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Farmers' understanding of climate change in Nepal Himalayas: important determinants and implications for developing adaptation strategies

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Abstract
Climate change affects the livelihood of farmers in a variety of ways. Farmers' indigenous knowledge influences their perception of climate-related issues. A perception-based, semi-structured questionnaire survey of 530 households was performed to gather information about the awareness of, indicators for, and determinants of climate change. The survey covered three ecological regions of Nepal. The statistical analysis was done with a chi-square (χ^2) test and a binary logistic regression (BLR) model to screen farmers' perception of climate change. This study shows that socio-economic and agricultural characteristics of the farmers directly influence their perception of climate change. Farmers have identified climate change indicators in various forms, e.g., an increase in temperature (99.2% of those surveyed), a decrease in precipitation (98.9%), and an increase in climate-induced diseases and pests (96.8%) for agricultural crops. Observed precipitation (− 16.093 mm/year; $p = 0.055$) and temperature (0.0539 °C/year; $p = 0.007$) between 2000 and 2015 are both consistent with farmers' perception. The selected independent variables are significantly correlated with the dependent variables, as confirmed by the BLR model, where $\chi^2 = 83$ with $p = 0.002$. The BLR shows there is a strong relationship between farmers' perception of climate change and the group of descriptive variables, with a coefficient of determination of 85%. The biophysical characteristics and impact variables were the most important determinants. It is important that organizations and policymakers in Nepal develop adaptation strategies that improve the livelihoods of farmers. These strategies include introducing drought-tolerant crops, developing disease- and pest-tolerant seeds, constructing irrigation systems, and building hospitals.

Keywords Climate change · Farmers' perception · Logistic regression · Adaptation strategies · Nepal

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1 Introduction

Climate change refers to changes in meteorological conditions over decadal and longer-term periods (IPCC 2014a; Kaufman et al. 2009; Travis et al. 2018) and can have a negative impact on agricultural systems (Tesfahunegn et al. 2016). Farming in the Himalayan countries tends to be more susceptible to climate change compared with other sectors and regions (Khanal et al. 2018; Negi et al. 2017; Rahut and Micevska 2012), and the Intergovernmental Panel on Climate Change (IPCC) reports that agricultural activities in the Himalayan region are greatly affected by climate change (IPCC 2014b; Manandhar et al. 2011). Agricultural activities began to become particularly affected after the 1990s, due to increasing trends in temperature and drought events and decreasing trends in precipitation (Paudel et al. 2016). The impact of climate change varies regionally and is more serious in developing countries, such as Nepal (Shrestha and Aryal 2011), where the majority of farmers practice rain-fed farming (CBS 2012). Farmers' perception and indigenous knowledge are very important not only for understanding these problems but also for solving them by involving local people in an effective away (Metz 1989; Ives 1987; Ives and Messerli 1989). Farmers' indigenous knowledge also provides multiple solutions to minimize environmental risk, in favor of nature and society, between upstream and downstream regions (Ives and Messerli 1989; Blaikie and Muldavin 2004). Several previous studies (Bhatt et al. 2014; Chapagain et al. 2017; Devkota et al. 2017; Dhakal et al. 2016; Sujakhu et al. 2016) have demonstrated that climate change is a challenge for agricultural production because of decreasing precipitation, increasing short-term heavy rainfall, and more frequent droughts, and it is therefore important to study farmers' views of climate change, including the associated indicators and determinants. This knowledge can be used to develop community-based and farmer-friendly adaptation strategies and programs.

The farmer's perception of climate change plays a vital role in developing mitigation and adaptation strategies for land use and farming activities (Mertz et al. 2009; Pröbstl-Haider et al. 2016). In fact, some farmers in the Himalayan region successfully mitigate the impact of climate change by diversifying and rotating crops, adjusting planting times (early and late), and selecting crops suitable for the landscape and the time of year (Aase and Chapagain 2017; Negi et al. 2017). The theoretical basis for adaptation strategies in the Himalayas suggests that there are three basic elements for mountain adaptation: creating zones for vertical production, selecting the right production approach by the inhabitants, and planning production (Guillet et al. 1983). Further, these adaptation strategies include the interaction between social, agricultural, and land tenure systems, as well as productivity and the possible modification of existing strategies. A recent study in Nepal (CBS 2017) indicated that common adaptation measures include the use of chemical fertilizers, mixed cropping with new crop varieties, and increased investment in preventing climate-induced disease in livestock. In addition, based on location, farmers have educated themselves about the impact of climate change, as manifested in early or late rainfall and the drying up of rivers, reservoirs, and ponds. However, they are not completely aware of the possible impacts on their livelihood and the economy (Tesfahunegn et al. 2016; Uprety et al. 2017), and a detailed study, therefore, on farmers' understanding of climate change can reduce knowledge gaps for both farmers and planners.

Studies done in various parts of the world have suggested that temperature change and erratic rainfall are often accompanied by floods (Bielders et al. 2003; Devkota et al.

2017; Tripathi et al. 2014). Many farmers are aware of climate change, but how they respond, the impact they experience, their understanding of the reasons, and the costs to them vary (Hou et al. 2015; Hou et al. 2017; Tang et al. 2018; Tesfahunegn et al. 2016). Conversely, some farmers may not care about or notice climate change (Deressa et al. 2009). For example, a lack of involvement in agricultural activities, lack of experience, and illiteracy or low education levels may decrease awareness of climate change. Some farmers view climate change in a scientific way while others have a religious perspective (Kemausuor et al. 2011), and their awareness of climate change depends on their education level, local long-term climate observation experience, past and present status of resources, and the availability of climate-related information (Tesfahunegn et al. 2016). In addition, some farmers' perceptions and adaptation practices vary with the type of vertical production zone and the cultural setting (Guillet et al. 1983; Manandhar et al. 2011).

Those who are directly associated with farming activities may have a great deal of information about climate change. Studies have shown the importance of including the knowledge of farmers in formulating suitable adaptation plans and policies and in developing technological measures to improve farmers' livelihoods and economic status (Devkota et al. 2017; Khanal et al. 2018; Manandhar et al. 2011; Mertz et al. 2009; Pandey and Bardsley 2015; Pröbstl-Haider et al. 2016; Sujakhu et al. 2016). Farmers' perception of climate change, covering all the ecological regions of Nepal, is not well documented, and most previous studies have concentrated on specific locations in Hill and Mountain regions, with limited attention given to the Tarai region. A perception-based climate change study in west Nepal, covering two ecological regions (Mountain and Tarai), noted that Mountain farmers have somehow benefitted while Tarai farmers have mainly lost out mostly (Manandhar et al. 2011). Moreover, the Tarai region's farmers mostly indicated changes in temperature, untimely erratic rainfall, and flood indicators of climate change, while the Mountain farmers observed changes in precipitation and temperature, and more crop diseases, again indicators of climate change. Studies covering Mountain and Hill ecological regions, the Budhi Gandaki River basin, and the Melamchi Valley in Nepal found that farmers are highly aware of changes in temperature, rainfall, and increasing numbers of drought and flood events as climate change indicators (Devkota et al. 2017; Sujakhu et al. 2016). A further study covering part of the Tarai region, within the West Rapti River Basin, indicated that the temperature has risen over the past 20 years, and that people's perception was consistent with the recorded changing trend in climate (Devkota 2014). These kinds of studies have helped reduce the knowledge gaps of farmers and planners; consequently, better climate-change adaptation plans that positively impact the livelihoods of farmers can be developed (Devkota et al. 2017). The perception of peoples'/farmers' also helps to determine whether the existing adaptation practices are effective in minimizing the impact of climate change on farmers (CBS 2017; Mertz et al. 2009).

