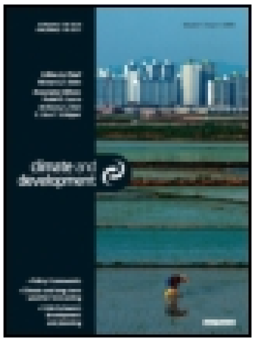

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Climate change and high-altitude food security: a small-scale study from the *Karnali* region in Nepal

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ABSTRACT

This study attempted to understand the local perspective on climate change and its impacts on agriculture and household food security in the *Karnali* region of Nepal – one of the most inaccessible and least researched mountain regions in Nepal. Using the small-scale survey data collected in 2017 from farm households in *Tatopani* rural municipality of *Jumla* district, the study found that a majority of households perceived changes in temperature and rainfall patterns, timing of seasons, incidence of drought and water availability, compared with the situation 10 years ago (2007 or earlier). They perceived mixed impacts of climate change on the production of major crops: a decline in the production of brown rice, wheat and barley, and an increase in the production of potato and local beans. Food security analysis showed that farm households had low dietary diversity, and 42% of them were food insecure. Regression analysis found that perceived climate-induced changes in water availability, timing of seasons, incidence of hazards and incidence of crop pest attacks had negative relationship with household food security. Based on the findings, the study suggested some key strategies to improve local food security in the face of climate change in the study area and other similar areas.

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Climate change; agriculture; household food security; mountains; *Karnali* region; Nepal

1. Introduction

In the Hindu Kush Himalaya (HKH),[1] around one-third of the population is suffering from food insecurity and almost half is facing malnutrition (Rasul et al., 2019). In the HKH, two challenges out of many – climate change and agrobiodiversity loss – are the most important factors severely affecting the food and nutrition security (Hussain & Qamar, 2020). In last three decades, climate induced changes such as changes in temperature and precipitation patterns, frequent floods, prolonged droughts and changes in timing of seasons have significantly affected crops and livestock productivity, people's economic access to food and overall sustainability in mountain food systems (Devkota, 2014; Hussain & Qamar, 2020; Mertz et al., 2009). Likewise, declining agrobiodiversity is affecting the dietary diversity and nutrition security of the people in the HKH (Adhikari et al., 2017, 2019; Rasul et al., 2019).

In Nepal, nearly 60% households in mountain regions are food insecure (NDHS 2016). In mountain regions, climate change is severely impacting water resources, agriculture, food security and local livelihoods (Bandara & Cai, 2014; Gautam & Andersen, 2016; Karki et al., 2020; Paudel et al., 2020; Rasul et al., 2019). Projections suggest that in general wet seasons are likely to become wetter and dry seasons to become drier that can result in high variability in water availability for agriculture, low crop productivity and degradation of rangelands and pasture with a loss of soil nutrients (Hussain et al., 2018; Poudel et al., 2017). A majority of mountain farmers are autonomously adopting different practices to cope with the severe impacts of these changes (Bartlett et al., 2010; Hussain et al., 2018; Khanal et al., 2019; Saikia, 2012; Sarkar et al., 2012).

The *Karnali* region (now province [2]) is considered as one of the most vulnerable mountain regions to food insecurity in Nepal due to high climate induced impacts, changing agricultural systems, inadequate access to production technology, high rate of outmigration of the youth, poor road connectivity, market inaccessibility and difficult terrain (Paudel et al., 2010; Pokhrel & Pandey, 2011). In this region, around 80% households are vulnerable to food insecurity (NDHS, 2016). Some studies (Adhikari, 2008; Paudel et al., 2010) found that in the *Karnali* region (now province), climate change has resulted in a decline in snowfall and overall water availability in rivers during the winter, and a decline in rainfall in summer (Adhikari, 2008; Paudel et al., 2010). The incidence of climate induced extreme events, particularly drought, has also increased in the region (Shrestha & Aryal, 2011). Changes in precipitation patterns and incidence of drought induce very serious impacts on crop growth and production when they coincide with critical crop stages such as flowering (Poudel & Kotani, 2013). Climate-induced changes are directly affecting the livelihoods of the local farmers who already face high poverty and food insecurity (Gautam, 2019). The scenario gets worse during hazards (e.g. landslides) which affect food supply and sometimes result in a rise in food prices (Rasul et al., 2019).

Despite having limited accessibility, high food insecurity and facing severe impacts of climate change, an adequate attentions has not been paid to the *Karnali* region in research.

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There is dearth of good quality local level studies on impacts of climate change on agriculture and food security in this region. Historically, the agriculture of this region has been characterized by traditional food crops such as buckwheat, barley and millets. There is little known on the changes happening in the local agricultural systems and climate-induced impacts on agriculture and household food security. This academic study attempts to fill this knowledge gap. First, this study qualitatively examines the changes in agricultural systems in response to climate change in last 10 years. Second, it documents the local perception of climate change and its perceived impacts on crops and livestock. Study also attempts to validate the climate data with local perceptions on climate change. Finally, the study statistically tests the relationship of perceived climate change with household food security status using the regression models. In general, perception based climate studies relatively have low reliability and external validity compared with pure quantitative studies relying on time series observed climatic and recoded agricultural data. Despite this limitation, this study makes a significant contribution to existing literature on the linkages of climate change, agriculture and household food security the least researched mountain region – *Karnali* – in Nepal.

2. Methodology

2.1. Study area

For this study, *Jumla* district (Figure 1) from *Karnali* region was purposively selected due to its high vulnerability to food insecurity despite the having the diverse agriculture production systems. Moreover, this district is experiencing severe impacts of climate change on local agriculture and food security but there is dearth of good quality empirical studies on the subject. The district is located in the north-west of Nepal and is considered as the original home of the *Khas* ethnic group. It is mountainous, and the elevation ranges from 915 meter to 4679 metre above sea level (masl). More than 90% population still depends on local agriculture for their food consumption. Agriculture also heavily contributes to the income and livelihoods of around 45% population in the district. It is characterized by diverse range of crops (including traditional crops) and livestock. The district, with sub-alpine and alpine climate, has total 39,486 ha of cultivable land, and a significant portion of its territory is grass-land and highland meadow, often used for grazing Himalayan goats, sheep and yaks. The district is also abundant in medicinal herbs with great potential for sustainable economic development. On average 65–70% of cultivable land is actually cultivated in the district, and only 12% of cultivated land is irrigated. From November to April, most areas of the district receive snowfall. The annual temperature ranges from −10°C (November–January) to 30°C (May–July), and annual rainfall ranges from 600 to 850 mm (GoN, 2015).

