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## Climate change in Lamjung District, Nepal: meteorological evidence, community perceptions, and responses

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## LETTER

## Climate change in Lamjung District, Nepal: meteorological evidence, community perceptions, and responses

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**Abstract**

Climate change is a global threat which has particularly strong impacts on countries whose economies are highly dependent on agriculture and still developing—like Nepal. As these impacts increase, there is a need to understand how those most vulnerable are experiencing and reacting to climate change. As such, this study aims to understand the effects of climate change via changes in atmospheric conditions in Bansar Village Development Committee, a rural community located in Lamjung District, and document community-led adaptation strategies. Household surveys and focused group discussions were conducted in conjunction with long-term meteorological data. Results show the temperature has increased significantly in the study area. Additionally, precipitation has increased in the pre-monsoon, monsoon, and post-monsoon season while it has decreased in winter leading to droughts. The probability of erratic rainfall occurrence and severe weather such as hailstorms has also increased. Lastly, invasive species have been reported and observed. The combination of these impacts has led to increased crop failure and consequently decreased agricultural production thus threatening the livelihoods of this agricultural based community. However, Bansar residents are actively working to adapt to and mitigate the effects of climate change. Their responses include changing farming methods and installing new water infrastructure.

**Introduction**

Climate change is now recognized as a major global issue bearing social, political and economic dimensions (Reilly, 2001). While climate change ultimately affects all countries, some countries are at more and immediate risk. This is especially true for those countries which are economically dependent on agricultural resources and do not have robust infrastructures. Nepal is one of those countries. In fact, it has been ranked as the 4th most vulnerable country to climate change (Maplecroft 2011). Landlocked between India and China, the country is one of the most geographically and biologically diverse places on Earth. Its topography ranges from the Himalayas, including the highest point on the planet, Mt. Everest, in the east to the near sea-level Terai plains and Saara jungle in the west. This divides the country into five major physiographic regions: the Terai Plains, Siwalik Hills, Middle Mountains, High Mountains (consisting of the Main Himalayas and the Inner Himalayan valleys) and the High Himalayas. Its climate ranges from subtropical in the south to arctic in the north (Shrestha and Aryal 2011). Nepal is significantly affected by the south-easterly monsoon which provides most of the precipitation during the rainy summer months (June to September) (Shrestha and Aryal 2011). Monsoonal precipitation is the most important climatic element for agriculture as well as water resources of the country (Malla 2009).

A number of studies conducted on historical climate in Nepal have proved significant warming trends particularly in recent decades (Shrestha and Nepal 2016). Moreover, results from Coupled Model Intercomparison Project, Phase 5 (CMIP5) models suggest that the mean annual temperatures are projected to increase between 1.3 °C–3.8 °C by the

2060's (World Bank 2019). Winters are also projected to be drier and monsoon summers wetter and more intense likely leading to more frequent summer floods and winter droughts (World Bank 2019).

Consequently, this may result in an increase in frequency and intensity of extreme events (Aryal *et al* 2014). However, due the strong geological diversity in Nepal, the level of climate change's impacts vary across the country. For example, temperature levels in western and central Nepal are expected to increase at a higher rate as compared to eastern Nepal (Timsina 2011). Specifically, the observed impacts of climate change in Nepal include temperature increase, erratic rainfall, unpredictable monsoon seasons, increased occurrence of storms, landslides, and droughts (Gentle and Maraseni 2012; Devkota *et al* 2013; Khanal 2014). Furthermore, there is an increasingly concern about Himalayan glacier melt as it has resulted in glacial lake outburst floods (GLOF) which have proven deadly (Mool *et al* 2001; Bajracharya *et al* 2007; Shrestha and Aryal, 2011).

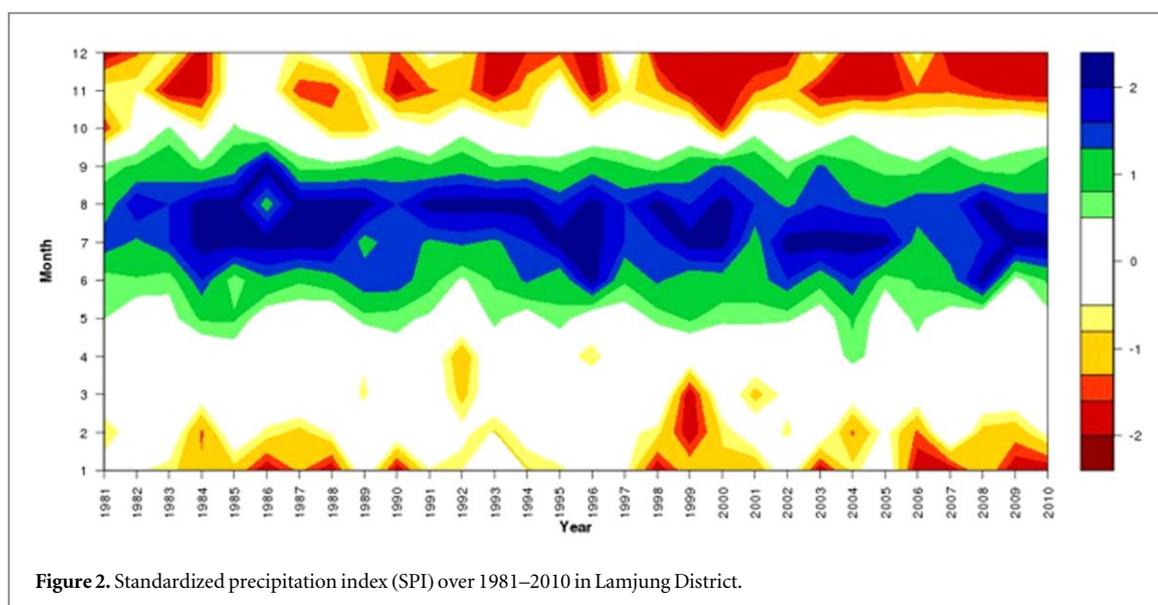
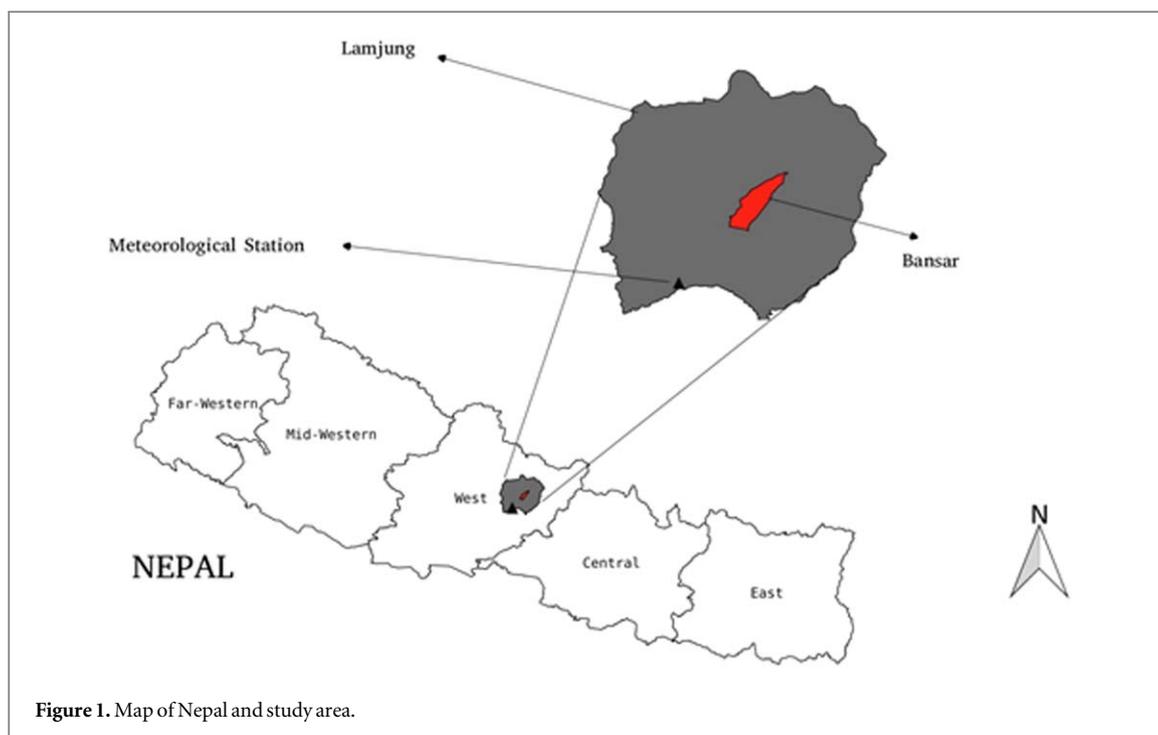
Climate change can significantly affect crop production thereby increasing food and livelihood insecurity (Malla 2009; Ministry of Environment (MOE) 2010, IPCC 2018). In Nepal, in 2012/2013, rice, maize, and millet production fell by 11.3, 8.3, and 3%, respectively, due to inadequate rainfall and prolonged droughts (Ministry of Finance MOF (2013)). Over the last decade, around 30,845 hectares of land became uncultivable due to the climate-related hazards. 76% of the land was dependent on rain and consequently affected by the erratic patterns of rainfall, drought, flash floods, and landslides (CBS Central Bureau of Statistics of Nepal (2004)). Given that in Nepal, over 68% of the population relies on agriculture for livelihood and the sector accounts for 34% of the country's gross domestic product (GDP), rapid changes in cultivable land can have grave impacts (International Labour Organization ILO (2016)). This especially creates concern for the food security of those who reside in the remote, rural hill or mountain regions of Nepal which are already significantly more food insecure than other areas (Nepal Food Security Monitoring System NeKSAP (2016)).