The opinions of farmers on climate change and on suitable adaptation measures are considered at two different stages of the decision-making process (Bryan et al. 2009; Valdivia et al. 2010): (1) understanding climate change and its consequences and (2) the use of this knowledge to choose suitable adaptation practices (Tesfahunegn et al. 2016). Technological adaptations depend mainly on factors that influence farmers' understanding of climate change and how they implement adaptation policies (Adger et al. 2003).

The most effective types of adaptation involve how farmers' knowledge and understanding is taken into account (Nguyen et al. 2016).

Farmers' perception of climate change has emerged as an interesting issue for both researchers and policymakers because of increasing climate change risk. Their livelihood is highly vulnerable to climate change, particularly in countries like Nepal which has limited land suitable for agriculture. Despite that the impact of climate change on farmers is increasing in Nepal, the number of studies of its indicators and determinants, covering the whole country and all its ecological regions, are limited. Therefore, the goals of this study are to assess farmers' socio-economic, agricultural, and biophysical characteristics as indicators of their awareness of climate change and to analyze the determinant factors for farmers' understanding of climate change in Nepal. The findings of the study can be utilized to formulate adaptation strategy in Nepal, as well as to increase the adaptive capacity of farmers.

2 Materials and methods

2.1 Study area

This study of farmers' perception covered three ecological regions (Mountain, Hill, and Tarai) of Nepal (Fig. 1 and Supplementary Information Table SI1), in the central Himalayan region between latitudes 26°22′ and 30°27′N and longitudes 80°04′ and 88°12′E. Nepal shares a border with China and India, its population is 26.4 million (CBS 2012), and it has a land area of 147,181 km^2 (LRMP 1986). The geography of the country is unique. It is a mountainous country with seven provinces and 77 districts. Although Nepal is in a subtropical zone, the climate varies because of the vast topographical differences between the southern Tarai plain and the northern High Mountain regions (Shrestha and Aryal 2011).

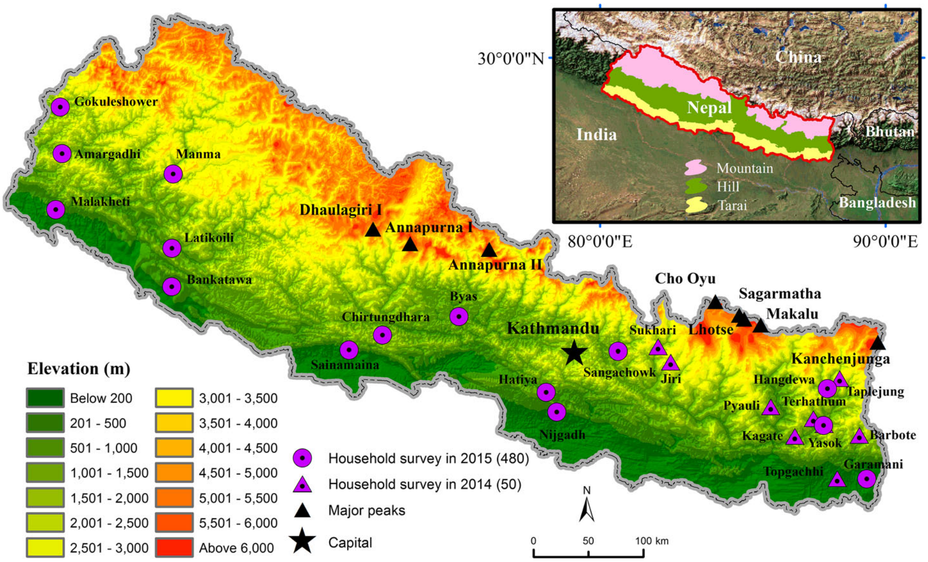

Fig. 1 Topographic distribution and sampling sites of the study area (Nepal)

2.2 Household questionnaire survey, sample size, and sampling procedure

Farmers' perceptions have been widely used in screening status, driving factors (Paudel et al. 2019), climate change impacts, and adaptation strategy (Bhandari et al. 2018; Devkota et al. 2017; Pradhan et al. 2015). This study applied household survey (HHS), a commonly used method, to find the indicators and determinants of farmers' perception of climate change in Nepal. A semi-structured questionnaire was developed (Supplementary Information 2), and the survey was carried out in 50 households in the Koshi River Basin (KRB) in eastern Nepal, in 2014 (Fig. 1). Additionally, an extensive HHS was carried out in 2015, with 480 questionnaires covering the remaining regions of the country. The questionnaire was mainly administered to the elderly household head, who understood the climate history of their location. A total of 530 households were surveyed, covering the three ecological regions of the country, from south to north and east to west. This study sampled over 10% of the households of the sampled settlement, and after selecting a settlement for sampling, we implemented a random sampling method with 32 HHS in each settlement, in 15 districts of the country, in 2015 (Fig. 1 and Supplementary Information Table SI1). We also used a survey of 50 households conducted in the KRB in 2014, bringing the total sample size to 530 HHS.

The survey was conducted by a researcher who employed nine enumerators and conducted interviews in the selected sample sites. The enumerators were well trained by the researchers about handling interviews with local farmers and were also trained in how to screen and focus on the main issues: farmers' perception of climate change, indicators, socio-economic status, and agricultural characteristics. We used the Nepali national language, which is the common tongue understood by all. In a few cases, in the Tarai region, the survey was conducted in the local language to the best of our ability. We also conducted a series of focus group discussions (FGDs) to involve a small group of senior and elderly local people, including farmers, teachers, and local community leaders. The purpose of this widely used method (Bernués et al. 2016) is to acquire information from a group of respondents (the target population), at predetermined places and times, so the information we gathered from HHS could be supplemented and verified.

2.3 Sources of data

Both secondary and primary data sources were used in this study. The observed climate datasets (annual mean temperature and total precipitation) of the country from 2000 to 2015 (115 stations for temperature and 272 stations for precipitation) were obtained from the Department of Hydrology and Meteorology, Government of Nepal. The observed climate datasets were compiled and analyzed to determine the trend in climate change in Nepal. This provided the basis to assess the differences between farmers' perceptions and scientific observations. The main source of primary data was the household survey and FGDs.

2.4 Description of explanatory variables

The dependent variable is farmers' perception of climate change, which is widely used in similar studies (Arunrat et al. 2017; Devkota 2014; Mertz et al. 2009). Using the theoretical background of previous studies (Khanal et al. 2018; Tesfahunegn et al. 2016) and characteristics of the interviewed farmers, we selected various variables for statistical analysis. The appropriate descriptive variables are listed and details analyzed in Supplementary Information Table SI3, and their hypothesized effects are presented in Table 1.