2.2. Sample size and sampling design

This study was mainly based on small scale survey design. However, it also used on some secondary data sources and qualitative information collected through focus group discussions and key informant interviews. For survey, Cochran's formula (Cochran, 1977) (Equation 1) was used to estimate the sample size.

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

In Equation (1), n denotes the sample size, and$p$ is the percentage of households picking a choice (expressed as decimal = 0.5) and $(p) \times (1 - p)$expresses an estimate of variance. Z Denotes Z-value (1.96 for 95% confidence interval), e denotes the margin of error (±0.1), and $R$is the factor (1.05) which covers the 5% non-response rate of households. Using the equation (Equation 1), a sample size of 101 households was determined. However, in total, 102 households were actually surveyed. To survey the sampled households, random sampling design was applied. In first step, one rural municipality '*Tatopani*' was selected randomly out of total eight municipalities of the district – one urban and seven rural. The elevation of the selected rural municipality ranges from 2000 to 4600 masl. In second step, one ward (number 4) was selected randomly from total eight wards of the rural municipality. In the ward, households were also selected randomly using the 'random route procedure'. Despite following the random selection procedure in all three steps of sampling design, this study still remains a non-representative small-scale study due to its small sample size and limited geographical coverage (only one ward of a single rural municipality). Therefore, researchers suggest not to generalize study findings for the whole *Karnali* region.

2.3. Data collection

To conduct household survey, a standardized questionnaire was administered, covering the aspects of households' socio-economic status, perceptions of climate change and its perceived impacts on agriculture and household food security. In addition to questionnaire survey, key Informant Interviews (KII), Focus Group Discussions (FGDs) and Field Observation (FO) tools were used to procure qualitative information. KII were conducted with local leaders and elderly people to validate the household data and obtain in-depth information on cropping systems. Likewise, FDGs were conducted to procure information on cropping systems, and to identify the key factors which influence household food security. FO was used to observe the type of crops, irrigation system and other farm practices.

In addition to primary data, some important secondary data on climatic parameters, e.g. temperature, humidity and rainfall, was also collected from the nearest hydro-metrological station of the Department of Hydrology and Meteorology (DHM) of Nepal. The station (8 km from study site) is located at the altitude of 2300 masl. The rainfall data for the period 1957–2016, humidity and temperature for 1977–2016, and number of rainy days for 1980–2016 was collected.

2.4. Data analysis

Secondary time series data of climatic parameters, e.g. annual rainfall, relative humidity, annual minimum and maximum temperatures and number of rainy days, has been presented

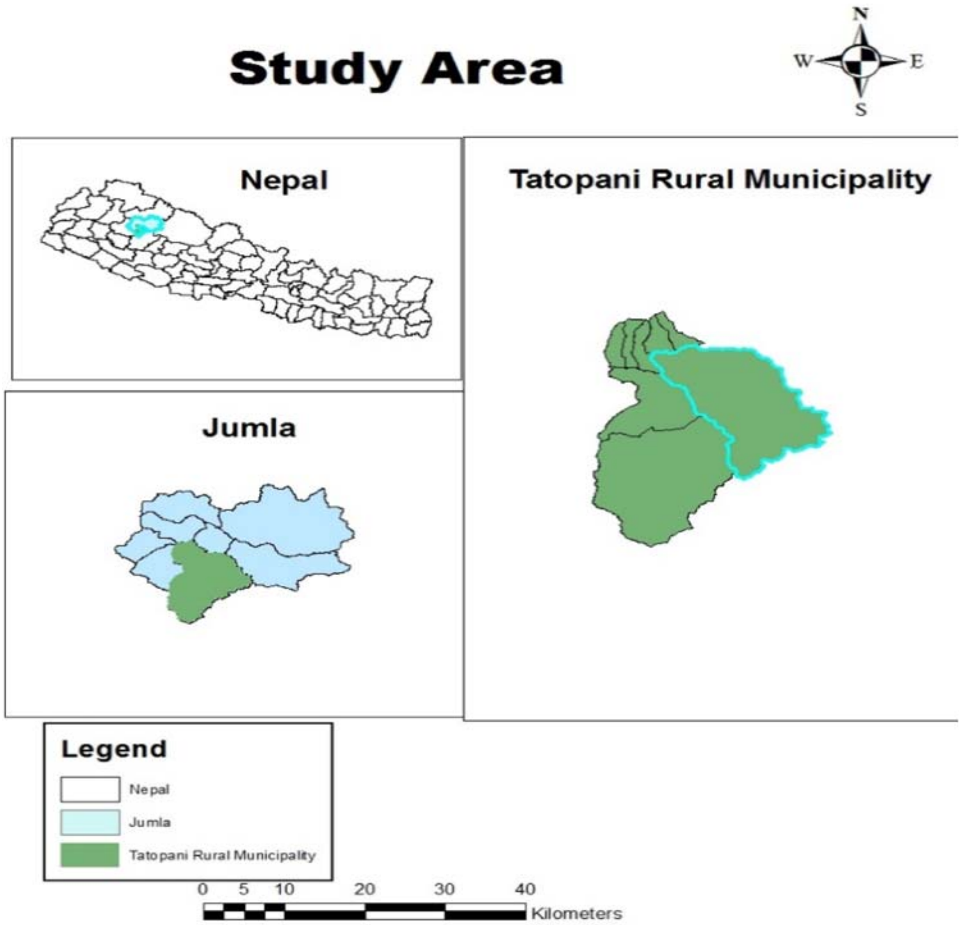

Figure 1. Study area in Jumla District, Nepal.

in graphical forms to observe the trend over the years. In trend lines, the accuracy of the fit and statistical significance has been interpreted respectively using the *R*-squared and *P*-values.

For analysis of household data, mainly descriptive statistics (averages, frequencies and percentages) have been used. For food security assessment, the study has estimated the household dietary energy intake (kilocalorie/day/capita), food variety score (FVS) and dietary diversity score (DDS).