Many studies have investigated the impacts of climate change on communities in Nepal (Aryal *et al* 2014; Becken *et al* 2013; Chaudhary and Bawa 2011; Maharjan *et al* 2011; ect) but given the number of Districts in Nepal and diversity of communities among them, there is still a gap in research between the impacts of climate change and associated local responses. Therefore, this study aims to understand the impacts of climate change on livelihoods and community adaptation strategies based on meteorological data and community perceptions. Several studies have shown how people's perception on environmental changes match with the conclusions derived from institutionalized scientific research (Maddison 2006, Devkota 2014). While by definition, people's perception is changing per se, at the same time as it is shaped by a complex interaction of socio-economic and cultural aspects (Vedwan 2006, Gbetibouo 2009), it remains that perception and traditional local knowledge can fill data-less related gaps (Huntington 2000). These data gaps are more frequent in Least Developed Countries such as Nepal, which, in turn, are also the most vulnerable to climate change impacts (Huq *et al* 2003). Thus, we hope to use this study to add to the growing body of literature on climate change impacts in rural communities and illuminate adaptation and mitigation strategies.

## Methods

### Study area

Bansar is a rural village located in West Nepal in the Lamjung District (figure 1). It is one of the 57 Village Development Committees (VDCs) in Lamjung District and covers an area of 43 km<sup>2</sup>. As for Lamjung District, it covers a total area of 1692 km<sup>2</sup> and is comprised of three geographic regions: the mid-hill, high-himal and high hill. The mid-hill and high hill combined cover eighty percent of the total district land while high himal covers twenty percent. While plains are found along riverbanks and foothills, much of the land is steeply sloped and is highly prone to soil erosion. Land suitable for cultivation covers about 35% of total land in the district. On average, the annual temperature is recorded from a minimum of 14.1 °C to a maximum of 26.7 °C. Furthermore, the annual precipitation is recorded as 2944.23 mm. The district shows diverse climatic conditions which is primarily a reflection of the gradient in topography. Lamjung is comprised of 5 climatic zones: tropical (up to 1000 m), sub-tropical (1000–2000 m), temperate cold (2000–3000 m), sub-Alpine (3000–4000 m), and Alpine and Tundra (above 4000 m) (AEPC 2014; Shrestha 2014). The Bansar VDC itself is very similar to other villages found in the hill area. It is only accessible by trekking and is located among terraced hillsides. The last census VDC-level census of Bansar was in 1991 and reported approximately 500 households scattered throughout the area (CBS Central Bureau of Statistics of Nepal (1991)). Most villages in Nepal are associated with a specific indigenous group who has mastered a certain type of subsistence farming. In the case of Bansar VDC, this is the Tamang people who traditionally practice subsistence farming that consists of maize and millet. Bansar VDC was chosen as the study site due to the social connections that the lead author had with the community.



## Data collection and analysis

### Climatic data

For climatic data, long-term temperature and rainfall data was obtained at nearby meteorological station (figure 1) from the Department of Hydrology and Meteorology. Data has a monthly temporal resolution and spans a 30 year period from 1989 to 2010. The seasonal mean rainfall and temperature for four prominent seasons (i.e. pre-monsoon, monsoon, post-monsoon, and winter) were calculated. Furthermore, the significance of trends (against the null hypothesis of no trend) in temperature and rainfall were tested using the non-parametric Mann–Kendall test as seen in table 2 (Yue *et al* 2002). A standardized precipitation index (SPI) was also modeled using the long-term precipitation data following McKee *et al* (1993) as seen in figure 2. SPI represents the probability of occurrence of an observed rainfall amount when compared with the rainfall climatology at a certain geographical location, over a long-term reference period. The index corresponds to the number of standard deviations that observed cumulative precipitation deviates from the climatological average, and can be calculated for any time scale.



**Figure 3.** Focused group discussion with indigenous women's group Aama Samuha.

## Survey data

Ethnographic research was undertaken for three weeks during the spring of 2016. Data was collected from three sources including: (i) household surveys, (ii) focused group discussions, and (iii) key informant interviews. The social connection that the lead author had with the community (i.e. an uncle of a relative) allowed for trust to be established with Bansar residents and led to honest dialogue and responses from those interviewed in a relatively short amount of time. The combination of household surveys, focused group discussions, and key informant interviews allowed for wide range of responses from diverse number of participants ( $N = 50$ ). Additionally, direct field observations were undertaken to understand agricultural pattern changes. Particularly, changes in farming land and forest cover were noted along with invasive species observed and dry community wells.

### Household surveys

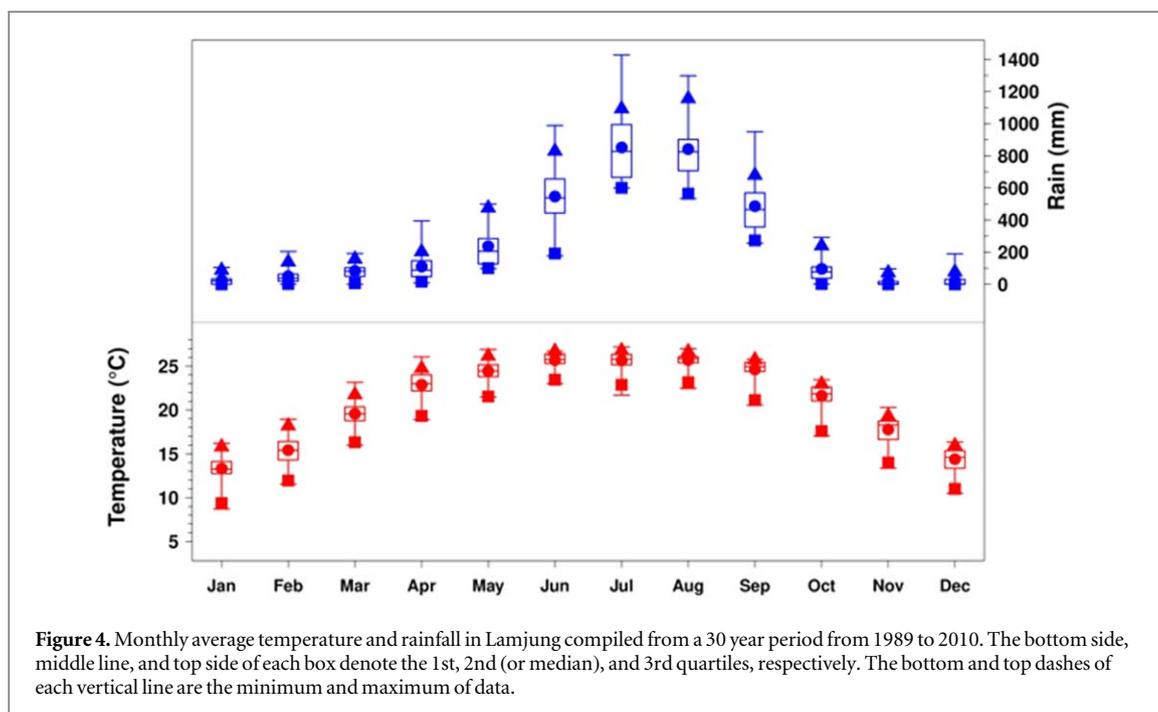
Twenty household surveys using a semi-structured questionnaire were completed. Questions were designed to determine the participants' perception of climate change through changes such as disaster intensity and frequency, rainfall and temperature (See [appendix](#)).