Table 1 Assigned variables in the binary logistic regression and descriptions of their hypothesized impact

Variables	Dummy variable and explanation	Impact
Dependent		
Farmers' awareness of climate change	1 for perceived climate change, 0 if not	
Independent: household characteristics		
Age of respondent	Respondent's age in years[a]	±
Gender of respondent	1 if male, 0 if not	±
Wealth of respondent	1 if wealthy, 0 if not	+
Education of respondent	1 if literate[b] respondent, 0 if not	+
Family size of respondent	Total number of family members[a]	±
Total livestock owned	Total number of livestock owned by a respondent's family[a]	+
Independent: agricultural characteristics		
Total land farmer owned	1 if land > 20 ropani (1.02 ha) in Mountain and Hill or > 20 kattha (0.68 ha) in Tarai, 0 if not	+
Land tenure system	1 if land transferrable to farmer's family (in this situation the farmer feels more secure), 0 if not	+
Use of machinery for farm work	1 if uses machinery for farm work, 0 if not	+
Off-farm income of farmer	1 if off-farm income, 0 if not	–
Availability of irrigation facilities	1 if irrigation facilities available, 0 if not	–
Rain-fed cultivation practices	1 if practices rain-fed cultivation, 0 if not	+
Soil management practices	1 if practices soil management, 0 if not	+
Water harvesting practices	1 if has structures and practices of harvesting, 0 if not	+
Independent: biophysical variables		
Temperature change	1 if observed change, 0 if not	+
Precipitation change	1 if observed change, 0 if not	+
Increase in droughts	1 if perceived, 0 if not	+
Increase in floods	1 if observed, 0 if not	+
Climate-induced diseases and pests	1 if noticed, 0 if not	+
Change in crops	1 if noticed, 0 if not	+
Land use changes	1 if noticed, 0 if not	+
Vegetation changes	1 if noticed, 0 if not	+
Soil characteristics	1 if fertile, 0 if not	±
Independent: impact variables		
Experienced adverse impact on staple crops	1 if adverse impact on staple crop, 0 if not	+
Experienced adverse impact on vegetation	1 if adverse impact on vegetation, 0 if not	+
Experienced adverse impact on livestock	1 if adverse impact on livestock, 0 if not	+
Experienced adverse impact on human health	1 if adverse impact on health, 0 if not	+
Experienced adverse impact from disasters	1 if adverse impact from disasters, 0 if not	+

[a] Dummy variable for continuous independent variables

[b] Literate refers to primary, secondary, or read and write education

2.5 Data analysis

A chi-square (χ^2) nonparametric test and binary logistic regression (BLR) model were applied, and also a descriptive method (percentage and frequency). For the calculations and analysis, we used IBM SPSS Statistics 20 (SPSS 2011). We also tested for multicollinearity special effects among the independent variables using a Spearman nonparametric correlation. The majority of the variables were correlated with a correlation coefficient of $r < \pm 0.35$, with some up to $\pm$ 0.40. We confirmed that, based on these test results and consistent with previous studies (Bhandari et al. 2018; Tesfahunegn et al. 2016), multicollinearity among the independent variables was not a problem.

In this study, the majority of the variables have a qualitative basis perceived by farmers; thus, we used a chi-square (χ^2) test, as has been commonly used in qualitative analysis (Agresti 1996; Tesfahunegn et al. 2016):

$$\chi^2 = \sum \frac{(\mathrm{O}_i - \mathrm{E}_i)^2}{\mathrm{E}_i} = \frac{(\mathrm{O}_1 - \mathrm{E}_1)^2}{\mathrm{E}_1} + \frac{(\mathrm{O}_2 - \mathrm{E}_2)^2}{\mathrm{E}_2} + \ldots + \frac{(\mathrm{O}_n - \mathrm{E}_n)^2}{\mathrm{E}_n} \tag{1}$$

In this expression, O_1, $\mathrm{O}_{2,}\ldots$, O_n are the observed frequencies and E_1, $\mathrm{E}_{2,}$, …, E_n are the corresponding expected or theoretical frequencies.

We further applied the BLR model to screen the contributing variables, which weighted the perception of local farmers of climate change. The BLR model is appropriate for calculating discrete values of a forked dependent variable from independent variables, which may result in continuous, discrete, or forked variables, or consolidation of these variables (Retherford and Choe 1993). In the BLR model, the dependent variable is forked with a dummy value of 1 or 0. If the farmer perceived climate change, we assigned 1, if not, we assigned 0. Data assignments were made from the household survey in binary form, as well as from a mixture of discrete and continuous independent variables (Supplementary Information Table SI3 and Table 1).

This study employed the BLR model to analyze the correlation between the dependent and independent variables (Retherford and Choe 1993). The model was defined as follows:

$$\mathrm{In}\left[\frac{P}{1-P}\right] = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_k x_k \tag{2}$$

In this expression, $P / (1 - P)$ is the odds ratio, P is the probability of a farmer perceiving climate change, and $1 - P$ denotes the probability of not perceiving climate change. Also, β_0 is the intercept; x_1, x_2,…, and x_k are the independent variables, and β_1 , β_2,…, and β_k are partial regression coefficients. If the odds ratio is above 1, the relationship between the independent variable and the dependent variable is known as a positive relationship. When the value is 1, there is no relationship, and if the value is below 1, it shows a negative relationship (Field 2009). To determine the accuracy of the logistic regression model, Nagelkerke's R^2 was calculated (Nagelkerke 1991).

Moreover, based on the daily observed climate records of 115 stations for temperature and 272 stations for precipitation between 2000 and 2015, we calculated the annual mean temperature and annual total precipitation. We then performed a simple linear regression to analyze inter-annual trends in annual mean temperature and annual total precipitation, respectively, and we determined the significance of variation via an f test to calculate a confidence level. In addition, the term, "socio-economic characteristics" refers to farmers' demographic and economic activity related characteristics, including age, gender, education, health, family size, livestock, economic status, and monthly income, while "agricultural characteristics" refers to the farm-related characteristics of the farmers.

3 Results and discussion

3.1 Farmers' socio-economic and agricultural characteristics

3.1.1 Socio-economic characteristics

Farmers were interviewed and information about different variables was gathered. The socio-economic characteristics of the farmers are summarized in Table 2. Of the respondents, 71.3% were male and 28.7% were female. In Nepal, the decision at household level is dominated by the male. So, the number of male household head is obvious. However, in a few, females also take the responsibility as household head. Moreover, if household head is absent during the time of interview, then we considered his/her spouse as household head. Out of 530 HHS, 86.8% of farmers had both parents alive, 0.4% were divorced, and 12.8% were widowed. Thus, there were significant differences in the marital status of the respondents. The literacy of the respondents was 68.3%, with different levels of education from preschool to college and above. The physical health of the respondents varied, with 64.1% possessing good, 25.9% general, 7.9% poor, and 2.1% very poor health. The majority of the farmers were in good physical health. Thus, they were able to actively participate in agricultural activities and directly experience climate change and its impacts on livelihood and agriculture. The average age and family size of the respondents were 55.5 years (range 36–91) and 5.7 members (range 1–19). These variables changed slightly across the country's ecological regions (Table 2).