In the questionnaire survey, households' weekly food consumption data was procured. They were asked to recall and report all food items which were consumed by them in the last 7 days (before the day of survey). They were also asked to report the quantities of consumed food items. Weekly food consumption data was converted into dietary energy (kilocalorie/day/capita) based on the official 'food composition table' of Nepal (GoN, 2012). It is important to mention that number of household members were converted to 'adult equivalent' using the criteria presented by Hussain et al. (2014). Therefore, in this study, 'per capita' refers to 'per adult equivalent'. To estimate FVS and DDS of individuals and households, two time periods - 24 hours or 7 days – are considered as standard recall periods in the literature on food and nutrition security assessment. In this study, 7 days recall method was applied because 24 hours recall data is more likely to result in biased estimation due to the effect of some social events (e.g. arrival of guests at home, funerals, social festivals or traveling of any household member). Moreover, the occasionally consumed food items (e.g. animal proteins, fresh and dried fruits, nuts, and vegetables) are difficult to capture in the 24 hours recall (Arimond & Ruel, 2002; Kant et al., 1993). Based on these facts, the study applied 7 days recall method. FVS was estimated by simple count of individual food items in last 7 days, and DDS was estimated by summing the number of unique food groups consumed by individuals in 7 days (Hussain et al., 2014; Kant et al., 1993).

Food groups considered were cereals, fruits, vegetables, meat and pulses, milk, fats and oil, and sweets (Hussain et al., 2014; USDA, 1992). Cereals group rich in carbohydrates included raw grains, flour and all processed cereal products such as bread and biscuits. A diverse range of vegetables and fruits were included in their respective groups. Both these groups were considered as rich source of vitamins, fiber and micronutrients. The group of meat and pulses is considered as a rich source of proteins. In addition to all types of meat and pulses, this group also included fish, egg and nuts. Due to its high importance, milk was considered as a separate group. It included yogurt, cheese and all local products prepared from milk. The group of fats and oil included butter, local and processed ghee, and cooking oil. The group of sweets considered as a rich source of sugars included all types of traditional and bakery sweets.

To analyse the statistical relationship of household perceptions of climate change with their food security (variables:

calorie intake, food variety score and dietary diversity score), Ordinary Least Squared (OLS) regression model (Equation 2) was used.

$$Y = \alpha + B1X1 + B2X2 + \cdots + B10X10 + e \qquad (2)$$

In equation (Equation 2), 'α' is constant, and $B1$ to $B10$ are coefficients of respective variables. 'e' is the error term in the model. 'Y' denotes the dependent variable. In this study, three models are run separately for dependent variables – calorie intake (CI), FVS and DDS. All three models included 10 independent variables – decline in water availability (X_1), change in timing of seasons (X_2), increase in the incidence of crop pest attacks (X_3), increase in the incidence of livestock disease (X_4), increase in the incidence of hazards (landslides and soil erosions on farm lands) (X_5), household size (X_6), female to male ratio (X_7), migrant sending household (X_8), number of income sources (X_9) and share of agricultural income in total household income (%) (X_{10}). Variables from X_1 to X_5 are household perceptions of climate-induced changes (decline, increase or overall change) at farm level showing variation across farms due to land slope and types of crops. It is also important to highlight that all 10 variables were mainly selected based on the focus group discussions in the study site. During the process, group of peoples and key informants were asked to enlist the key climatic factors which influence the local food systems and food security. Preceding climate perception studies (Bandara & Cai, 2014; Devkota, 2014; Gautam & Andersen, 2016; Hussain et al., 2016; Karki et al., 2020; Mertz et al., 2009; Paudel et al., 2020; Poudel et al., 2017) were also very useful to shortlist the reported list of climatic factors by the local people. Related to variable 'X_5', households reported drought and landslides as the most important hazards which had been affecting respectively local agricultural productivity and supply of food items from other areas. However, due to the uniformity in households' response on drought occurrence in survey data (96% households reported an increase in drought incidence), it has not been included in variable 'X_5'. Moreover, drought was also a suspected endogenous variable to perceived decline in water availability (X_1). Thus only the occurrence of landslides and soil erosions on farm land is considered to construct the proxy variable for climate-induced hazards.

In regression analysis, climate perception variables are considered as 'cross-sectional data' because these are the perceived differences (one-time dummy variables) by households in the current climatic situation compared with the situation 10 years ago. The statistical relationship of cross-sectional food security indicators with these perception variables should be considered as 'indicative message', which can be further investigated in future research, using the time series data of observed climatic variables and food security indicators.

3. Results

3.1. Climatic trends

The Annual rainfall data from 1957 to 2016 was examined. The highest rainfall occurred in 1975 (1157 mm) and the lowest in 1965 (491 mm). Overall, annual rainfall did not show a

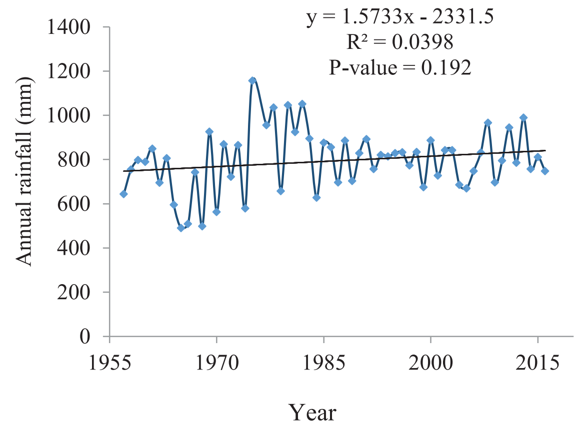

Figure 2. Annual rainfall trend (1957–2016).

statistically significant trend (Figure 2). Annual relative humidity (ARH) showed a declining trend from 1977 to 2016 (statistically significant). The highest ARH (70.2) was recorded in 2000 and the lowest in 2010 (45.2) (Figure 3). The average annual maximum temperature from 1977 to 2016 showed an increasing trend (statistically significant). The highest average maximum temperature (22.2°C) was recorded in 2016. The lowest average maximum temperature (19.5°C) was recorded in 1978 and 1981 (Figure 4). The average annual minimum temperature from 1977 to 2016 also showed an increasing trend (statically significant). The highest average minimum temperature (6.4°C) was recorded in 2016, and the lowest (2.1°C) in 2000. The minimum average temperature was found below 0°C in the years 1970, 1973 and 1974 which was −0.26°C, −0.22°C and −1.3°C respectively (Figure 5). Number of rainy days (annual) did not show a statistically significant trend over the years (1980–2016) (Figure 6).