### Focused group discussions

In order to acquire information regarding specific changes in livelihood patterns, agricultural practices, and temperature and precipitation levels, a focused group discussion together with a local indigenous community group known as Aama Samuha was conducted (figure 3). The Aama Samuha are made up of women from each household in the village. They are involved in planning community activities, looking after finances, fetching water, and getting fodder from the jungle. These women work closely with the nature and are often more active in agriculture given that many men leave the village in search of work. Thus, they can provide valuable local knowledge of the climate conditions for Bansar.

### Key informant interviews

Lastly, elders from select households were used as key informants in order to help identify perceived changes that occurred over 30 years ago. The same questions from the household survey were used for the focused group discussion and key informant interviews, but the latter two allowed for more detail to be conveyed and more open-ended responses.



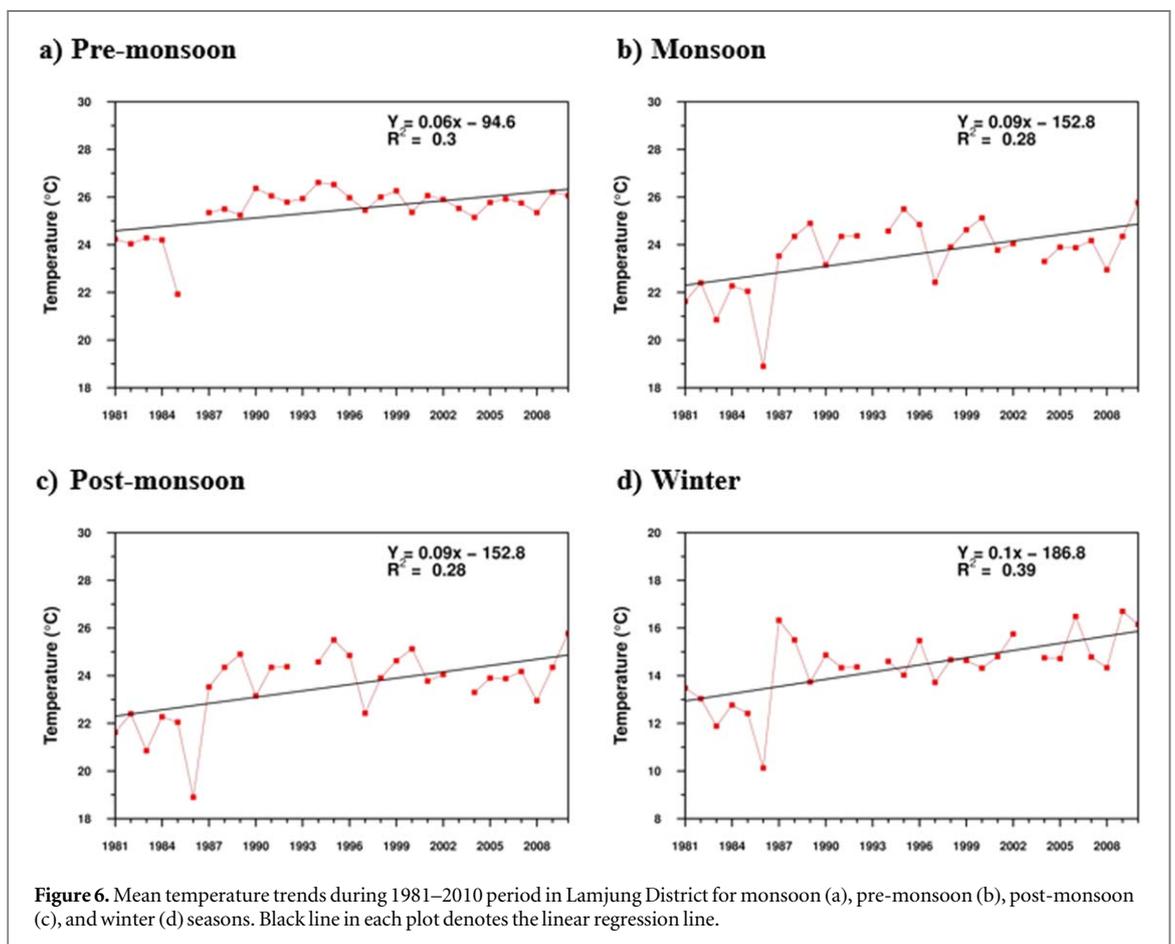
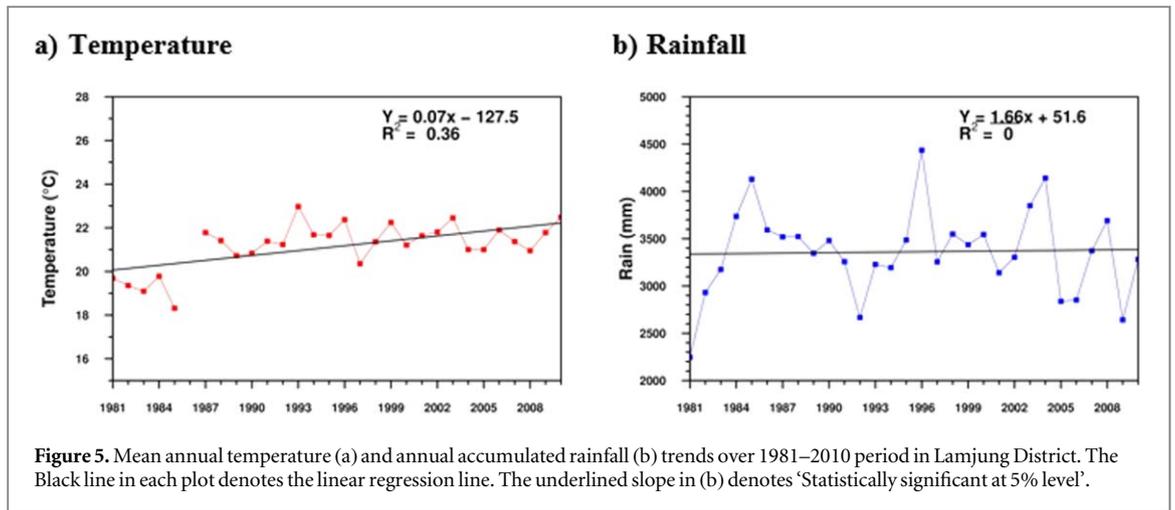
**Table 1.** Monthly temperature and rainfall data for 1981–2010.

