (23.1)	Spent savings on food (16.1)

Figures in parenthesis are % HHs who reported the strategies

Source ICIMOD Survey 2011–12

Although SBs have invested in adaptation practices to mitigate extreme climate events attributed to climate change, households in these areas still face transitory food insecurity when hazards, such as floods, landslides and droughts strike, owing to their effects on farming systems and other livelihood activities.

In view of this study's findings, the following policies are suggested in order to achieve sustainable food security in mountainous areas subject to extremes of climate.

- Governments need to establish separate food security policies for mountains and plains because mountains are different from plains in terms of nature, type and magnitude of vulnerabilities. There is also a need to re-evaluate agricultural policies under the projected changes in climatic conditions (Lu et al. 2012). Some current policies appear to be inappropriate. For example, the Nepalese government promotes cultivation of rice and pulses in mountainous areas, although these crops are resource-intensive and very sensitive to water stress.
- Climate change has also brought some opportunities, which are not adequately capitalized. For instance, In UI, a substantial proportion of households observed an increase in the production of summer vegetables and fruits such as apple, cherries, apricots and walnuts over the 10 years. Likewise, a significant proportion of households reported an increase in the production of summer potato, onion and vegetables in Koshi, tea in EB, and walnut, tea, garlic, tobacco and sugarcane in SM. National and sub-national planning processes should take into account such rising opportunities while preparing strategies to achieve sustainable food security in the SBs.
- Government and non-government experts in HKH countries need to identify the specific zones within the SBs with higher agro-ecological potential for specific high value crops such as fruits, nuts, vegetables, tea, tobacco and other cash crops. Strategies may focus on exploiting the existing potential through land use intensification, efficient water use, integration of livestock and crop diversification.
- Areas having less agro-ecological potential and that are highly vulnerable to hazards may be encouraged not to pursue agricultural activities. In such areas, strategies may focus on the subsistence use of resources, ecotourism and non-agricultural enterprises to reduce the dependence on local resources and ensure food security.
- Governments should encourage private investment in production and post-harvest facilities. There is also a need to improve accessibility to institutional services (i.e. roads, markets, extension services and technology (Rasul et al. 2014). Capitalizing on local potential and opportunities will also help to control out-migration, excessive switching to the non-farm sector and frequent labor shortages in agriculture.

Future research

This is a descriptive study of local perceptions of climate change, its attributable impacts on agriculture and food security, and local adaptive measures. In short, this study is a situation analysis of food security and climate change linkages in the study areas. It is hoped that it will provide a good platform for researchers to design and conduct empirical studies in the same areas to further understand the key factors of vulnerability and adaptation to climate change, and to establish different adaptive measures to achieve food security in the face of climate change.

Acknowledgments This study has been accomplished under the Himalayan Climate Change Adaptation Programme (HICAP) which is implemented jointly by International Centre for Integrated Mountain Development (ICIMOD), CICERO, and Grid-Arendal in four Hindu-Kush Himalayan (HKH) countries, i.e. Pakistan, China, Nepal and India. The HICAP is funded by the Ministry of Foreign Affairs, Norway, and Swedish International Development Agency (Sida). The authors also gratefully acknowledge the support of core donors of ICIMOD: the Governments of Afghanistan, Australia, Austria, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Norway, Pakistan, Switzerland and the United Kingdom. The views and interpretations in this publication are those of the authors and are not necessarily attributable to ICIMOD.

References

Abbas, Z. (2009). *Climate Change, Poverty and Environmental Crisis in the Disaster Prone Areas of Pakistan*. Pakistan: Oxfam Gilgit-Baltistan.

Andersen, P., Tuladhar, J. K., Karki, K. B., & Maskey, S. L. (Eds.) (2005). *Micronutrients in South and South East Asia*. Kathmandu: ICIMOD.

Bhatt, D., Maskey, S., Babel, M. S., Uhlenbrook, S., & Prasad, K. C. (2014). Climate trends and impacts on crop production in the Koshi River basin of Nepal. *Regional Environmental Change, 14*(4), 1291–1301.

Basu, A. K., & Bandhyopadhyay, P. K. (2004). The effect of season on the incidence of ticks. *Bulletin of Animal Health and Production in Africa, 52*(1), 39–42.