The HHS was used to assess the economic status of farmers based on family income. The proportion of farmers with a low family income (63.8%) was much higher than with a medium (20.8%) or a high income (15.5%). This shows that the majority of farmers had low economic status, and even when they focused on agricultural activities, their production levels were not satisfactory. Thus, their livelihood was even more vulnerable to climate change. The majority of the farmers who responded to the field survey produced only enough for their family to survive, with no surplus commercial excess. Furthermore, in some places, agricultural production was not even sufficient for the family, particularly in the high mountain areas of the mid- and far-western regions of the country. This was also reported in a previous study of the region (Humla, Nepal) (Gautam and Andersen 2016). The average monthly income from off-farm activities of each family surveyed, including remittances, was about 23,166 Nepalese rupees (NRS) (about US$220, with an approximate exchange rate of 105 NRS = US$1, in 2015). In most households, some family members were engaged in off-farm activities and went abroad to work (labor migration), sending remittances to their family. Off-farm income helped farmers maintain their livelihood but was not enough to allow them to adapt to climate change. The average number of livestock was 7.3 per household. We assumed that farmers' socio-economic characteristics and their agricultural practices influenced their perception of climate change and its indicators. The socio-economic characteristics varied slightly across different regions of the country, as summarized in Table 2.

3.1.2 Agricultural characteristics

The area of agricultural land owned by farmers varied by region, the average being 0.62 ha, with a range of 0.02 to 5.08 ha (Table 3). The land tenure system was 96.2% privately owned and 3.8% rented. A private land ownership policy exists in Nepal, where land can easily be transferred to children, providing security for farmers and encouraging them to try different

Table 2 Characteristics of household heads for surveyed farmers in Nepal

Household head characteristics	Details	Total number	Percent	By ecological region (%) Mountain	Hill	Tarai
Gender of respondent	Male	378	71.3	71.1	71.9	74.2
	Female	152	28.7	28.9	28.1	25.8
Respondent marital status	Both parents alive	460	86.8	85.2	88.3	89.8
	Divorced	2	0.4	0.0	0.0	0.0
	Widowed	68	12.8	14.8	11.7	10.2
Level of education	Illiterate	168	31.7	33.6	22.7	35.2
	Preschool/ Informal	67	12.6	16.4	14.1	10.8
	Primary (1–5)	67	12.6	11.7	14.1	12.5
	Junior high school (6–10)	122	23.1	21.1	26.6	18.0
	Senior high school (11–12)	58	10.9	10.9	12.4	10.2
	University (B.A.) and above	48	9.1	6.3	10.1	13.3
Age of respondent (years)	Average age (range 36–91)	55.5		55.3	55.9	55.5
Physical health	Good	340	64.1	65.6	70.3	66.4
	General	137	25.9	22.7	26.6	24.2
	Poor	42	7.9	10.9	2.3	6.3
	Very poor	11	2.1	0.8	0.8	3.1
Family size of respondent	Average family size (range 1–19)	5.7		6.1	5.6	6.1
Total livestock owned	Average livestock size	7.3		9.2	7.1	5.2
Economic status[a]	High	82	15.5	14.8	11.7	22.7
	Medium	110	20.8	23.4	24.2	12.5
	Low	338	63.8	61.7	64.1	64.8
Monthly average income (NRS)	Off-farm family income including remittance	23,166		15,391.9	27,863.7	16,271.6

Total values were calculated based on 530 HHS. Values by ecological region were calculated based on 384 HHS (four sites and 128 HHS in each ecological region) in Nepal

[a] Economic status refers to: low: below 50,000 NRS/year, medium: 50,000 to 300,000 NRS/year, and high: above 300,000 NRS/year, where NRS is Nepalese rupees. Sources: Field Survey 2014 and 2015

climate-change adaptation strategies, such as new crops and cropping systems. This is directly associated with the agricultural system, availability of water resources, and irrigation practices. Among the farmers surveyed, 55.5% practiced rain-fed cultivation and 44.5% full or partially irrigated cultivation. The highest proportion (53.9%), practicing rain-fed cultivation, was in the Hill region. This illustrates that farmers have experience with both rain-fed agriculture and irrigated cultivation, which provides knowledge for understanding climate change and its impact on agriculture and livelihood.

The proportion of farmers who practiced water harvesting was 75.5%, while 24.5% did not. More farmers in the Mountain regions of the country used water harvesting (86.7%), a group which had a particularly strong understanding of climate change and its impact on agriculture. Only 7.9% farmers practiced soil management, while the majority of farmers were unaware of it (92.1%). The majority of farmers had lower quality or infertile land (67.9%), with only 32.1% of farmers having fertile soil for cultivation. Signs of climate change are more apparent to farmers with lower quality or infertile soil, because the impact on them is greater. In the Tarai region, more farmers had fertile land (54.7%), compared with other regions of the country. The percentage of respondents using modern agricultural machinery was 49.8%, e.g., a tractor for plowing or a pumping set or water pump for irrigation; however, many farmers (50.2%) still practiced traditional agriculture and were more vulnerable to even small

Table 3 Agricultural characteristics of surveyed farmers in Nepal

Agricultural characteristics	Details	Total number	Percent	By ecological region (%)		
				Mountain	Hill	Tarai
Total land owned (ha)	Average land area (range 0.02–5.08 ha)	0.62 ha		0.66 ha	0.56 ha	0.63 ha
Land tenure system	Land owned	510	96.2	100	99.2	93.0
	Land rented	20	3.8	0	0.8	7.0
Farming practices	Rain-fed cultivation	294	55.5	44.5	53.9	47.7
	Irrigated cultivation	236	44.5	55.5	46.1	52.3
Water harvesting practices	Yes	400	75.5	86.7	85.2	82.0
	No	130	24.5	13.3	14.8	18.0
Practices soil management	Yes	42	7.9	15.6	4.7	9.4
	No	488	92.1	84.4	95.3	90.6
Characteristics of soil	Fertile	170	32.1	8.6	27.3	54.7
	Normal or infertile	360	67.9	91.4	72.7	45.3
Uses machinery for farm work	Yes	264	49.8	10.9	45.3	86.7
	No	266	50.2	89.1	54.7	13.3

Total values were calculated based on 530 HHS and values by ecological region were calculated based on 384 HHS (4 sites and 128 HHS in each ecological region) in Nepal

variations in climate. Only 10.9% of the farmers in the Mountain regions used machinery; however, the majority of the farmers in the Tarai region used machinery (86.7%). Based on farmers' agricultural characteristics and practices, we can generalize that the respondents' characteristics could influence their perception of climate change and its indicators.

3.2 Farmers' perception of climate change and its impact

The indicators of climate change perceived by farmers are summarized in Table 4. Temperature change was the most common indicator of climate change in Nepal, which was perceived by 99.2% of those surveyed. Other highly perceived indicators were rainfall (98.9%), climate-induced diseases and pests (96.8%), changes in vegetation species and diversity (96.0%), and drought frequency (80.2%). The χ^2 (chi-square) test demonstrated that these were highly perceived indicators of climate change. A smaller proportion of respondents noticed changes in flood frequency (16.4%) or changes in crop types (20%) as indicators of climate change. Table 4 summarizes the indicators of climate change, as perceived by the surveyed farmers in different ecological regions of Nepal. Temperature change was the most highly perceived indicator in the Mountain region, while precipitation change was perceived more by the farmers of the Hill and Tarai regions. Drought events were commonly noted by the residents who live in the Mountain and Hill regions but were perceived slightly less in the Tarai region. Additionally, climate-induced diseases and pests were experienced more in the Tarai and Hill regions than in the Mountain region. Changes in vegetation were observed by a slightly higher number of the farmers of Tarai region compared with the Hill and Mountain regions. Flood events were observed more in the Hill and Tarai regions than in the Mountain region, and crop changes were noticed more in the Tarai and Mountain regions than in the Hill region.