Month	Monthly temperature (°C)			Monthly rainfall (mm)
	Max	Min	Mean	
January	20.1	6.6	13.4	25.6
February	22.1	8.9	15.5	49.4
March	26.4	12.6	19.5	83.3
April	29.9	15.8	22.9	110.4
May	30.5	18.3	24.4	237.7
June	30.9	20.5	25.7	546.5
July	30.1	21.2	25.7	852.3
August	30.3	21.1	25.7	842.1
September	29.6	19.6	24.6	485.4
October	27.8	15.4	21.6	95.9
November	24.7	11.0	17.8	15.4
December	21.1	7.7	14.4	20.9
Average	27.0	14.9	20.9	280.4

## Results and discussion

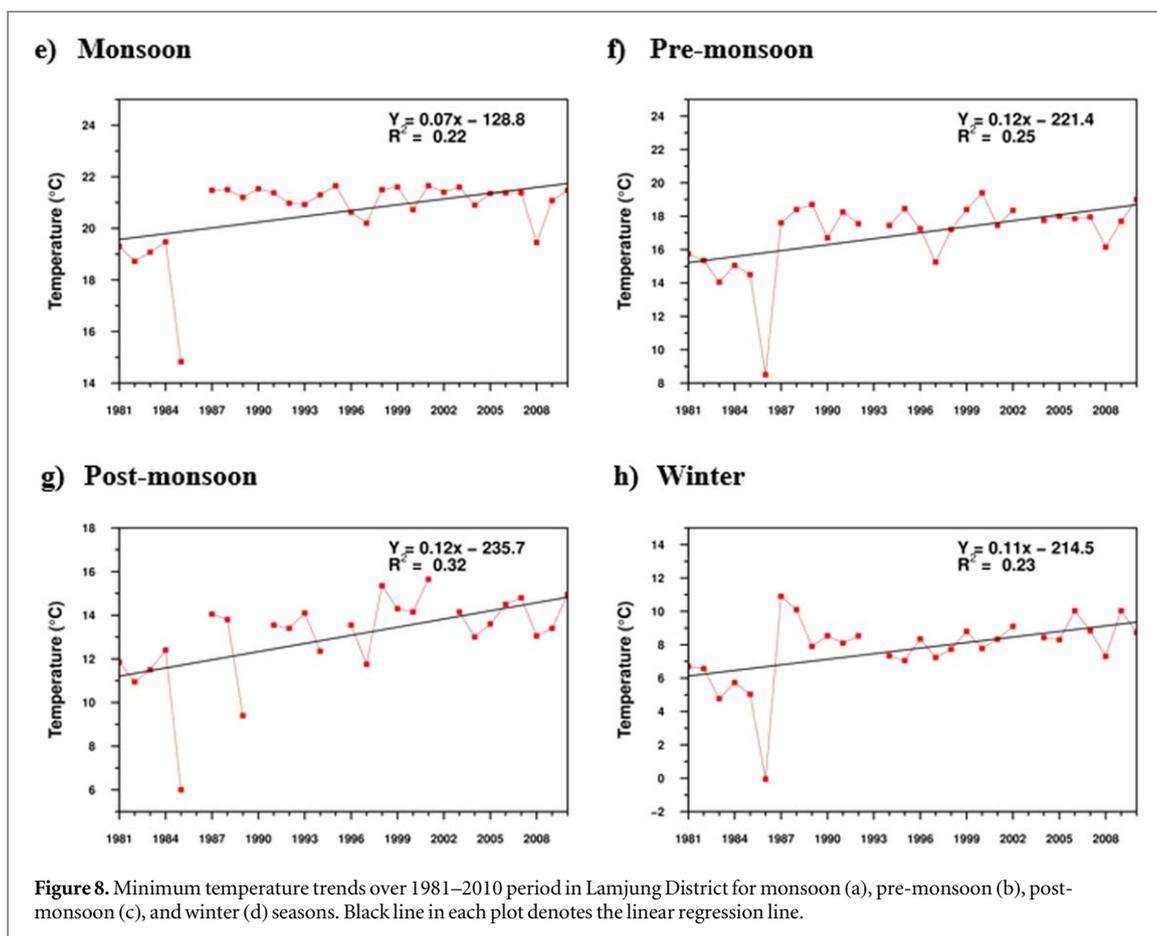
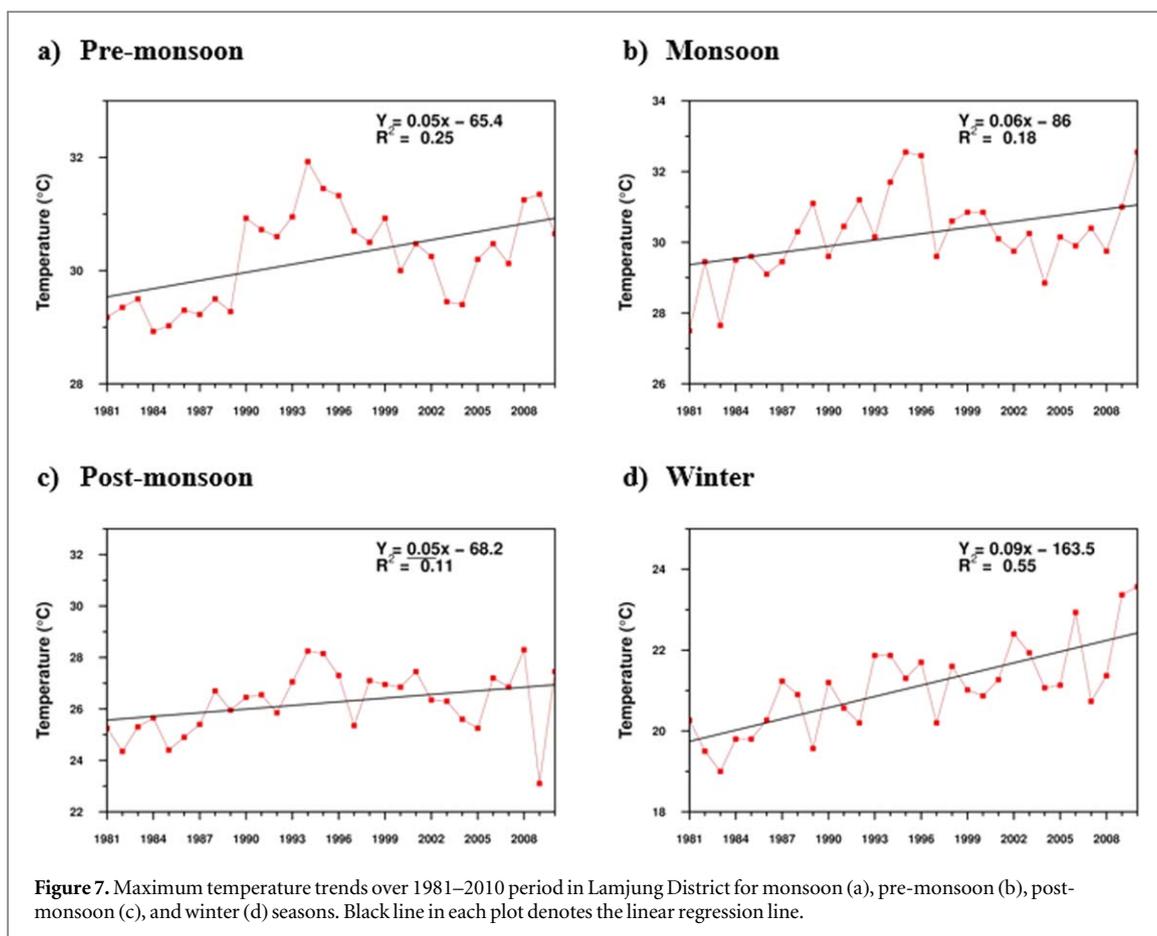
### Temperature