Bhandari, B. S., & Grant, M. (2007). Analysis of livelihood security: A case study in the Kali–Khola watershed of Nepal. *Journal of Environmental Management, 85*, 17–26.

Bharati, L., Gurung, P., & Jayakody, P. (2012). Hydrologic Characterization of the Koshi Basin and the Impact of Climate Change. *Hydro Nepal: Journal of Water, Energy and Environment* , 18–22. doi:10.3126/hn.v11i1.7198.Special Issue: Conference Proceedings 2012

Bhatta, L. D., van Oortb, B. E. H., Storkc, N. E., & Baral, H. (2015). Ecosystem services and livelihoods in a changing climate: Understanding local adaptations in the Upper Koshi. *Nepal. International Journal of Biodiversity Science, Ecosystem Services & Management., 11*(2), 145–155.

Chatterjee, B., & Khadka, M. (2013). *Farmers' Perception about Climate and Food Security: Evidence from South Asia. Conference on 'Redefining Paradigms of Sustainable Development in South Asia*. Pakistan: Sustainable Development Policy Institute (SDPI),.

Chen, N. S., Hu, G. S., Deng, W., Khanal, N., Zhu, Y. H., & Han, D. (2013). On the water hazards in the trans-boundary Kosi River Basin. *Natural Hazards and Earth System Sciences, 13*, 795–808.

Devkota, L. P., & Gyawali, D. R. (2015). Impacts of climate change on hydrological regime and water resources management of the Koshi River Basin. *Nepal Journal of Hydrology: Regional Studies, 4*, 502–515.

Dhakal, K., Silwal, S. & Khanal, G. 2010. Assessment of Climate Change Impacts on Water Resources and Vulnerability in Hills of Nepal. A Case Study on Dhare Khola Watershed of Dhading District Submitted to National Adaptation Program of Action (NAPA) to Climate Change Ministry of Environment, Government of Nepal.

Din, K., Tariq, S., Mahmood, A., & Rasul, G. (2014). Temperature and Precipitation: GLOF Triggering Indicators in Gilgit-Baltistan, Pakistan. *Pakistan Journal of Meteorology, Vol. 10*(20) : Jan. 2014.

Dixit, A., Upadhya, M., Dixit, K., Pokhrel, A. & Rai, D. R. 2009. Living with Water Stress in the Hills of the Koshi Basin, Nepal. Joint study of Institute for Social and Environmental Transition-Nepal (ISET-N), and International Centre for Integrated Mountain Development (ICIMOD)

FAO. 2008. *Food security in mountains – High time for action. Brochure of the International Mountain Day 2008.* http://www.fao.org/fileadmin/templates/mountainday/docs/pdf_2008/IMD08_brochure_En_LR.pdf (accessed 11 March 2015)

FAO (2013). *FAO Statistical Year Book 2013. Food and Agriculture Organization of the United Nations*. Italy: Rome.

FAO-AIPP-IWGIA (2015). *Shifting Cultivation, Livelihood and Food Security: New and Old Challenges for Indigenous People in Asia*. Bangkok: Published by the Food and Agriculture Organization of the United Nations and International Work Group For Indigenous Affairs and Asia Indigenous Peoples Pact.

FSA (2009). *Food Insecurity in Pakistan. Food Security Analysis 2009*. Pakistan: . Sustainable Development Policy Institute-Swiss Agency for Development and Cooperation-World Food Programme.

Ge, S., Yang, D. T., & Zhang, J. (2012). *Population Policies, Demographic Structural Changes, and the Chinese Household Saving Puzzle. IZA Discussion Paper No. 7026, November 2012. Forschungsinstitut zur Zukunft der Arbeit*. Germany: Institute for the Study of Labor. Bonn.

Ghimire, T. B., & Thakur, N. S. (2014). Constraint and opportunity of raw jute production: A case study of eastern Terai, Nepal. *Agronomy Journal of Nepal, 3*(1), 117–122.

Giribabu, M. (2013). Food and Nutritional Security in North East India: some contemporary issues. *International Journal of Development Research., 3*(5), 1–8.