3.2. Socioeconomic characteristics of households

Among the total surveyed households, around 80% were headed by males, and only 20% were headed by females. More than half of household heads were illiterate. Even among the literate heads, more than 40% just completed the primary education, implying that level of education is very low in the study area (Table 1). In the study area, several

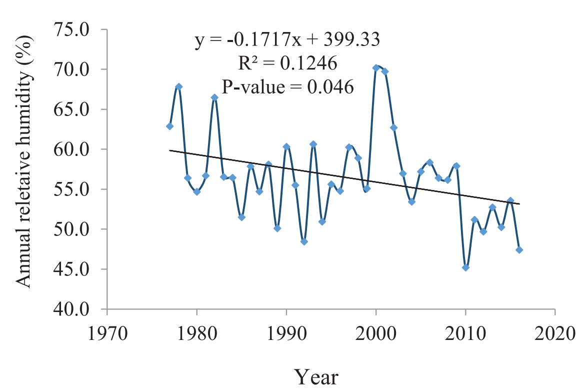

Figure 3. Annual relative humidity trend (1977–2016).

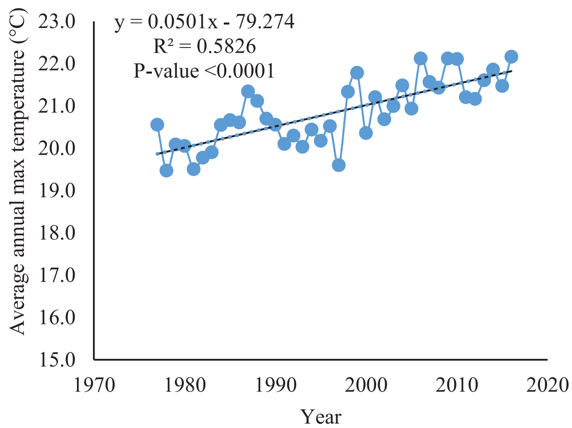

Figure 4. Average annual maximum temperature (1977–2016).

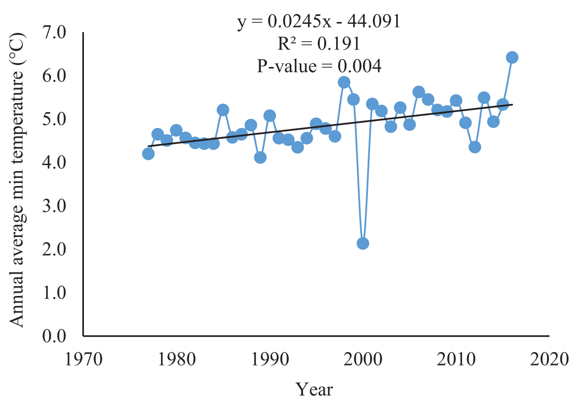

Figure 5. Average annual minimum temperature (1977–2016).

new income sources (e.g. remittances, honey beekeeping and small businesses) are emerging but agriculture still remains the main source of income and livelihoods for the local people. Results showed that more than 90% households were dependent on agriculture for their income. Livestock was also an important income source for around 45% households. Casual labor was a source of income for more than 60% households. In the recent past, the local people started out-migrating in search of income opportunities in other areas of Nepal or abroad (particularly India). Remittances sent by out-migrants contributed to the income of around one-fifth households (Table 1). Among other income sources, salaried employment, pension/social grants and small businesses were also reported as income sources.

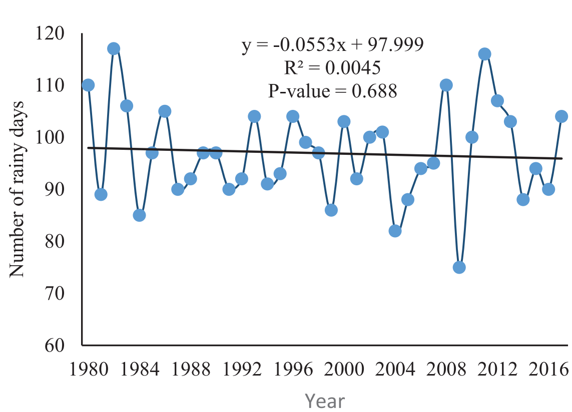

Figure 6. Number of rainy days (annual) (1980–2016).

Table 1. Households' socioeconomic characteristics.

Characteristics	Specifications	Statistics
Household head's sex (%)	Male	81
	Female	19
Household head's level of education (%)	Illiterate	51
	Primary schooling	41
	Intermediate	3
	Bachelors	4
	Masters	1
	Above Masters	0
Main income sources (% households)	Agriculture	91
	Livestock	44
	Remittances	22
	Pension/social grants	14
	Salaried employment	29
	Casual labor	62
	Own small business	8
	Honey beekeeping	6
Household's access to insurance facility	Yes	3
	No	97
Households' agricultural landholding status (%)	Landless	5
	Landowners	95
Average size of owned agricultural land (hectare)		0.6 (0.4)
Average size of irrigated agricultural land (hectare)		0.2 (0.2)
Average size of agricultural land dependent on rainfall (hectare)		0.4 (0.3)
Food secure households (%)		58

Figures in parentheses are respective standard deviations.
Source: Field Survey 2017.

In the study area, an overwhelming majority of households (95%) owned agricultural land but the average size of land was very small (0.6 ha). Around two-third of agricultural land was completely dependent on rainfall. However, one-third land had partial or full access to small-scale farmers' managed irrigation systems (Table 1).