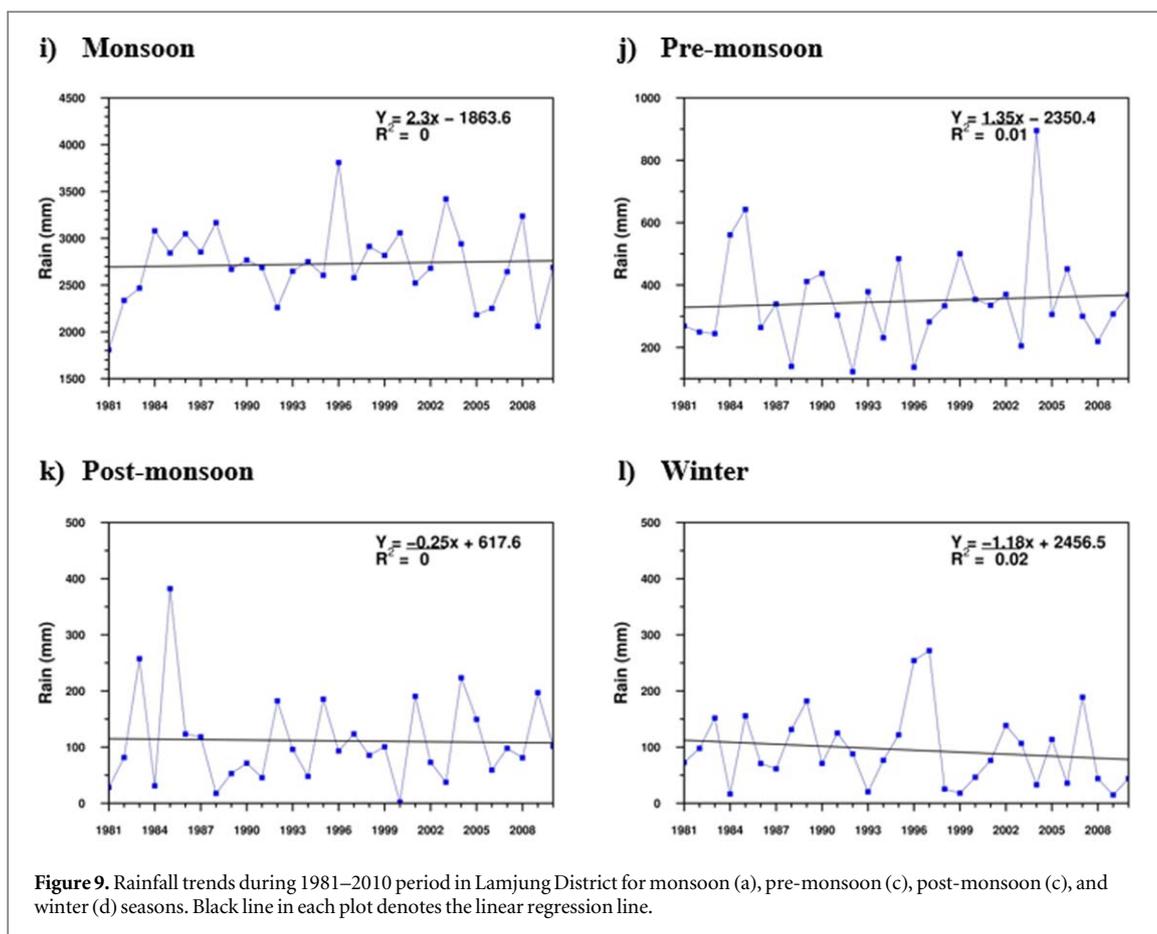
Temperature and rainfall are considered as two major climate change indicators in this study and their variation in the 30-year period of 1981–2010 are analyzed and presented in this section. The monthly climatic data averaged for 1981–2010 are given in table 1 and can be visualized in figure 4. The average annual maximum and minimum temperatures are 27 °C and 14.9 °C, respectively. The mean annual temperature for the same period is 20.9 °C. Temperature was also averaged for each year (figure 5). The highest mean maximum temperature of 28.84 °C was recorded in 1999. Similarly, the lowest mean maximum temperature of 25.41 °C was recorded in 1983. The result of the Mann–Kendall test for the variation of average, maximum and minimum temperature are summarized in table 3, suggesting that the trends of all temperature-related parameters are increasing and statistically significant at 95% confidence level. Since the seasonal variations in temperature can significantly affect the overall trend, it is also of interest to investigate the trends for each season separately. The seasonal trends for mean, maximum, and minimum temperature are shown in figures 6, 7, and 8 respectively. Moreover, variations in maximum temperature trends in figure 7 are stronger compared to those of mean and minimum temperatures which can be attributed to the potential cyclic impact of the El Nino Southern Oscillation (ENSO) events over the study area (Shrestha *et al* 2000).



## Rainfall

Monthly accumulated rainfall at the meteorological station of Lamjung for 1981–2010 are given in table 1 and seen in figure 4. The months of June–September disclose the higher rainfall rates (i.e. Monsoon season) whereas the months of November–February have the lowest. The highest annual rainfall rate of 4435.9 mm was recorded in 1996, while the lowest annual rainfall rate of 2245.9 mm was recorded in 1981 (figure 5). The results of the Mann–Kendall test for the variation of annual average and seasonal rainfall from 1981 to 2010 are shown in table 3 and figure 9. As it can be seen, the pre-monsoon, monsoon, and post-monsoon rainfalls have increasing trend while the winter rainfall has decreasing trend. However, all trends are statistically insignificant at the 95% level. Moreover, there are strong fluctuations in rainfall for all seasons. The precipitation fluctuation in Nepal, according to Shrestha *et al* (2000), is strongly correlated with the ENSO. For instance, dry year of 1992 coincides





**Table 2.** Mann-Kendall results for mean, maximum, and minimum temperature for 1981–2010

Temperature	p-value	Tau ( $\tau$ ) value	Linear slope ( $^{\circ}\text{C}/\text{year}$ )	Trend	Significance	Alpha value
Tmax	< 0.05	0.31	0.06	Increasing	Significant	0.05
Tmin	< 0.05	0.39	0.14	Increasing	Significant	0.05
Mean	< 0.05	0.43	0.07	Increasing	Significant	0.05

**Table 3.** Mann-Kendall results for variation of rainfall in 1981–2010.

Temperature	p-value	Tau ( $\tau$ ) value	Linear slope (mm /year)	Trend	Significance	Alpha value
Pre-monsoon	0.70	0.05	1.35	Increasing	Insignificant	0.05
Monsoon	0.91	0.05	2.3	Increasing	Insignificant	0.05
Post-monsoon	0.41	0.41	0.25	Increasing	Insignificant	0.05
Winter	0.31	-0.13	-1.18	Decreasing	Insignificant	0.05

with the elongated El Nino of 1992–1993 could, therefore, be an indication of cyclical variability rather than of linear change.

**SPI analysis**

The SPI index map in Lamjung district over 1981–2010 period is shown in figure 2. The probability of occurrence of a drought event is higher in the post-monsoon and winter season of 2001–2010 period as compared to previous years. Moreover, the probability of occurrence of erratic rainfall in the monsoon season is stronger in the same period, while the frequency of rainfall is less.

**Community perceptions**

Ethnographic research revealed valuable perceptions on changing climatic parameters (figures 10–13). The majority of respondents (90%) reported that there was an increase in erratic rainfall frequency, but a decrease in the frequency of rain overall (65%) (figure 10). These results are both consistent with the observed pattern of

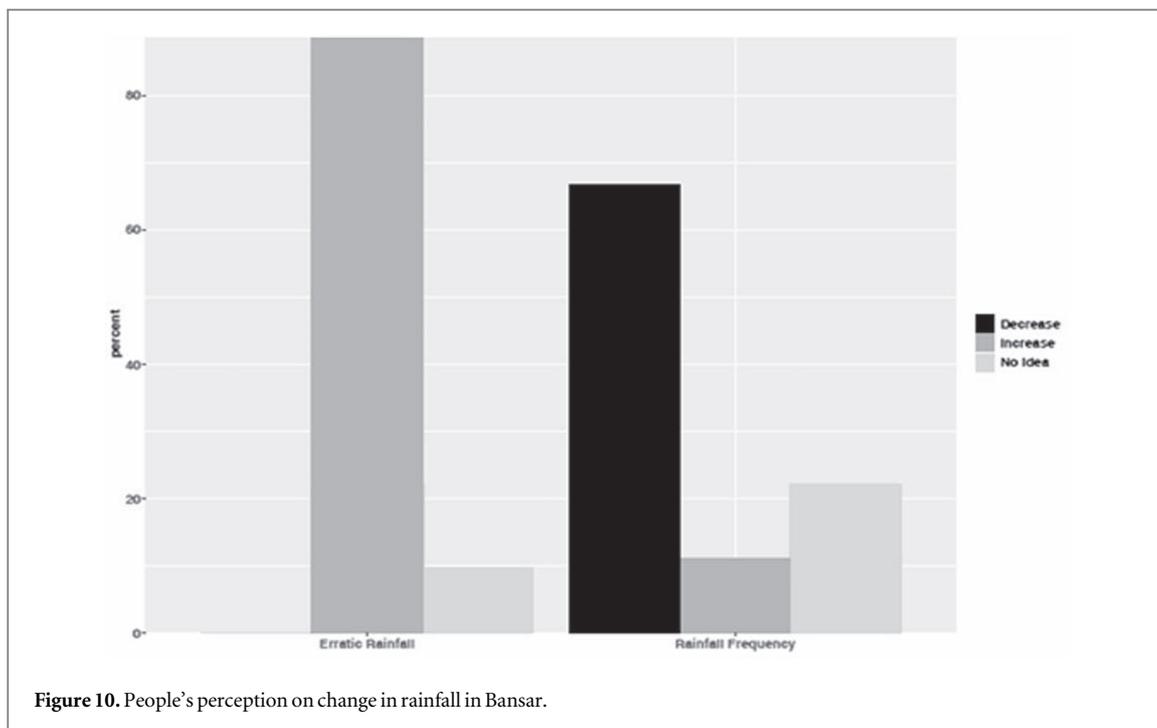


Figure 10. People's perception on change in rainfall in Bansar.