GoPRC. 2007. China's National Climate Change Programme. National Development and Reform Commission. Government of People's Republic of China, Beijing, China. http://en.ndrc.gov.cn/newsrelease/200706/P020070604561191006823.pdf (Retrieved on 14 October 2015).

Government of Nepal (2011). *Water resources of Nepal in the context of climate change. Water and Energy Commission Secretariat*. Kathmandu, Nepal: Singha Durbar.

Gurung, G. B., & Bhandari, B. (2009). Integrated Approach to Climate Change Adaptation. *Journal of Forest and Livelihood, 8*(1), 91–99.

GWP-JVS. 2014. Traditional Climate Change Adaptation Practices by farmers in Nepal. Global Water Partnership (GWP) Nepal/ Jalsrot Vikas Sanstha (JVS). http://www.jvs-nwp.org.np/sites/default/files/Document%20Traditional%20Climate%20

Change%20Adaptation%20Practices%20by%20Farmers.pdf (Retrieved on 13 October, 2015).

Haslett, S., Jones, G., Isidro, M., & Sefton, A. (2014). *Small Area Estimation of Food Insecurity and Undernutrition in Nepal*. National Planning Commissions Secretariat, World Food Programme, UNICEF and World Bank, Kathmandu, Nepal: Central Bureau of Statistics.

Huddleston, B., Ataman, E., & d'Ostlanl, L. F. (2003). *Towards a GIS-based analysis of mountain environments and populations*. Rome, Italy: Food and Agricultural Organization http://www.fao.org/3/a-y4558e.pdf (accessed 13 March 2015).

Hussain, A., & Routray, J. K. (2012). Status and factors of food security in Pakistan. *International Journal of Development, 11*(2), 164–185.

Hussain, A., Agrawal, N. K., & Leikanger, I. (2016). Action for Adaptation: Bringing climate change science to policy makers - a synthesis report of a conference held in Islamabad on 23–25 July 2015. *Food Security., 8*(1), 285–289.

ICIMOD (2008) Food security in the Hindu Kush Himalayan region: A position paper. Kathmandu, Nepal: International Centre for Integrated Mountain Development (ICIMOD)

IFAD. 2015. Economic Transformation Initiative Gilgit-Baltistan: Programme Design Report. Asia and the Pacific Division, Programme Management Department. International Fund for Agricultural Development, Rome, Italy. https://webapps.ifad.org/members/eb/114/docs/EB-2015-114-R-14-Project-design-report.pdf (Retrieved on 12 October, 2015).

IFRC. 2015. Emergency Plan of Action (Pakistan Floods): A situation Analysis. International Federation of Red Cross and Red Crescent Societies (IFRC). adore.ifrc.org/Download.aspx?FileId=95372 (Retrieved on 12 October, 2015).

ISET. 2008. Climate Adaptation in Asia: Knowledge Gaps and Research Issues in South Asia. Institute for Social and Environmental Transition. Kathmandu, Nepal. http://www.preventionweb.net/files/8125_ClimateAdaptationSASept081.pdf (Retrieved on 15 October, 2015).

Keliang, Z., & Prosterman, R. (2007). *Securing Land Rights for Chinese Farmers: A Leap Forward for Stability and Growth*. The CATO Institute, Massachusetts Avenue, N.W., Washington, D.C.: Development Policy Analysis. Center for Global Liberty and Prosperity.

Khan, M. Z., Khan, B., Awan, S., Khan, G., & Ali, R. 2013. High-altitude rangelands and their Interfaces in Gilgit-Baltistan, Pakistan: Current Status and Management Strategies. In (ed.) Ning, Wu; Rawat, GS; Joshi, S; Ismail, M; Sharma, E., High-Altitude Rangelands and their Interfaces in the Hindu Kush Himalayas, Pages 189. ICIMOD, Kathmandu, Nepal

Laping, W. (2006). *Integration of China's Major Agricultural Product Markets. College of Economics & Management*. Beijing, China: , China Agricultural University Yuan Mingyuan http://cerdi.org/uploads/sfCmsContent/html/192/Wulaping.pdf (retrieved on 11 October, 2015).