3.3. Household perception of climate change

Almost all surveyed households perceived an increase in overall and summer and winter temperatures, and a decline in average amount of rainfall and snowfall, compared with the situation 10 years ago. Likewise, around half of the households perceived a decline in average amount of hailing. Almost all households perceived an increase in a number of dry days per year (Table 2). Around 95% households reported that incidence of erratic rainfall and drought increased, compared with the situation 10 years ago. However, only a small percentage of them (around 5%) reported an increase in the incidence of flood. Around 50% of households reported a decrease in the incidence of hailstorms, and 21% of them reported an increase in the incidence of landslides (Table 2).

Around 55% households reported a decline in water availability for crops and livestock, compared with the situation 10 years ago (Table 2). More than two-third households reported an increase in the drying up of freshwater resource such as springs. More than 80% households reported an increase in the incidence of crop pest attacks, and only one-fifth of them perceived an increase in the incidence of livestock diseases.

Table 2. Household perception of climate change.

Perceived changes*		% reporting households: No change	Increased	decreased
Climatic indicators	Overall temperature	0	100	0
	Average temperature in summers	0	100	0
	Average temperature in winters	0	94	6
	Average amount of rainfall	0	1	99
	Average amount of snowfall	1	0	99
	Average amount of hailing	39	12	49
	Number of dry days per year	1	99	0
Incidence of climate-induced hazards	Drought	4	96	0
	Flood	96	4	0
	Water logging	95	2	3
	Windstorm	98	2	0
	Hailstorm	39	13	48
	Erratic rainfall	4	96	0
	Landslide/soil erosions	79	21	0
Climate change induced impacts	Water availability for crops and livestock	45	2	53
	Drying up of fresh water sources (e.g. springs)	33	64	2
	Incidence of crop pest attacks	18	82	0
	Incidence of livestock diseases	78	22	0
	Crop productivity	1	0	99
	Livestock productivity	90	0	10
	Degradation of rangelands/pastures	90	10	0

*Current situation compared with the situation 10 years ago (2007 or earlier).
Source: Field Survey 2017.

However, almost all households reported a decline in the productivity of crops due to climate change. On the other hand, 90% households perceived no change in livestock productivity in last 10 years. It may be because of very less impact of climate change on rangelands and on the incidence of livestock diseases (Table 2).

Households also perceived changes in the timings of seasons in last 10 years. More than 90% households reported the early start and delayed end of the summer. Similarly, around 98% households reported the delayed start and early end of the winter. It implies that the summer is longer, and the winter is shorter now compared with the situation 10 years ago. Almost all households reported a delayed start of monsoon, and two-third of them reported early end of this season (Table 3). It reveals that a majority of households perceive that monsoon duration has shrunk in last 10 years.

Table 3. Household perception of changes in timing of seasons.

Timing of seasons	% households perceiving changes* in timing of seasons: No change	Delayed	Early
Start of summer	8.8	1.0	90.2
End of summer	8.8	89.2	2.0
Start of winter	2.9	97.1	0
End of winter	2.9	2.0	95.1
Start of monsoon	2.0	98	0
End of monsoon	30.4	2.9	66.7

*Current situation compared with the situation 10 years ago (2007 or earlier).
Source: Field Survey 2017.

Table 4. Comparison of climatic data with household perception of climate change.

Indicators	Climatic data	Household perception*	Remarks
Average rainfall	Statistically non-significant trend	Households perceived a decline in average rainfall	It may be considered consistent.
Average temperature	Average minimum and maximum temperatures showed an increasing trend (statistically significant)	Households perceived an increase in overall, summer and winter temperatures	Consistent
Relative humidity (RH)	RH showed a decreasing trend (statistically significant)	Households perceived an increase in number of dry days (assumed as an inverse proxy of humidity)	Consistent
Number of rainy days per year	Statistically non-significant trend	Households perceived a decline in average rainfall (proxy of a number of rainy days)	It may be considered consistent

*Current situation compared with the situation 10 years ago (2007 or earlier).

Comparison of the climatic data and household perception of climate change were made to cross-validate the information (Table 4). Both climatic and perception data showed an increase in average temperature (Table 2, Figures 4 and 5). Annual relative humidity showed a decreasing trend in climatic data (Figure 3). Perception data showed an increase in a number of dry days and a decline in average annual rainfall (Table 2). The variable 'number of dry days' was considered as an inverse proxy of relative humidity. It showed a consistency with the climatic data on relative humidity. Climatic data for average annual rainfall and number of rainy days did not show statistically significant trend over the years (Table 2).

3.4. Agriculture system and perceived impacts of climate change

The agriculture systems in the *Karnali* region were historically characterized by a vast range of traditional food crops and local breeds of livestock. In the focus group discussions, the local people highlighted that around 10 years ago, study areas was mainly producing traditional crops such as barley, millets, horse gram, black gram, indigenous brown rice (*Jumli Marshi*), indigenous beans and buckwheat. Among these crops, only brown rice and barley remain among the main crops. Key informants reported that brown rice is more resilient to extreme cold conditions and can be grown even up to the altitude of 3000 masl. They also reported that it has been an integral part of local agriculture systems for centuries. Survey data also shows that around 96% farmers cultivated brown rice, and around 80% cultivated local beans and potato. Likewise, almost 75% and 65% cultivated respectively barley and wheat (Table 5). In focus group discussions, farmers reported that they gradually replaced traditional crops, e.g. proso-millet, foxtail millet, black gram, horse gram and buckwheat by potato, wheat and vegetables in response to low market value of traditional crops and changing dietary habits of local people. Among vegetables, households mainly cultivated mustard, cucumber, squashes, peas, onions, carrot, radish, tomato, coriander, brinjal and garlic. In field some fruits such as banana, plum, grapes, and apricot trees were also observed during field survey.

An overwhelming majority of household perceived impacts of climate change on the production of main crops compared with the situation 10 years ago. More than 90% households reported that climate change has impacted brown rice, local beans and potato. Very interestingly, a majority has reported positive impacts on the production of local beans and potato. However, on brown rice and wheat production, a majority of farmers reported negative impacts (Table 5). Around half of the households reported negative impact of climate change on barley production. Despite being located in same geographical area, the possible reasons of variations in household perception of climate-induced impacts on crops include the difference in slope and altitude of cultivated land and distance from the water sources. These natural factors determine the severity of climate change impacts on agriculture and variation in farmers' adaptation measures in mountain areas, as reported by other studies from the HKH (Rasul et al., 2019; Tiwari & Joshi, 2012).