The farmers who were surveyed and participated in group discussions noted increasing temperatures and decreasing precipitation from 2004/05 to 2014/15. The observed climate records (115 stations for temperature and 272 stations for precipitation) of the Department of Hydrology and Meteorology, Nepal, between 2000 and 2015, show that the annual mean temperature

Table 4 Perceived indicators of climate change for surveyed farmers in Nepal

Indicators	National responses (%)			Ecological region responses (%)					
				Mountain		Hill		Tarai	
	Yes	No	χ^2 test	Yes	No	Yes	No	Yes	No
Temperature change	526 (99.2)	4 (0.8)	0.000	99.2	0.8	99.1	0.9	98.4	1.6
Precipitation change	524 (98.9)	6 (1.1)	0.000	98.4	1.6	99.2	0.8	99.2	0.8
Increase in droughts	425 (80.2)	105 (19.8)	0.016	90.6	9.4	90.6	9.4	86.7	13.3
Increase in floods	87 (16.4)	443 (83.6)	0.581	11.7	88.3	23.4	76.6	18.8	81.3
Increase in climate-induced diseases and pests	513 (96.8)	17 (3.2)	0.000	96.1	3.9	97.7	2.3	98.4	1.6
Change in crops	106 (20)	424 (80)	0.503	16.4	83.6	9.4	90.6	20.3	79.7
Vegetation changes	509 (96.0)	21 (4.0)	0.000	97.7	2.3	93.8	6.3	98.4	1.6

χ^2 (two-tailed); probability level $p \leq 0.05$. National level results were calculated based on 530 HHS and values by ecological regions were calculated based on 384 HHS (four sites and 128 HHS in each ecological region) in Nepal. Sources: Field Survey 2014 and 2015

significantly increased by 0.05 °C/year (Fig. 2). In the same period, the change in annual precipitation was − 16.09 mm/year. This study reveals that local farmers' perception of climate change is not only consistent with the observed data obtained from meteorological stations in Nepal but also with the observed trend reported at the global scale. Furthermore, the historical long-term average temperature in Nepal trended upward by 0.06 °C/year between 1977 and 1994 (Shrestha et al. 1999) and continued to increase through 2000 (Shrestha and Aryal 2011). Thus, farmers' perception of climate change is consistent with observed climate records.

Previous studies in Nepal have examined how farmers and other people perceive climate changes at specific locations. A study of the Budhi Gandaki River Basin found that local farmers perceived an increased frequency of floods (Devkota et al. 2017). However, our study covered three ecological regions of Nepal, and we found that a smaller proportion of farmers perceived this as a sign of climate change. This inconsistency may be because Devkota et al. (2017) covered only one river basin, whereas our study covered the entire country.

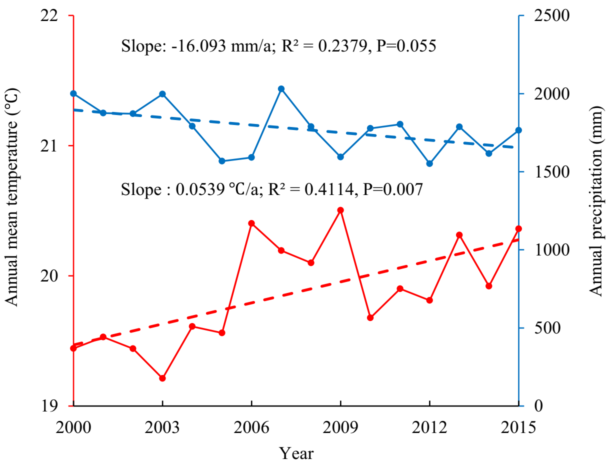

Fig. 2 Observed station-based annual mean temperature and total precipitation trends in Nepal between 2000 and 2015 (Data source: DHM, Nepal)

The surveyed farmers' perceived adverse impacts of climate change in Nepal comprise five major sectors: adverse impact on staple crops (98.7%), adverse impact on human health (97.9%), adverse impact on vegetation (94.7%), adverse impact from disasters (particularly hailstorms) (90.4%), and an adverse impact on livestock (88.3%). These are strongly perceived impacts of climate change, all over the country. The χ^2 test (Table 5) also found that these sectors were highly impacted by climate change. Such impacts are also noted by other studies, mainly on the agricultural sector in Koshi Basin (Bhatt et al. 2014) and in the Tarai plain (Dhakal et al. 2016). Such adverse impacts on the vegetation sector have also been reported (Baniya et al. 2018; Zhang et al. 2013). Table 5 summarizes the impacts of climate change, as perceived by the surveyed farmers in the different ecological regions of Nepal.

Farmers perceived that climate change had a significant impact on livestock and perceived that the frequency of climate-change-induced disease increased. A study of the Mustang District, which is in a high mountain region, found that farmers perceived a negative impact from climate change on livestock, and that climate change has had a large impact on livestock production in that region (Koirala and Shrestha 2017). The results from HHS and FGDs indicate that most farmers noticed an adverse impact on human health, with many having suffered from diseases, such as viral influenza, Japanese encephalitis, and dengue fever, diseases perceived as strong indicators of climate change. These results are supported by a recent study of climate change and human health in Nepal (Dhital et al. 2016). Another study of community perception in the Tanahu District also found an adverse impact of climate change on human health in recent years (Mishra et al. 2015). In addition, farmers noted that climate change has resulted in disasters, such as crop-damaging hailstorms, occurring more frequently than in previous decades. Over the past decade, farmers have perceived significant changes in climate, with the impact on crops being very negative.

3.3 Determinant of farmers' perception of climate change

The descriptive variables of the BLR model are presented in Table 6. $\chi^2 = 83$, with a probability of 0.002, and the correct prediction value is 85%. These values indicate that there is a statistically significant relationship between the hypothesized independent variables and the dependent variable (farmers' perception of climate change). Nagelkerke's $R^2 = 0.853$, which verifies that the BLR model was appropriate for use in this study. We calculated β for the independent variables; a

Table 5 Perceived adverse impact of climate change for surveyed farmers in Nepal

Impact	National responses (%)			Ecological region responses (%)					
				Mountain		Hill		Tarai	
	Yes	No	χ^2 test	Yes	No	Yes	No	Yes	No
Adverse impact on staple crops	523 (98.7)	7 (1.3)	0.000	99.2	0.8	98.5	1.5	97.7	2.3
Adverse impact on human health	519 (97.9)	11 (2.1)	0.000	97.7	2.3	98.4	1.6	97.6	2.4
Adverse impact on vegetation	502 (94.7)	28 (5.3)	0.001	94.5	4.7	93.0	7.0	97.5	2.5
Adverse impact from disasters	479 (90.4)	51 (9.6)	0.010	90.6	9.4	92.2	7.8	89.1	10.9
Adverse impact on livestock	468 (88.3)	62 (11.7)	0.013	92.2	7.8	87.5	12.5	95.3	4.7

χ^2 (two-tailed); probability level $p \leq 0.05$. National level results were calculated based on 530 HHS and values by ecological regions were calculated based on 384 HHS (four sites and 128 HHS in each ecological region) in Nepal. Sources: Field Survey 2014 and 2015 positive value indicates that farmers perceived the variable as a strong indicator of climate change, with the reverse being true for a negative value. For example, temperature change (3.238) is a strong indicator of climate change for farmers, while soil management experience (− 4.882) is not. The Wald value of the statistical analysis (Table 6) indicates that the independent variables have a strong influence on the dependent variable. The odds ratios suggest that there is a significant association between farmers' perception of climate change and assigned variables (Table 6). The odds ratio is highest for temperature change (10.120) and lowest for soil management practices (0.046), and therefore, the majority of the independent variables are significantly associated with the dependent variable.