Lu, J., Su, Y., Manandhar, S., & Ahmad, A. (2012). *The role of tree crops in local adaptations to climate variability – Cases in China, Nepal and Pakistan*. Kunming Institute of Botany: Centre for Mountain Ecosystem Studies.

Manzoor, M., Bibi, S., Manzoor, M., & Jabeen, R. (2013). Historical Analysis of Flood Information and Impacts Assessment and Associated Response in Pakistan (1947–2011). *Research Journal of Environmental and Earth Sciences, 5*(3), 139–146.

Milbert, I. (2009). Policy dimensions of human security and vulnerability challenges: The case of urban India". In H. G. Brauch (Ed.), *Facing global environmental change – environmental, human, energy, food, health and water security concepts, Berghof Foundation* (pp. 233–242). Berlin, Heidelberg: Springer.

Ministry of Health & Population Nepal (2012). *Nepal Demographic and Health Survey 2011*. Kathmandu, Nepal: Ministry of Health and Population, Kathmandu, Nepal.

MoHP-Nepal (2012). *Nepal Demographic and Health Survey 2011*. Kathmandu, Nepal: Ministry of Health and Population, New ERA, and ICF International, Calverton, Maryland.

Nautiyal, S., Kaechele, H., Rao, K. S., Maikhuri, R. K., & Saxena, K. G. (2007). Energy and economic analysis of traditional versus introduced crops cultivation in the mountains of the Indian Himalayas: A case study. *Energy, 32*, 2321–2335.

Pan, S. Malaga, A. & He, X. 2010. Market liberalization and crop planting decision: a case of China. *China Agricultural Economic Review*, Vol. 2 Iss: 3, pp. 240–250.

Park, A. 2008. Agricultural Development in China: Lessons for Ethiopia. Part of DFID funded study "Understanding the constraints to continued rapid growth in Ethiopia: the role of agriculture". Department of Economics, University of Oxford, UK. http://users.ox.ac.uk/~econstd/Brief_Park%20_rev_.pdf (retrieved on 11 October, 2015).

Rasul, G. (2011). The role of the Himalayan Mountain system in food security and agricultural sustainability in South Asia. *International Journal of Rural Management, 6*(1), 95–116.

Rasul, G., Hussain, A., Khan, M. A., Ahmad, F., & Jasra, A. W. (2014). Towards a framework for achieving food security in the mountains of Pakistan. In *ICIMOD Working Paper 2014/5*. Kathmandu: ICIMOD.

Rasul, G., & Hussain, A. (2015). Sustainable Food Security in the Mountains of Pakistan: Towards a Policy Framework. *Ecology of Food and Nutrition, 54*(6), 625–643.

Rasul, G., & Karki, M. (2007). *Pro-poor Policy Agenda for Sustainable Agriculture Development in the Hindu Kush-Himalayan region: Talking Points 2/07*. Kathmandu: ICOMOD.

Riley, N. E. (2004). China's Population: New Trends and Challenges. *Population Bulletin: a Publication the Population Reference Bureau, Washington, DC., 59*(2), 1–38.

Saikia, A. 2012. Jute or Flood: Exploring the fate of certain schemes in the Brahmaputra River Valley. Paper Presented to conference on "Resources: Endowment or Curse, Better or Worse? February 24–25, 2012, held in YALE UNIVERSITY, USA

Sarkar, A., Garg, R. D., & Sharma, N. (2012). RS-GIS Based Assessment of River Dynamics of Brahmaputra River in India. *Journal of Water Resource and Protection, 2012*(4), 63–72.

Shafiq, M., & Kakar, M.A. (2007). Effects of drought on livestock sector in Balochistan Province of Pakistan. International Journal of Agriculture and Biology 9(4):657–665.

Sikka, A. & C. Ringler, C. 2009. Introduction to the special issue. *International Journal River Basin Management*, Vol. 7 (2), 107–110.

Singh, A. P., Singla, L. D., & Singh, A. (2000). A study on the effects of macroclimatic factors on the seasonal population dynamics of *Boophilus microplus* infesting the crossbred cattle of Ludhiana district. *International Journal of Animal Sciences, 15*(1), 29–31.