The main livestock in study area included cow, ox, goat, horse and poultry (Table 6). Cow and ox were the major livestock reared by households. A majority of households did not report notable impact of climate change on their livestock production (Table 6). This may be because of very low impact of climate change on rangelands and pastures in the area (Table 2).

3.5. Household food security

To analyse household food security, three main aspects of food security, e.g. food variety score (FVS), dietary diversity score (DDS) and calorie intake (kcal per day per capita), were estimated. Analysis showed that mean FVS and DDS of households were 14 and 4.2 respectively (Table 7). It implies that households consumed on average 14 types of food items in the last 7 days. They consumed these items from four nutritionally distinct food groups. The mean value of calorie intake was almost 2728 kcal per day per capita. The mean value does not show the clear status of household food security, particularly after observing large ranges in the values of FVS (9-19), DDS (2-6) and calorie intake (453–9363 kcal) (Table 7). It showed that food security status varied significantly across households. To further investigate it, calorie intake at household level was compared with the national line of adequate calorie intake of 2220 kcal per day per capita set by the government of Nepal (CBS, 2012). It was found that nearly 58% households were food secure, and 42% were food insecure (Table 1).

In terms of contribution of different food groups in calorie intake, cereals remained the main food group with around 77% contribution (Figure 7). Meat and pulses contributes respectively 2% and 13% to calorie intake. Other food groups – fruits, vegetables, milk, fats and oils and sweets collectively contributed only 8% to total calorie intake (Figure 7). It implies that diet of the households is not diverse and heavily dominated by cereals.

Table 5. Perception of climate change impacts on agriculture.

Five main crops*	% households who cultivated particular crops in last 12 months	% households who perceived climate change impacts on crops during last 10 years	% households who perceived changes** in crop production due to climate change		
			Increased	Decreased	No change
Brown rice	95.9	97.9	1.0	96.9	2.1
Local beans	84.3	96.6	85.2	11.4	3.4
Potato	79.4	90.6	50.6	41.0	8.4
Barley	74.5	62.6	13.8	48.8	37.4
Wheat	64.7	82.8	21.4	61.4	17.2

*Five main crops were identified based on the percentage of households (see column 2) who cultivated them in last 12 months. This criteria of 'percentage of households' was only used to rank crops. In fact, farmers have been cultivating these crops in the study area for several decades.
**Current situation compared with the situation 10 years ago (2007 or earlier).
Source: Field Survey 2017.

Table 6. Perception of climate change impacts on livestock.

Five main livestock types	% households who raised the particular livestock in last 12 months	% household who perceived a decline in livestock production*	
		Yes	No
Cow	72.5	2.7	97.3
Ox	58.8	0.0	100.0
Goat	26.5	14.8	85.2
Horse	23.5	4.2	95.8
Poultry	22.5	0.0	100.0

*Compared with the level of production 10 years ago (2007 or earlier).
Source: Field Survey 2017.

3.6. Relationship of climate change perceptions and household food security

Variables which were included in the regression analysis to investigate the linkages of climate change perceptions and household food security are presented in Table 7. Key independent variables – from X_1 to X_5 – have already been interpreted in the subsection on household perception of climate change. Variables from X_6 to X_{10} are control variables (CVs) included to avoid omitted-variable bias in the regression estimates. Descriptive statistics of CVs showed that mean household size of the surveyed sample was almost 6, and female to male ratio was 1.17. More than 50% households reported that they had sent at least one member from household (out-migrants) to other areas of Nepal or abroad in search of better income opportunities. Households have on average three income sources including agriculture and non-agriculture sources (Table 7). However, on average, agriculture contributes almost 30% to total household income.

Table 7. Description of variables.

Variables	Variable type	Specification	Mean	Standard deviations
*Calorie intake (CI)	Dependent	kilocalorie (kcal) per day per capita (adult equivalent)	2727.64	1442.61
Food variety score (FVS)	Dependent	Number of food items consumed in one week	14.42 (9-19)**	8.11
Dietary diversity score (DDS)	Dependent	Number of nutritionally distinct food groups consumed in one week	4.20 (2-6)**	0.92
Decline in water availability (X_1)	Independent	If household perceived a decline in water availability = 1; Otherwise = 0	0.53	0.50
Change in the timing of seasons (X_2)***	Independent	Cumulative score of responses (Yes = 1; No = 0) on six questions on timing of start and end of summer, winter and monsoon.	5.45	0.92
Increase in the incidence of crop pest attacks (X_3)	Independent	If household perceived an increase in the incidence of pest attacks on crops = 1; Otherwise = 0	0.82	0.38
Increase in the incidence of livestock diseases (X_4)	Independent	If household perceived an increase in the incidence of livestock disease = 1; Otherwise = 0	0.22	0.41
Increase in the incidence of hazards (X_5)	Independent	If household perceived an increase in the incidence of landslides and soil erosions = 1; Otherwise = 0	0.21	0.41
Household size (X_6)	Control	Number of members in the household	5.97	2.41
Female to male ratio (X_7)	Control	Female members divided by male members of the household	1.17	0.87
Migrant sending household (X_8)	Control	If household sent at least one migrant to other places for more than 6 months = 1 Otherwise = 0	0.53	0.50
Number of income sources (X_9)	Control	Number of income sources including agriculture and non-agriculture sources	2.70	1.27
Share of agricultural income in total household income (%)(X_{10})	Control	(Agricultural income /total household income) × 100	29.80	26.06

Note: Variables from X_1 to X_5 are household perceptions of climate-induced changes (decline, increase or overall change) at farm level, compared to the situation 10 years ago. *Calorie intake does not take into account spices; ** (min–max); *** It is considered as a proxy variable of 'changes in the timing of sowing and harvesting of crops at farm level' because households reported changes in the timing of seasons in the context of sowing and harvesting of crops (vary across farms).