The majority of the biophysical and impact variables are highly significant for farmers' perception of climate change (Table 6). Temperature and precipitation changes; climate-induced diseases and pests; and adverse impacts on staple crops, vegetation, livestock, and human health are all strong determinant factors for climate change in Nepal. Previous studies in Nepal, based on a BLR model, found that the dependent variables were influenced by socio-economic and climatic factors, and related variables (Paudel et al. 2016). A study of the Melamchi Valley in central Nepal noted that around 95% of the respondents perceived an increase in temperature and a decrease in precipitation over the last two decades (Sujakhu et al. 2016). In the Budhi Gandaki River Basin, in the western mountain region, 81% of respondents recognized climate change, with 83% noting changes in the amount of precipitation as an indicator (Devkota et al. 2017). We also constructed a BLR model, using each ecological region to screen for the determinants of farmers' perception of climate change. The outcomes of the majority variables from the three ecological regions also came out in the same line of a national analysis (Supplementary Information Table SI4.1 (Mountain), SI4.2 (Hill), and Table SI4.3 (Tarai)). To analyze these results by ecological region, the biophysical and impact determinant variables of farmers' perception of climate change, such as temperature change, frequency of drought event, adverse impact on staple crops, and adverse impact from disaster, suggested that farmers' livelihoods suffered more in the Hill and Mountain regions than in the Tarai region. A farmer from the eastern Hill District Panchthar shared his experience with us during the field survey: "He has had an orange orchard with good production for about 10–15 years, but recently, the orchard has dried up, except for a few orange trees, due to frequent drought events and climate-induced diseases and pests". However, the results suggested that the flood events, adverse impact from disasters, and the adverse impact on livestock were experienced more by the farmers in the Hill and Tarai regions compared with the Mountain region; the former also suffering a greater loss in livelihood. Thus, it is evident that further adaptation strategies and programs need to focus on community-based and farmer-friendly adaptation strategies based on the ecological regions in Nepal.

3.4 Implications for developing adaptation strategies

Climate change and its impact directly affect farmers' livelihoods, through lost agricultural income, and result in decreased agricultural production (Paudel et al. 2017; Poudel et al. 2017), particularly in lower-income countries (Thornton et al. 2018). Furthermore, climate change impacts farmers' health and results in increased medical expenses, due to various climate-change-induced diseases (Dhital et al. 2016). Similarly, because of climate change, disasters and the associated loss of life and property for farmers have increased (Devkota et al. 2017), and farmers must understand this and adapt accordingly.

Our study found that 523 (98.7%) household heads noted that climate change impacted farmers' livelihoods and that better adaptation practices must be developed. Farmers expressed

Table 6 Descriptive variables used in the BLR model to estimate farmers' perception of climate change in Nepal

Variables	β	SE	Wald	Sig. (*p*)	Odds ratio
Independent: household characteristics					
Age of respondent	0.076	0.048	2.562	0.102	1.079
Gender of respondent	0.053	0.071	0.369	0.202	1.056
Wealth of respondent	0.748	1.004	0.554	0.451	2.112
Education of respondent	0.769	1.004	0.585	0.033*	2.157
Family size of respondent	0.044	0.230	0.037	0.655	1.045
Independent: agricultural characteristics					
Total land farmer owns	0.037	0.046	0.531	0.292	1.087
Land tenure system	2.185	1.178	3.441	0.026*	8.895
Use of machinery for farm work	1.099	1.158	0.900	0.323	3.000
Off-farm income of farmer	0.741	1.003	0.551	0.450	2.110
Availability of irrigation facilities	0.223	1.003	0.047	0.124	0.848
Rain-fed cultivation practices	0.221	1.001	4.041	0.023*	1.801
Soil management practices	− 4.882	0.501	0.347	0.555	0.046
Water harvesting practices	3.011	1.212	3.331	0.593	2.049
Total livestock owned	0.058	0.102	0.326	0.068	1.060
Independent: biophysical variables					
Temperature change	3.238	1.037	7.121	0.000**	10.120
Precipitation change	3.169	1.021	6.230	0.000**	9.110
Increase in droughts	2.403	1.173	4.732	0.013*	5.080
Increase in floods	− 3.013	1.076	3.514	0.376	0.076
Increase in climate-induced diseases and pests	3.018	1.186	15.689	0.000**	9.001
Change in crops	− 3.225	1.006	3.214	0.314	0.071
Land use changes	− 3.413	1.116	3.003	0.317	0.803
Vegetation changes	2.939	1.179	14.166	0.000**	8.512
Soil characteristics	0.351	1.158	0.092	0.757	0.962
Independent: impact variables					
Experienced adverse impact on staple crops	3.020	1.259	22.483	0.000**	9.003
Experienced adverse impact on vegetation	2.776	1.173	12.201	0.000**	7.813
Experienced adverse impact on livestock	2.532	1.161	5.948	0.001**	6.059
Experienced adverse impact on human health	2.893	1.078	6.130	0.000**	8.031
Experienced adverse impact from disasters	2.584	1.087	5.670	0.000**	7.610
Model constant	3.875	0.502		0.015*	31.000
Model χ^2	83			0.002**	
Model Nagelkerke's R^2	0.853				
Model correct prediction	85%				

β is the estimated coefficient; SE is standard error; p is probability, and R is the coefficient of determination. Sources: Field Survey 2014 and 2015

**Probability level $p \leq 0.01$; *$p \leq 0.05$; without asterisks value are non-significant at $p > 0.05$

that they are trying to employ several adaptation strategies to cope with the negative impacts, such as the intensification of the use of agricultural inputs, diversifying and rotating crops, diversification of occupation, and migration including short-term labor migration; however, these strategies are not effective enough in the absence of appropriate technologies and their adaptation. Thus, farmers expect subsidies in the form of loans, irrigation systems, and hospitals from the government to make a better living, and to adapt to changing climatic scenarios. There is a need for community authorities and organizations to develop adaptation strategies that are based on geographical location, which was also suggested by the farmers during the FGD. To determine which level of government or what type of organization can best assist, it is important to consider the specific needs of farmers. Adaptation strategies must be formulated based on indigenous knowledge and local geography. This study demonstrates that farmers' perception and meteorological observations increase understanding of climate change and its impact on their livelihoods in Nepal. Using this knowledge, better plans and policies can be developed for the sustainable improvement of agriculture. The indicators and determinants of perceptions analyzed in the study can be utilized to formulate suitable adaptation strategies for different ecological regions of the country. It is important that local farmers, scientists, policymakers, and responsible organizations work together at a community level to formulate scientifically sound solutions to the agricultural impacts of climate change.