Sirohi, S., & Michaelowa, A. (2007). Sufferer and cause: Indian livestock and climate change. *Climatic Change, 85*(3), 285–298.

Tiwari, P. (2000). Land-use changes in Himalaya and their impact on the plains ecosystem: need for sustainable land use. *Land Use Policy, 17*(2), 101–111.

Tiwari, P. C., & Joshi, B. (2012). Natural and socio-economic factors affecting food security in the Himalayas. *Food Security, 4*(2), 195–207.

Ward, F. A., Amer, S. A. & Ziaee, F. 2012. Water allocation rules in Afghanistan for improved food security.' *Food Security* 5(1): 35–53

World Bank (2009). *Why is South Asia Vulnerable to Climate Change?, The World Bank* .http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/0, retrieved on March 10, 2014

Yu, W., Yang, Y. C., Savitsky, A., Alford, D., & Brown, C. (2013). *The Indus basin of Pakistan: The impacts of climate risks on water and agriculture*. Washington DC, USA: World Bank Publications, The World Bank.

Zhen-Feng, M., Jia, L., & Shu-Qun, Y. (2013). Climate change in Southwest China during 1961–2010: impacts and adaptation. *Advances in Climate Change Research, 4*(4), 223–229.

Zulfiqar, F., & Hussain, A. (2014). Forecasting wheat production gaps to assess the state of future food security in Pakistan. Journal of Food and Nutritional Disorders, 3(3):1–6.

Dr. Abid Hussain a Pakistani national, joined the International Centre for Integrated Mountain Development (ICIMOD), Nepal, in December 2013 as a Food Security Economist. Prior to joining ICIMOD, he served as Assistant Professor at the Department of Economics in the University of Haripur, Khyber Pakhtunkhwa, Pakistan. He also served in the same position in the Department of Economics and Agricultural Economics at Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan. He was responsible for teaching advanced economics courses to MPhil and PhD students. He also supervised the research of post-graduate students who were mainly working in the areas of agriculture and food security, energy conservation and women empowerment. Dr. Hussain holds a PhD in Regional and Rural Development Planning (RRDP) from the Asian Institute of Technology (AIT), Thailand, from which he had earlier earned a Master degree in RRDP. Dr Hussain also has a bachelor's degree in Agricultural Economics from the University of Agriculture, Faisalabad (UAF), Pakistan. Dr. Hussain has been working on food security and poverty issues for more than six years in different capacities in different organizations. His areas of expertise include food and nutrition security, agricultural credit, poverty, smallholder farming, and conservation agriculture. His research findings have been published in reputable international journals.

Dr. Golam Rasul is a senior economist and leader of Livelihoods Theme, at the International Centre for Integrated Mountain Development (ICIMOD), Nepal. Dr Rasul holds a PhD in regional and rural development planning from the Asian Institute of Technology (AIT), Thailand. He has been working on food, water and energy security issues in the Hindu-Kush Himalayan region for more than a decade. He has been actively involved in research in areas that include agriculture, food and nutrition security, food-water-energy nexus, natural resource management, poverty alleviation, and sustainable development in the Hindu Kush Himalayan region. His research findings have been published in many international journals and four of his papers have appeared as 'most read papers' in their respective journals in Science Direct.

Dr. Bidhubhusan Mahapatra was working as Survey Research Specialist at the International Centre for Integrated Mountain Development (ICIMOD). Recently, he has joined Room to Read, New Delhi, India as South Asia Research, Monitoring and Evaluation Manager. He holds a Ph.D. in Population Studies from the International Institute for Population Sciences, Mumbai, India. He has more than 6 years experience in designing, implementing and evaluating research tools in the areas of health, education, food security and climate change. Dr Mahapatra has published more than three dozen high quality research papers in reputable journals.

Ms. Sabarnee Tuladhar is working as a Research Associate–Statistics at the International Centre for Integrated Mountain Development (ICIMOD). She has almost 4-years' experience on framing data collection, cleaning and analysis tools. Recently, she has been working on a Poverty and Vulnerability Assessment (PVA) tool with a focus on climate change. She holds a Master Degree in International Development and Environmental Analysis from Monash University, Australia.