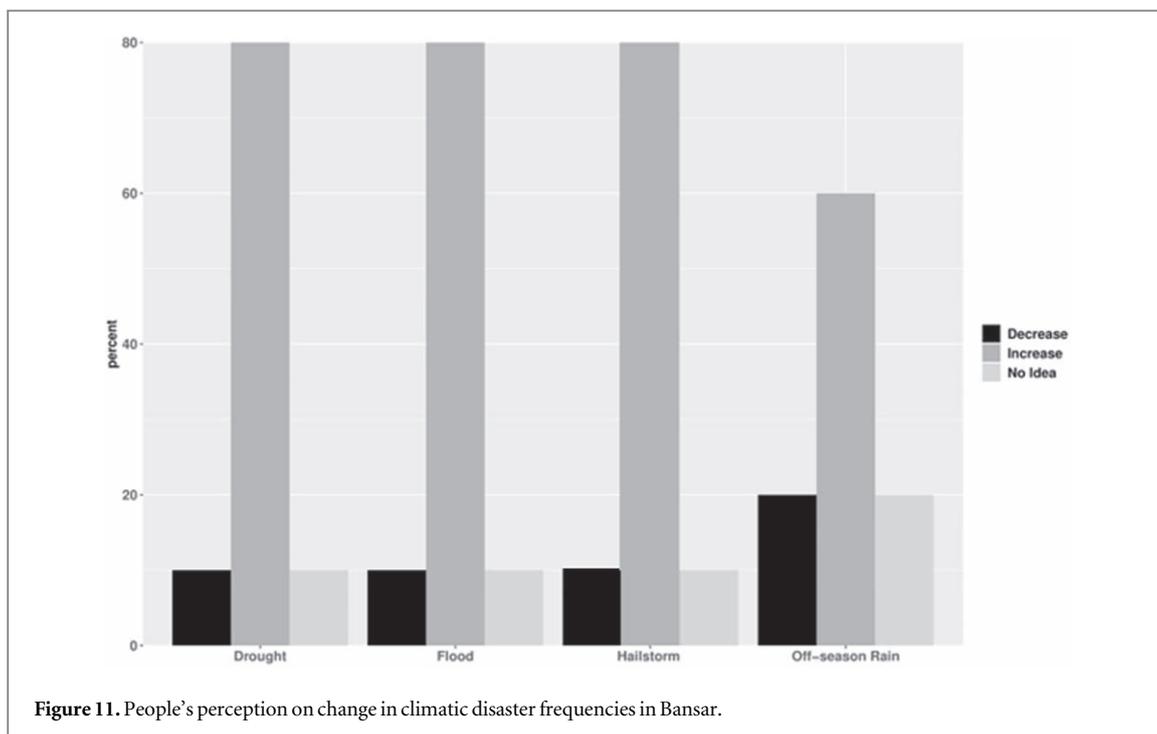


Figure 11. People's perception on change in climatic disaster frequencies in Bansar.

rainfall in this area shown by empirical data, and match the perception of the farmers from the lowland Rupandehi district, 130 km Southwest from Bansar (Manandhar *et al* 2011). This changing intensity and frequency of rainfalls can have negative impacts on the farmers livelihood by making their agricultural activity less secured.

The faster the climate changes, the faster farmers have to review and/or leave behind some of their knowledge and practices nested on their traditional agricultural routine, by, for example, shifting the crop variety (Morton 2007). As for people's perceptions on climatic disaster frequencies (figure 11), most of the respondents mentioned that there was an increase in flood (80%), drought (80%), and off-season rain frequencies (60%), as well as hailstorm frequency (80%). Regarding the changes in summer temperature (figure 12), 55% of respondents replied there had been an increase. Furthermore, all respondents reported experiencing decrease in agricultural harvest (100%), biodiversity (68%), and forest products (65%) (figure 13).

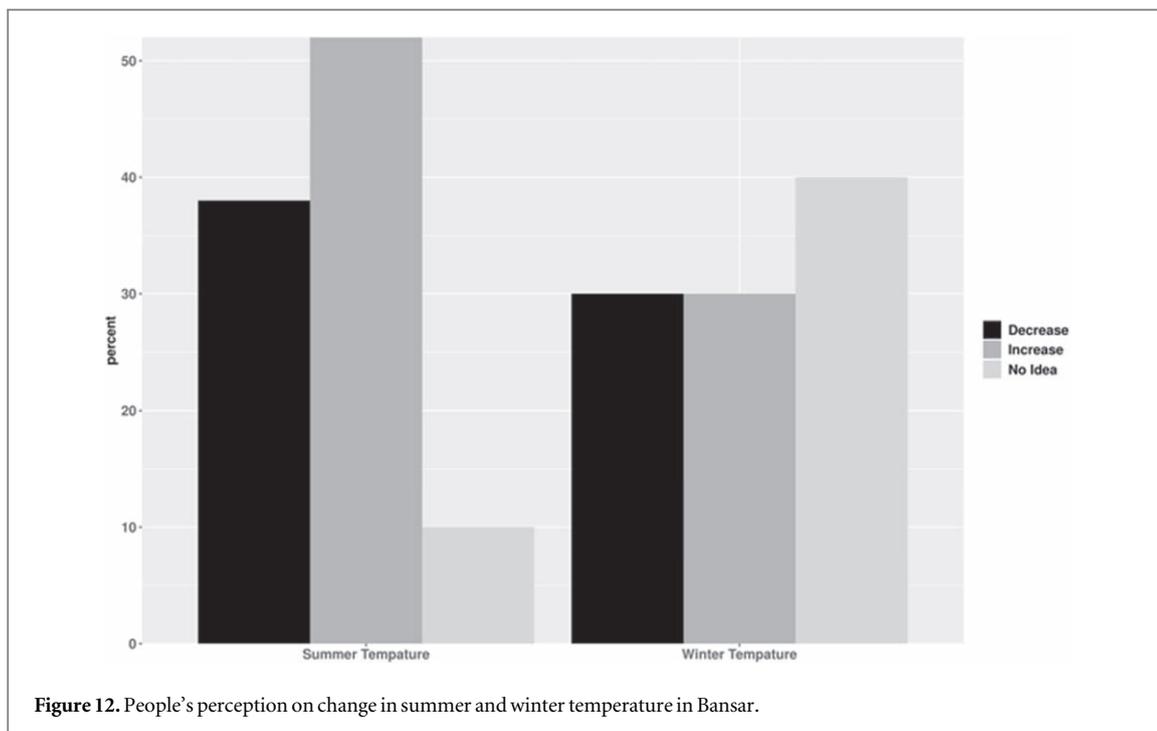


Figure 12. People's perception on change in summer and winter temperature in Bansar.