4 Conclusion

This study used a perception-based approach to assess the indicators and determinant factors in farmers' perception of climate change in Nepal. Farmers' socio-economic and agricultural characteristics were considered in examining the impact of climate change on their livelihoods. The socio-economic, agricultural, and biophysical characteristics of the farmers were shown to have a significant influence on their perception of climate change and its impact on their livelihood. Most farmers noticed trends of increasing temperature and decreasing precipitation as strong indicators of climate change consistent with the results of observed climate data between 2000 and 2015. A BLR analysis indicated that the important determinant variables for the respondents' perception of climate change were changes in precipitation and temperature, education status, and the agricultural system (rain-fed or irrigated). Furthermore, the odds ratios indicated that there is a strong association between farmers' perceptions of climate change and its adverse impact on staple crops, vegetation, livestock, and human health. Based on the findings of this study, there is a need for the government, responsible organizations, and policymakers to introduce scientifically sound adaptation strategies, such as drought-tolerant crops, disease- and pest-resistant seeds, irrigation facilities, and hospitals. Moreover, educational programs and training that improve farmers' livelihoods should be implemented. This study demonstrated the importance of considering the experience of farmers in developing adaptation plans. The results can contribute to the development of climate-resilient communities in Nepal, and insights and actions from Nepal and Nepali farmers' would be useful to serve broader populations around the world.

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References

Aase T, Chapagain P (2017) Organic Farmers on the Ridge: the Hyolmo of Sermathang, Nepal. In: Aase T (ed) Climate Change and the Future of Himalayan Farming. Oxford University Press, New Delhi, pp 229–266

Adger WN, Huq S, Brown K, Conway D, Hulme M (2003) Adaptation to climate change in the developing world. Prog Dev Stud 3:179–195. https://doi.org/10.1191/1464993403ps060oa

Agresti A (1996) An introduction to categorical data analysis, vol 135. Wiley, New York

Arunrat N, Wang C, Pumijumnong N, Sereenonchai S, Cai WJ (2017) Farmers' intention and decision to adapt to climate change: a case study in the Yom and Nan basins, Phichit province of Thailand. J Clean Prod 143: 672–685. https://doi.org/10.1016/j.jclepro.2016.12.058

Baniya B, Tang Q, Huang Z, Sun S, Techato K (2018) Spatial and temporal variation of NDVI in response to climate change and the implication for carbon dynamics in Nepal. Forests 9:329. https://doi.org/10.3390/f9060329

Bernués A, Tello-García E, Rodríguez-Ortega T, Ripoll-Bosch R, Casasús I (2016) Agricultural practices, ecosystem services and sustainability in High Nature Value farmland: Unraveling the perceptions of farmers and nonfarmers. Land Use Policy 59: 130–142.

Bhandari G, Atreya K, Yang X, Fan L, Geissen V (2018) Factors affecting pesticide safety behaviour: The perceptions of Nepalese farmers and retailers. Sci Total Environ 631-632:1560–1571. https://doi.org/10.1016/j.scitotenv.2018.03.144

Bhatt D, Maskey S, Babel MS, Uhlenbrook S, Prasad KC (2014) Climate trends and impacts on crop production in the Koshi River basin of Nepal. Reg Environ Chang 14:1291–1301. https://doi.org/10.1007/s10113-013-0576-6

Bielders CL, Ramelot C, Persoons E (2003) Farmer perception of runoff and erosion and extent of flooding in the silt-loam belt of the Belgian Walloon Region. Environ Sci Policy 6:85–93. https://doi.org/10.1016/S1462-9011(02)00117-X

Blaikie PM, Muldavin JSS (2004) Upstream, Downstream, China, India: The Politics of Environment in the Himalayan Region. Ann Assoc Am Geogr 94:520–548. https://doi.org/10.1111/j.1467-8306.2004.00412.x

Bryan E, Deressa TT, Gbetibouo GA, Ringler C (2009) Adaptation to climate change in Ethiopia and South Africa: options and constraints. Environ Sci Policy 12:413–426. https://doi.org/10.1016/j.envsci.2008.11.002

CBS (2012) National Population and Housing Census 2011 (National Report) vol 1. Government of Nepal, National Planning Commission Secretariat, Central Bureau of Statistics, Kathmandu, Nepal

CBS (2017) National Climate Change Impact Survey 2016: A Statistical Report, vol 1. Government of Nepal, National Planning Commission Secretariat, Central Bureau of Statistics, Kathmandu

Chapagain PS, Ghimire M, Shrestha S (2017) Status of natural springs in the Melamchi region of the Nepal Himalayas in the context of climate change Environ. Dev Sust 21:263–280. https://doi.org/10.1007/s10668-017-0036-4

Deressa TT, Hassan RM, Ringler C, Alemu T, Yesuf M (2009) Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Glob Environ Chang 19:248–255. https://doi.org/10.1016/j.gloenvcha.2009.01.002

Devkota R (2014) Climate change: trends and people's perception in Nepal. J Environ Prot 5:255–265. https://doi.org/10.4236/jep.2014.54029

Devkota R, Pandey V, Bhattarai U, Shrestha H, Adhikari S, Dulal K (2017) Climate change and adaptation strategies in Budhi Gandaki River Basin, Nepal: a perception-based analysis. Clim Chang 140:195–208. https://doi.org/10.1007/s10584-016-1836-5

Dhakal S, Sedhain G, Dhakal S (2016) Climate Change Impact and Adaptation Practices in Agriculture: A Case Study of Rautahat District, Nepal. Climate 4(63):61–22. https://doi.org/10.3390/cli4040063

Dhital S, Koirala M, Dhungel S, Mishra R, Gulis G (2016) Climate Change and Its Impacts on Human Health in Nepal. Health Educ J 4:1–4. https://doi.org/10.4172/2380-5439.1000174

Field A (2009) Discovering statistics using SPSS. Sage publications

Gautam Y, Andersen P (2016) Rural livelihood diversification and household well-being: Insights from Humla, Nepal. J Rural Stud 44:239–249. https://doi.org/10.1016/j.jrurstud.2016.02.001

Guillet D, Godoy RA, Guksch CE, Kawakita J, Love TF, Matter M, Orlove BS (1983) Toward a Cultural Ecology of Mountains: The Central Andes and the Himalayas Compared [and Comments and Reply]. Curr Anthropol 24:561–574 http://www.jstor.org/stable/2743164

Hou L, Huang J, Wang J (2015) Farmers' perceptions of climate change in China: the influence of social networks and farm assets. Clim Res 63:191–201. https://doi.org/10.3354/cr01295

Hou L, Huang J, Wang J (2017) Early warning information, farmers' perceptions of, and adaptations to drought in China. Clim Chang 141:197–212. https://doi.org/10.1007/s10584-017-1900-9

IPCC (2014a) Climate Change 2014: Impacts, Adaptation, and Vulnerability-Part A: Global and Sectoral Aspects-Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

IPCC (2014b) Climate Change 2014: Impacts, Adaptation, and Vulnerability-Part B: Regional Aspects- Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

Ives JD (1987) The Theory of Himalayan Environmental Degradation: Its Validity and Application Challenged by Recent Research. Mt Res Dev 7:189–199. https://doi.org/10.2307/3673192

Ives JD, Messerli B (1989) Himalayan Dilemma: reconciling development and conservation. Routledge, London. https://doi.org/10.4324/9780203169193

Kaufman DS et al (2009) Recent Warming Reverses Long-Term Arctic Cooling. Science 325:1236–1239. https://doi.org/10.1126/science.1173983

Kemausuor F, Dwamena E, Bart-Plange A, Kyei-Baffour N (2011) Farmers' perception of climate change in the Ejura-Sekyedumase District of Ghana. ARPN J Agric Biol Sci 6:26–37