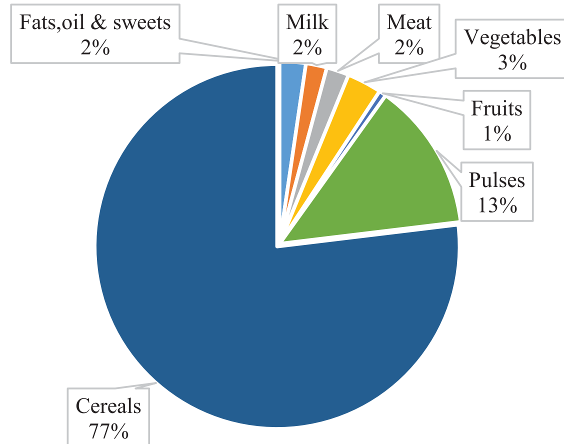

Figure 7. Share (%) of different food groups in calorie intake.

Results of regression models showed that included independent and control variables explained 22% of the variation in the FVS, 16% in DDS and 54% in calorie intake (see R-squared values in Table 8). Results of the model-1 revealed that perceived decline in water availability, perceived increase in the incidence of crop pests and increase in the incidence of hazards had statistically significant negative relationship with FVS (Table 8). Among the socioeconomic factors, share of agriculture income in total household income showed statistically significant negative relationship with FVS.

Results of the model 2 revealed that only one climate perception variable 'increase in the incidence of hazards' had statistically significant negative relationship with DDS (Table 8). None of the control variables showed statistically significant relationship with DDS. Results of the model 3 showed that perceived decline in water availability and changes in the timing of seasons had statistically significant negative relationship with calorie intake (Table 8). Among control variables, household size and households with out-migrants showed statistically significant negative relationship with calorie intake.

It is important to note that the coefficients of some independent variables did not show consistency in terms of statistical significance for their relationship with dependent variables. In general, food security indicators are likely to be correlated. However, in distant mountain areas, a prominent change being observed that calorie intake of the people is either stable or improving, but diets are gradually losing diversity (Adhikari et al., 2017; Rasul et al., 2019). In our study site, inflow of processed food items (dietary energy intensive but deficient in micronutrients) has increased, and consumption of traditional food crops has declined. In this scenario, food security indicators are likely to show weak correlation, leading to inconsistency in terms of statistical significance and the direction of relationship (+ or − signs of coefficients).

4. Discussion

In Nepal, *Karnali* region is considered as one of the most inaccessible regions with high incidence of poverty, food insecurity and limited access to market and other institutional services. Findings of this study revealed that the households perceive

Table 8. Results of Linear Regression Models (OLS).

	Model-1 Food variety score		Model-2 Dietary diversity score		Model-3 Calorie intake	
Variables	Coefficients	Standard Errors	Coefficients	Standard Errors	Coefficients	Standard Errors
Decline in water availability	−1.039**	0.478	−0.212	0.225	−529.131**	242.419
Change in the timing of seasons	−1.496	0.218	−0.393	0.102	−211.889*	110.611
Increase in the incidence of crop pest attacks	−1.108*	0.565	−0.269	0.265	46.851	286.277
Increase in the incidence of livestock diseases	−0.441	0.530	0.024	0.249	21.029	268.462
Increase in the incidence of hazards	−1.611***	0.474	−0.547*	0.222	−355.956	240.205
Household size	0.664	0.087	0.037	0.041	−344.043***	44.101
Female to male ratio	0.372	0.225	0.140	0.105	−102.222	113.757
Migrant sending household	0.323	0.441	0.125	0.207	−470.783**	223.493
Number of income sources	−0.134	0.186	−0.114	0.087	−90.213	94.238
Share of agricultural income in total household income (%)	−0.016*	0.009	−0.006	0.004	7.482	4.632
Constant	11.408***	1.618	5.050	0.759	6661.924	819.877
Prob. > *F*	0.00		0.01		0.00	
Adjusted *R*-squared (%)	22		16		54	

$p < 0.01$, **$p < 0.05$, *$p < 0.10$ for ***t values; Number of observations = 102. The range of variance inflation factor (VIF) values of variables ranges from 1.06 to 1.56, ruling out the chances of multicollinearity (MCL) in the models. VIF value above 5 indicates MCL in the model.

changes in climatic parameters such as temperature and rainfall patterns, droughts and timing of seasons, compared with the situation 10 years ago. These perceived changes are almost consistent with the metrological data of the study area (Table 4). Most households also perceived climate-induced negative impacts mainly on water availability and crop production (Table 2). A significant percentage of households perceived a decline in production of brown rice, wheat and barley. These cereal crops, particularly brown rice, are highly sensitive to water availability during the sowing and early growth periods (Groot et al., 2017). The decline in their production can be attributed to erratic rainfall, declined water availability for irrigation, increased number of dry days, and increased incidences of drought and pest attacks, as reported by studies from similar mountain areas (Bandara & Cai, 2014; Gautam & Andersen, 2016; Li & Zhang, 2020; Paudel et al., 2020; Poudel et al., 2017). On the other hand, a higher percentage of households perceived positive impacts of climate change on the production of local beans and potato. In mountain areas, nature of climate-induced impacts may vary from one area to other even within same region. In some areas such Gatlang (Nepal) and Hunza (Pakistan), snow covered high-altitude areas receive less snowfall in winter and have become suitable for the early cultivation of potato and other vegetables in February and March, leading to an increase in production at high-altitudes (Hussain et al., 2016; Merrey et al., 2018). This decline in snowfall at high-altitudes, together with temperature rise, also leads to low water availability in the valleys and consequent decline in crop production, as reported from mountain areas (Abbasi et al., 2017; Hashmi & Shafiullah, 2003; Mishra et al., 2016). In this study, around 90% households perceived no change in livestock production in last 10 years. It may be because of very less impact of climate change on rangelands and pastures (Table 2).

Food security analysis revealed that households' FVS and DDS are much lower than those in the plain areas of the HKH region (see Hussain et al., 2014). Cereals contributed almost 80% to average calorie intake of the households (Figure 6). It shows a substantial change in the dietary patterns of the mountain people whose diets have historically been diverse. Average daily calorie intake (per capita per day) is above the national line of minimum required calories (CBS, 2012) but it showed a significant variation (453–9363 kcal/day/capita) across households. Overall, 42% households were identified as food insecure (Table 1), which is consistent to findings of preceding studies in the same region (NDHS, 2016; Gautam, 2019) and other similar mountain areas of Nepal (Adhikari et al., 2017; Merrey et al., 2018; Rasul et al., 2019).