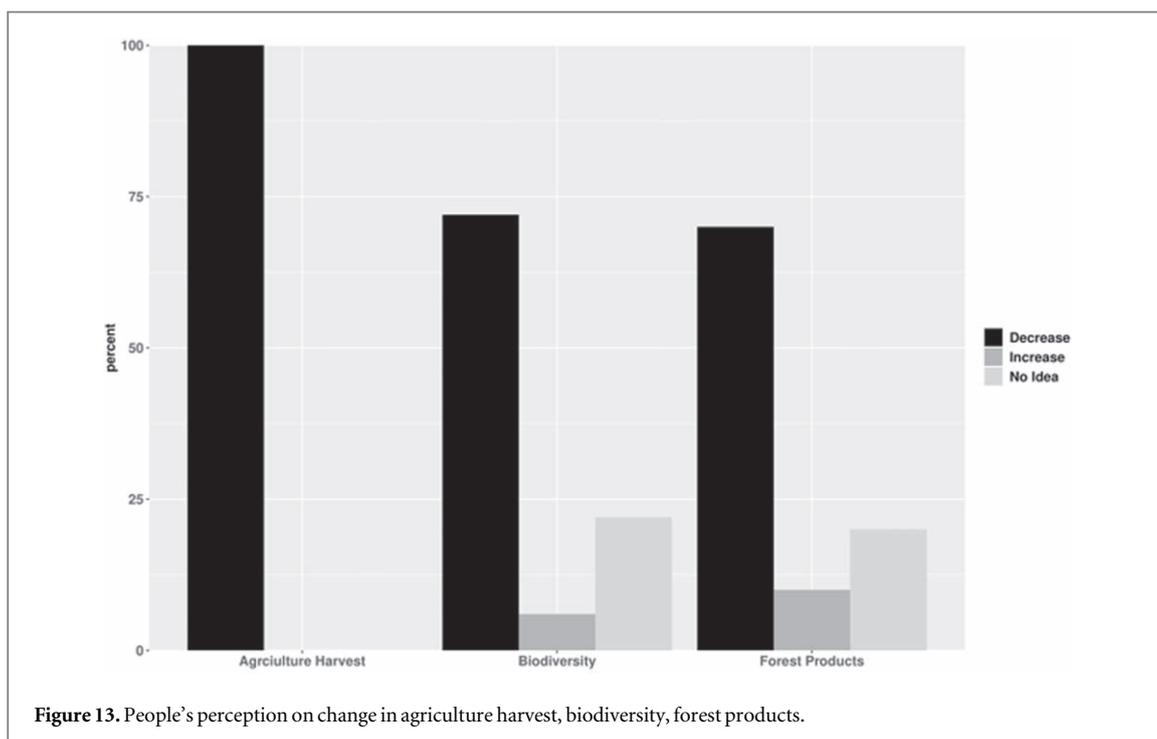


Figure 13. People's perception on change in agriculture harvest, biodiversity, forest products.

This is similar to the experiences that the Tharu indigenous community in Western Terai region has also experience especially in regards to agriculture loss (Maharjan *et al* 2011). In regards to biodiversity loss and loss of forest products, more detail was provided by the Aama Samuha group during a focused group discussion. These women have identified changes in the natural species found in the forest. Notably, they report an increased presence of invasive species such as banmara (*Chromolaena odorata*), and eupatorium weeds which are known to be aggressive and linked with warming temperatures (Kunwar 2003; Barik and Adhikari 2011). This invasion has resulted in loss of traditional herbs and pastoral land as locals gave up their goats and cows due to lack of fodder and grass.

Additionally, residents reported increasing difficulty in accessing water as their only drinking source dried up in recent years. They have since constructed a pipeline to transfer the water from a distant water spring to Bansar, but it is still a two hours walk away. Water availability in conjunction with the shifting seasons and

change in precipitation has reportedly affected resident's farming practices. The people in Bansar have traditionally farmed maize, millet and potato as their subsistence crop, but in the recent years, a potato disease infestation has resulted in halting of potato farming. The potato disease is likely attributed to the change in soil moisture (Gautam *et al* 2013). Reduced rainfall and the drying of the community well has made it difficult for the people to farm. By consequence, many people in the community have switched to elaichi farming in agroforestry systems, but Bansar residents question the sustainability of this new method as they worried that lack of precipitation will lead to deforestation or wildfires. Other changes mentioned by respondents included the early flowering of kaaphal (*Myrica esculenta*) and the increased presence of mosquitoes.

The relationship between climate change and livelihood depends to a large degree on when and which adaptation strategies are taken (IPCC 2018). Ultimately, our results coincide and support other studies from Nepal. Chalise *et al* (2015) showed in a survey of peasant farmers throughout the Central Region that the majority perceived a change in temperature and rainfall and had adapted by changing farming practices, cultural practices, or occupation. From the Himalaya region, Merrey *et al* (2018) report that VDCs of Rasuwa District, Nepal are adapting to climatic changes by alternating cropping patterns, integrating livestock with agriculture, and adopting non-farm income generating activities. Perhaps most relevant to this study, Gentle *et al* (2018) observed that four other VDCs in Lamjung who also suffered from climate change effects adapted by diversifying their income, migrating, sharecropping, taking consumption loans, using alternative energy sources, and employing bio-pesticides.

There is increasing evidence that farmers have commenced adapting to observed changes in climate, in particular through changing the timing of farm operations, growing diverse crop species and varieties, adopting soil and water conservation practices, and agroforestry (Asseng and Pannell 2013; Devkota *et al* 2017). Such adaptation measures can minimize the adverse impacts of climate change and contribute substantially to reducing the food insecurity of farming households (Challinor *et al* 2014). More recent research from Nepal shows that the adaptation measures taken are dependent largely on education, resources available, and support (Gentle *et al* 2018; Khanal *et al* 2018), but if adaptation is done well, food productivity can increase (Khanal *et al* 2018). Thus, there is a great need to identify the most successful adaptation measures, and communicate these via extension services throughout Nepal.

## Conclusion

The local knowledge provided by Bansar community members, especially the women, were supported by the historic meteorological data. This highlights the potential to use local knowledge to monitor climate change when meteorological data does not exist. Our results concluded that climate change is impacting Bansar VDC through rising temperatures, decreased precipitation, and more occurrences of erratic and severe weather. This in turn has led to increased water scarcity and invasive species, and decreased agriculture and livestock production. While the Bansar community has shown that it is adapting to these changes by adopting new farming practices and increasing water infrastructure, this research underscores how vulnerable this community is: Bansar is dependent on subsistence farming methods of which are increasingly under threat. This threat to food security paired with Bansar's remote location, inconsistent access to water, and lack of other economic opportunity warrants immediate risk to the wellbeing and livelihood of Bansar residents. Unfortunately, Bansar mirrors the same conditions—both socially and environmentally—of other VDCs. As the government of Nepal continues to develop climate resilient strategies and policies (Ministry of Environment MOE (2009)), special attention should be made to rural villages at greater altitudes. Extension services offered by District Agriculture Offices should be utilized and promoted to help communities farm climate-resilient crops, sustain livestock, and manage invasive species. In the case of Bansar VDC, a proper needs assessment should be completed so that infrastructure and resources can be identified and provided. As climate change affects become more apparent, particularly in vulnerable countries like Nepal, understanding how rural communities can adapt and manage will be key in promoting resilience.

## Acknowledgments

The authors would like to firstly thank the community of Bansar for the willingness to share their information and incredible hospitality. A special thanks goes to the Aama Samuha women's group who provided us valuable insight and perspective. Without them, this work would not have been possible. Additionally, we would like to acknowledge Dr Dinesh Raj Bhujju, Mr Prakash Wagle, and Ms Jenna Ashman for their continuous support, guidance, and feedback throughout this research. The author's have confirmed that any identifiable participants in this study have given their consent for publication

## Appendix

Semi-structured household questionnaire to determine the participants' perception of climate change.

General information

- a) Name of interviewer
- b) Date
- c) Time
- d) Sex
- g) Age
- h) Ethnicity
- i) Occupation
- j) Marital status
- k) Number of family

Questions

1. Do you have your own land?
2. If no, how did you become landless?
3. If yes, please give me information about your land
4. What do you farm ? How much?
5. Can you tell me how, if any, things have changed in regards to agriculture (i.e. production, seasonality, ect)?
6. Where do you get your water from?
7. Where do you get your food from?
8. What resources do you get from the forest?
9. Has the availability of these resources changed?
10. Have you noticed a change in the weather?
  - a. Temperature?
  - b. Rain?
  - c. Other weather events?
11. What do you think is causing these changes?
12. What has impacted your community the most?
13. How have you managed these impacts?
14. Anything else you would like to say?