Khanal U, Wilson C, Hoang V-N, Lee B (2018) Farmers' Adaptation to Climate Change, Its Determinants and Impacts on Rice Yield in Nepal. Ecol Econ 144:139–147. https://doi.org/10.1016/j.ecolecon.2017.08.006

Koirala A, Shrestha KB (2017) Effects of climate change on the livestock population in Mustang District, Nepal. Asian J Agric Dev 14:37–49

LRMP (1986) Land Utilization Report. Land Resource Mapping Project, Kenting Earth Science Canada and Department of Topography, Government of Nepal, Kathmandu, Nepal

Manandhar S, Vogt DS, Perret SR, Kazama F (2011) Adapting cropping systems to climate change in Nepal: a cross-regional study of farmers' perception and practices. Reg Environ Chang 11:335–348. https://doi.org/10.1007/s10113-010-0137-1

Mertz O, Mbow C, Reenberg A, Diouf A (2009) Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. Environ Manag 43:804–816. https://doi.org/10.1007/s00267-008-9197-0

Metz JJ (1989) Himalayan Political Economy: More Myths in the Closet? Mt Res Dev 9:175–181. https://doi.org/10.2307/3673480

Mishra SR, Bhandari PM, Rita I, Neupane D, Gurung S, Khanal V (2015) Climate change and adverse health events: community perceptions from the Tanahu district of Nepal. Environ Res Lett 10:1–6. https://doi.org/10.1088/1748-9326/10/3/034007

Nagelkerke NJD (1991) A note on a general definition of the coefficient of determination Biometrika 78:691-692. https://doi.org/10.1093/biomet/78.3.691

Negi VS, Maikhuri RK, Pharswan D, Thakur S, Dhyani PP (2017) Climate change impact in the Western Himalaya: people's perception and adaptive strategies. J Mt Sci 14:403–416. https://doi.org/10.1007/s11629-015-3814-1

Nguyen TPL, Seddaiu G, Virdis SGP, Tidore C, Pasqui M, Roggero PP (2016) Perceiving to learn or learning to perceive? Understanding farmers' perceptions and adaptation to climate uncertainties. Agric Syst 143:205–216. https://doi.org/10.1016/j.agsy.2016.01.001

Pandey R, Bardsley DK (2015) Social-ecological vulnerablity to climate change in the Nepali Himalaya. Appl Geogr 64:74–86. https://doi.org/10.1016/j.apgeog.2015.09.008

Paudel B, Gao J, Zhang Y, Wu X, Li S, Yan J (2016) Changes in Cropland Status and Their Driving Factors in the Koshi River Basin of the Central Himalayas, Nepal. Sustainability 8:933. https://doi.org/10.1126/science.1111772

Paudel B, Zhang Y, Li S, Wu X (2017) Spatiotemporal reconstruction of agricultural land cover in Nepal from 1970 to 2010. Reg Environ Chang 17:2349–2357. https://doi.org/10.1007/s10113-017-1164-y

Paudel B, Zhang Y, Yan J, Rai R, Li L (2019) Farmers' perceptions of agricultural land use changes in Nepal and their major drivers. J Environ Manag 235:432–441. https://doi.org/10.1016/j.jenvman.2019.01.091

Poudel S, Funakawa S, Shinjo H (2017) Household Perceptions about the Impacts of Climate Change on Food Security in the Mountainous Region of Nepal. Sustainability 9:641

Pradhan NS, Sijapati S, Bajracharya SR (2015) Farmers' responses to climate change impact on water availability: insights from the Indrawati Basin in Nepal. Int J Water Res Dev 31:269–283. https://doi.org/10.1080/07900627.2015.1033514

Pröbstl-Haider U et al (2016) Farmers' preferences for future agricultural land use under the consideration of climate change. Environ Manag 58:446–464. https://doi.org/10.1007/s00267-016-0720-4

Rahut D, Micevska S (2012) Livelihood diversification strategies in the Himalayas. Aus J Agric Res Ecol 56:558–582. https://doi.org/10.1111/j.1467-8489.2012.00596.x

Retherford RD, Choe MK (1993) Statistical models for causal analysis. Wiley

Shrestha AB, Aryal R (2011) Climate change in Nepal and its impact on Himalayan glaciers. Reg Environ Chang 11:65–77. https://doi.org/10.1007/s10113-010-0174-9

Shrestha AB, Wake CP, Mayewski PA, Dibb JE (1999) Maximum temperature trends in the Himalaya and its vicinity: an analysis based on temperature records from Nepal for the period 1971-94. J Clim 12:2775–2786. https://doi.org/10.1175/1520-0442(1999)012<2775:MTTITH>2.0.CO;2

SPSS (2011) IBM SPSS Statistics 20. International Business Machines Statistical Package for the Social Sciences in. Armonk, NY, USA

Sujakhu NM, Ranjitkar S, Niraula RR, Pokharel BK, Schmidt-Vogt D, Xu J (2016) Farmers' Perceptions of and Adaptations to Changing Climate in the Melamchi Valley of Nepal. Mt Res Dev 36:15–30. https://doi.org/10.1659/mrd-journal-d-15-00032.1

Tang L, Zhou J, Bobojonov I, Zhang Y, Glauben T (2018) Induce or reduce? The crowding-in effects of farmers' perceptions of climate risk on chemical use in China. Clim Risk Manag 20:27–37. https://doi.org/10.1016/j.crm.2018.02.001
Tesfahunegn GB, Mekonen K, Tekle A (2016) Farmers' perception on causes, indicators and determinants of climate change in northern Ethiopia: implication for developing adaptation strategies. Appl Geogr 73:1–12. https://doi.org/10.1016/j.apgeog.2016.05.009
Thornton PK, Kristjanson P, Förch W, Barahona C, Cramer L, Pradhan S (2018) Is agricultural adaptation to global change in lower-income countries on track to meet the future food production challenge? Glob Environ Chang 52:37–48. https://doi.org/10.1016/j.gloenvcha.2018.06.003
Travis WR, Smith JB, Yohe GW (2018) Moving toward 1.5°C of warming: implications for climate adaptation strategies. Curr Opin Environ Sustain 31:146–152. https://doi.org/10.1016/j.cosust.2018.03.003
Tripathi R, Sengupta SK, Patra A, Chang H, Jung IW (2014) Climate change, urban development, and community perception of an extreme flood: a case study of Vernonia, Oregon, USA. Appl Geogr 46:137–146. https://doi.org/10.1016/j.apgeog.2013.11.007
Uprety Y et al (2017) Perceptions of climate change by highland communities in the Nepal Himalaya. Clim Dev 9:649–661. https://doi.org/10.1080/17565529.2017.1304886
Valdivia C et al (2010) Adapting to climate change in Andean ecosystems: landscapes, capitals, and perceptions shaping rural livelihood strategies and linking knowledge systems. Ann Assoc Am Geogr 100:818–834. https://doi.org/10.1080/00045608.2010.500198
Zhang Y, Gao J, Liu L, Wang Z, Ding M, Yang X (2013) NDVI-based vegetation changes and their responses to climate change from 1982 to 2011: a case study in the Koshi River Basin in the middle Himalayas. Glob Planet Chang 108:139–148. https://doi.org/10.1016/j.gloplacha.2013.06.012

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