Results of regression analysis revealed that climate change perceptions have negative relationship with household food security in the study area. Climate induced decline in water availability has negative relationship with FVS and calorie intake of households (Table 8). It implies that variability in water availability may impact both food crops diversity and productivity, as found by other studies (Adhikari, 2008; Paudel et al., 2010; Shrestha & Aryal, 2011). Perceived changes in the timing of seasons showed negative relationship with calorie intake. This is possibly because of climate-induced negative impacts on productivity of food crops such as brown rice, barley and wheat due to changes in the timing of sowing and harvesting, and consequent impacts on household consumption, as reported in preceding studies in the HKH (Bandara & Cai, 2014; Gautam & Andersen, 2016; Hussain et al., 2016; Karki et al., 2020; Paudel et al., 2020; Rasul et al., 2019). Perceived increase in the incidence of pest attacks showed negative relationship with FVS, revealing that an increased incidence of pest attacks on crops is likely to result in a decline in agricultural diversity, as reported by a recent study (Hussain & Qamar, 2020). An increase in incidence of landslides and soil erosions showed negative significant relationship with both FVS and DDS. In mountains, landslides disrupt supply of food items from plain areas that impacts food variety and dietary diversity of households in the short run (Hussain et al., 2016). Soil erosions induce impacts on soil fertility and land use resulting in reduction of area under cultivation of diverse crops, as reported elsewhere (Merrey et al., 2018).

Among the socioeconomic factors, share of agriculture income in total household income showed statistically significant negative relationship with FVS. Key informants reported that several households in the study area are replacing traditional crops such as millets with cash crops such as apple to improve their income. This replacement has increased the share of agriculture in their total household income but resulted in loss to agrobiodiversity at farm level and reduced food variety in consumption patterns. Household size and outmigration of household member(s) showed statistically significant negative relationship with calorie intake. Negative influence of household size on calorie intake is very logical because each member in a large household is likely to get a smaller share in food. The reason of negative relationship of outmigration with calorie intake is that mostly active member of households migrate to other areas, resulting in added workload on elderly and female members. It becomes difficult for elderly and female members to handle agricultural activities effectively that results in low crop productivity, eventually leading to low calorie intake from home food production. Several studies (i.e. Malapit et al., 2015; Shively & Sununtnasuk, 2015) have already revealed that local food production has linkages with calorie intake, particularly in the mountain areas of Nepal.

5. Conclusion

The *Karnali* region of Nepal is considered as one of the most inaccessible regions with high incidence of poverty, food insecurity and limited access to market and other institutional services. The situation of food security is worsening in the region due to climate-induced impacts on agriculture. This study conducted in a rural municipality '*Tatopani*' in Jumla district found that a significant percentage of households perceive changes in climatic parameters such as temperature and rainfall patterns, incidence of drought and timing of seasons, compared with the situation 10 years ago. They also reported an increase in the drying up of freshwater resource, an increase in the incidence of crop pest attacks and decline in overall water availability in agriculture. They perceived mixed impacts of climate change on the production of crops. A majority of them perceived a decline in the production of brown rice, wheat and barley compared with situation 10 years ago. On the other hand, they perceived an increase in the production of potato and local beans. A majority of households did not perceive any impact of climate change on livestock productivity. Food security analysis showed that 42% of surveyed households were food insecure. Cereals were major contributor to household calorie intake of households who had low food variety and dietary diversity in their consumption. Regression analysis found that perceived climate-induced impacts such as decline in water availability, changes in the timing of seasons, increase in the incidence of hazards (landslides and soil erosions) and increase in the incidence of pest attacks had negative relationship with the indicators of household food security – food variety score, dietary diversity and calorie intake. Some other factors such as share of agriculture income in total household income, household size and outmigration also influenced household food security.

Based on the findings of this study, following suggestions are proposed to improve household food security in the study area.

- **Crop management:** Climate change has more severe impacts on water intensive crops such as brown rice due to an increased incidence of drought, erratic rainfall and overall decline in water availability in agriculture. Regressing analysis also indicated that a perceived decline in water availability has statistical relationship with indicators of food security. Households may plan a gradual shift from cultivation of water intensive crops to alternative traditional crops with less water requirements such as local beans, barley and millets. In addition to coping with climate impacts, it will also increase the production diversity in local agriculture systems, conducive to improving dietary diversity.
- **Balance in agriculture system:** There is need to keep a balance between crop diversity and productivity. Households may integrate high yielding crops without affecting overall diversity in production. Either, some uncultivated land can be brought under cultivation or area under cultivation of climate affected crops can be reduced to accommodate high yielding crops.
- **Integration of cash crops:** Households may integrate some cash crops such as potato and fruits in the agriculture systems to improve agricultural income. Findings also showed that more than half households reported a rise in potato production in changing climate. Households also showed tendency to integrate fruits crops such as apple and walnut with field crops. Fruit crops may increase the production diversity (if no crops are replaced) and enhance resilience of agriculture against climate-induced impacts.
- **Emphasis on livestock:** A negligible percentage of households reported negative impact of climate change on rangelands, pastures and livestock productivity. It implies that households need to strengthen their livestock in overall agriculture system.

6. Suggested future research

In this study, the regression analysis is run using the climate perception variables (considered as 'cross-sectional data') reported as the differences in the current situation, compared with the situation of 10 years ago. The statistical relationship of cross-sectional food security indicators with these perception based variables can only be considered as an indicative message. This analysis may also indicate that food insecure households are more likely to perceive changes in climate and related impacts. In future, there is further need of a quantitative investigation of climate-induced impacts on food security, using the time series data of observed climatic parameters and food security indicators in the *Karnali* region. Authors also suggest to consider a large representative sample size with expanded geographical coverage in the region.

Notes

1. The Hindu Kush Himalaya (HKH) is a hilly and mountainous region which extends 3500 km across eight countries – Afghanistan, Bangladesh, Bhutan, China, India, Nepal, Myanmar and Pakistan – covering an area of 3.4 million km^2, and accommodating 240 million people.
2. *Karnali* province has 10 districts – Dailekh, Dolpa, Humla, Jajarkot, Jumla, Kalikot, Mugu, Salyan, Surkhet and Western Rukum.

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