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## References

- AEPC 2014 *District Climate and Energy Plan of Lamjung District* (Kathmandu: Alternative Energy Promotion Centre)
- Aryal S, Cockfield G and Maraseni T N 2014 Vulnerability of Himalayan transhumant communities to climate change *Clim. Change* **125** 193e208
- Asseng S and Pannell D J 2013 Adapting dryland agriculture to climate change: farming implications and research and development needs in Western Australia *Clim. Chang.* **118** 167–81
- Bajracharya S R, Mool P K and Shrestha B R 2007 Impact of climate change on himalayan glaciers and glacial lakes: case studies on GLOF and associated hazards in Nepal and Bhutan *International Centre for Integrated Mountain Development (ICIMOD)* **169**
- Barik S K and Adhikari D 2011 Predicting the geographical distribution of an invasive species (*Chromolaena odorata* L. (King) & HE Robins) in the Indian subcontinent under climate change scenarios ed J R Bhatt *et al Invasive Alien Plants: an Ecological Appraisal for the Indian Subcontinent* (Wallingford, UK: CABI) 77–88
- Becken S, Lama A K and Espiner S 2013 The cultural context of climate change impacts: perceptions among community members in the Annapurna Conservation Area, Nepal *Environmental Development* **8** 22–37
- CBS (Central Bureau of Statistics of Nepal) 1991 *Population census, 1991, Nepal. His Majesty's Govt.* (Kathmandu: National Planning Commission Secretariat)
- CBS (Central Bureau of Statistics of Nepal) 2004 *Nepal Living Standards Survey 2003/2004* (Kathmandu: CBS)
- Chalise S, Maraseni T N and Maroulis J 2015 Adapting to climate variability: the views of peasant farmers in Nepal *International Journal of Global Warming* **7** 380
- Challinor A, Watson J, Lobell D, Howden S, Smith D and Chhetri N 2014 A meta-analysis of crop yield under climate change and adaptation *Nat. Clim. Chang.* **4** 287–91
- Chaudhary P and Bawa K S 2011 Local perceptions of climate change validated by scientific evidence in the Himalayas *Biology Letters* **7** 767–70
- Devkota R P 2014 Climate change: trends and people's perception in Nepal *J. Environ. Prot.* **5** 255–65
- Devkota R P, Maraseni T N, Cockfield G and Devkota L P 2013 Indigenous Knowledge for Climate Change Induced Flood Adaptation in Nepal *The International Journal of Climate Change: Impacts and Responses* **5** 35–46

- Devkota R P, Pandey V P, Bhattarai U, Shrestha H, Adhikar S and Dulal K N 2017 Climate change and adaptation strategies in Budhi Gandaki River Basin, Nepal: a perception-based analysis *Clim. Chang.* **140** 195–208
- Gautam H R, Bhardwaj M L and Kumar R 2013 Climate change and its impact on plant diseases *Curr. Sci.* **105** 1685–91
- Gbetibouo G A 2009 Understanding farmer's perception and adaptations to climate change and variability. the case of the Limpopo Basin, South Africa *IFI Discussion Paper 00849* (Pretoria: International Policy Research Institute)
- Gentle P and Maraseni T N 2012 Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal *Environ. Sci. Policy* **21** 24–34
- Gentle P, Thwaites R, Race D, Alexander K and Maraseni T 2018 Household and community responses to impacts of climate change in the rural hills of Nepal *Clim. Change* **147** 267–82
- Huntington H P 2000 Using traditional ecological knowledge in science: methods and applications *Ecol. Appl.* **10** 1270–4
- Huq S, Rahman A, Konate M, Sokona Y and Reid H 2003 Mainstreaming adaptation to climate change in Least Developed Countries (LDCs) (London: International Institute for Environment and Development)
- International Labour Organization (ILO) 2016 *The ILO in Nepal. Kathmandu*
- IPCC *Global warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* ed V Masson-Delmotte et al 2018 (Accepted)
- Khanal U 2014 Perception and adaptation of the producers to the impacts of climate change in apple production: an assessment of Mustang district of Nepal *J. Agric. Environ.* **15** 11–7
- Khanal U, Wilson C, Lee B L and Hoang V-N 2018 Climate change adaptation strategies and food productivity in Nepal: a counterfactual analysis *Clim. Change* **148** 575–90
- Kunwar R M 2003 Invasive alien plants and Eupatorium: biodiversity and livelihood *Himalayan Journal of Sciences* **1** 129–33
- Maddison D 2006 The Perception of and adaptation to climate change in Africa *CEEPA. Discussion Paper No. 10. Centre for Environmental Economics and Policy in Africa* (Pretoria: University of Pretoria)
- Malla G 2009 Climate change and its impact on Nepalese agriculture *J. Agric. Environ.* **9** 62–71
- Manandhar S, Vogt D S, Perret S R and Kazama F 2011 Adapting cropping systems to climate change in Nepal: a cross-regional study of farmer's perception and practices *Reg. Environ. Change.* **11** 335–48
- McKee T B, Doesken N J and Kleist J 1993 The relationship of drought frequency and duration of time scales *Eighth Conference on Applied Climatology, American Meteorological Society (Anaheim CA, Jan 17 - 23)* 179–86
- Merrey D J, Hussain A, Tamang D D, Thapa B and Prakash A 2018 Evolving high altitude livelihoods and climate change: a study from Rasuwa District, Nepal *Food Security* **10** 1055–71
- Ministry of Environment (MOE) 2009 *Nepal: Strategic Program for Climate Resilience. Kathmandu*
- Ministry of Environment (MOE) 2010 Climate change vulnerability mapping for Nepal *Kathmandu: National Adaptation Program of Action with Ministry of Environment*
- Ministry of Finance (MOF) 2013 *Economic survey: fiscal year 2012/13. Kathmandu, Nepal*
- Mool P K, Wangda D, Bajracharya R S, Kunzang K, Gurung D R and Joshi S P 2001 *Inventory of Glaciers, Glacier Lakes and Glacier Lake Outburst Floods—BHUTAN* (ICIMOD Special Pub)
- Morton J F 2007 The impact of climate change and subsistence agriculture *PNAS* **104** 19680–5
- Nepal Food Security Monitoring System (NeKSAP) 2016 Food Security Phase Classification Map. Retrieved October 28, 2018, from <http://neksap.org.np/allmaps/food-security-phase-classification-map-mid-november-2015-to-mid-march-2016>
- Reilly J 2001 *Agriculture: The potential Consequence of Climate Variability and Change for the United States. New York, NY: US National Assessment of the Potential Consequences of Climate Variability and Change* (Cambridge: Cambridge University Press)
- Shrestha A B and Aryal R 2011 Climate change in Nepal and its impact on Himalayan glaciers *Regional Environmental Change* **11** 65–77
- Shrestha A B, Wake C P, Mayewski P A and Dibb J E 2000 Precipitation fluctuations in the Nepal Himalaya and its vicinity and relationship with some large scale climatological parameters *Int. J. Climatol.* **20** 317–27
- Shrestha M 2014 The dynamics of mountain agriculture and land change in lamjung district, Nepal *Global Environmental Research* **18** 151–60
- Shrestha R P and Nepal N 2016 An assessment by subsistence farmers of the risks to food security attributable to climate change in Makwanpur, Nepal *Food Secur.* **8** 415–25
- Timsina N P 2011 Climate change phenomenon in Nepal *NGO Federation of Nepal*
- Vedwan N 2006 Culture, climate and the environment: local knowledge and perception of climate change among apple growers in northwestern India *J. Ecol. Anthropol.* **10** 4–18
- World Bank 2019 World bank climate change knowledge portal Nepal Retrieved March 27, 2019, from <https://climateknowledgeportal.worldbank.org/country/nepal/climate-data-projections>
- Yue S, Pilon P and Cavadias G 2002 Power of the Mann-Kendall and Spearman's rho tests for detecting monotonic trends in hydrological series *J. Hydrol.* **259** 254–71