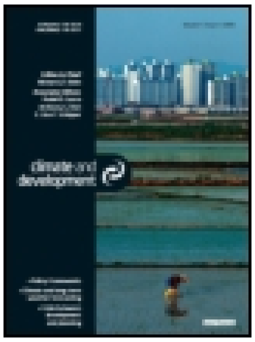

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RESEARCH ARTICLE

Perceptions of climate change by highland communities in the Nepal Himalaya

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The impacts of climate change in remote communities of the Himalaya have been relatively underexplored. This study combines traditional knowledge of people from three Village Development Committees (VDCs) of three districts of the high altitudinal regions in Nepal with scientific data to document the changes in climatic patterns, natural hazards, ecological systems and agricultural practices. The respondents perceived notable changes in the local climatic conditions, the frequency of natural disasters and ecological processes. Their perception of warming over the past 15–20 years parallels the increase in mean annual temperature recorded in the Thehe VDC of the Humla district, Tukuche VDC of the Mustang district and Lelep VDC of the Taplejung district from 1973 to 2012 by 0.02°C/year, 0.04°C/year and 0.01°C/year, respectively. Most respondents perceived an increase in the frequency of floods and landslides. The recorded average frequency of natural hazards including fire, flooding, landslide and avalanche has increased significantly from 1.5 $\pm$ 0.61 incidences/year for the period 1972–1991 to 10.4 $\pm$ 2.91 incidences/year for the period 1992–2011. Increased occurrence of pests and insects was also noted. The results show that climate change has already affected local communities and they are responding by spontaneously developing adaptive livelihood strategies.

Keywords: climate change; local communities; Himalaya; Nepal; traditional knowledge

1. Introduction

The Himalaya – 1 of 34 global biodiversity hotspots, rich in cultural, ethnic and biological diversity – has recently undergone unprecedented environmental change such as depletion of water resources, loss of biodiversity, increasing pollution, decrease in agricultural productivity, deforestation, urbanization and climate change (Aase, Chaudhary, & Vetaas, 2010; Bawa et al., 2010; Pandit, Manish, & Koh, 2014). This region is viewed as one of the most vulnerable regions in the world to climate change due to the high ecological sensitivity of ecosystems and low adaptive capacity of local people (Aryal, Cockfield, & Maraseni, 2014; Sharma, 2012). The rise in average annual temperature is three times higher in the Himalaya than the global average for the last 25 years (Shrestha, Gautam, & Bawa, 2012). The impacts of climate change in the Himalaya can be observed in various sectors, including hydrology, natural hazards, biodiversity, agriculture and human health and livelihood (Shrestha et al., 2012; Xu et al., 2009).

Nepal lies in the central part and accounts for 20% of the area of the Himalayan biodiversity hotspot (Mittermeier et al., 2004). The country has been consistently warming up over the last few decades, with an annual rate of 0.04–0.06°C (Ministry of Environment [MoE], 2010). It is considered the 19th most vulnerable country in the recent Climate Risk Index (Kreft, Eckstein, Junghans, Kerestan, & Hagen, 2014). The Nepalese National Adaptation Programme of Action (NAPA) to climate change identified six key sectors: agriculture and food security, forests and biodiversity, water resources and energy, climate-induced disasters (floods, landslides, avalanches, glacier lake outbursts and droughts), public health, and urban settlements and infrastructure vulnerable to climate change (MoE, 2010). The mountain communities of Nepal are considered the most vulnerable to climate change due to their

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remoteness and marginalization (Aryal et al., 2014; Macchi, Gurung, & Hoermann, 2014; MoE, 2010). Furthermore, the magnitude of warming is higher in the mountain region of Nepal than in the low altitude region (Shrestha & Aryal, 2011; Shrestha, Wake, Mayewski, & Dibb, 1999). Additionally, vegetation in the mountain region is highly sensitive to climate change because it relies on low temperatures at high altitudes (Körner, 2003). This exerts an indirect effect on mountain communities, as they are predominantly dependent on mountain ecosystems for various ecosystem services such as timber, medicinal plants, edible fruits, fodder and pastures for livestock grazing to sustain their livelihood. Furthermore, the poverty incidence in Nepal is higher in the mountain region compared to the low-land areas (National Planning Commission/United Nations Development Programme, 2014), meaning that mountain people are living in extreme poverty, which makes them further vulnerable to shocks caused by natural disasters such as floods and drought.

Compared to other mountain regions of the world, Himalaya is relatively underexplored in the scientific literature that deals with climate change and its impacts (Intergovernmental Panel on Climate Change, 2007; Pandit et al., 2014). Despite recent attempts to analyse climatic variables (temperature and precipitation) and their impacts at a regional scale (e.g. Kulkarni, Patwardhan, Kumar, Ashok, & Krishnan, 2013; Shrestha et al., 2012; Xu et al., 2009), little is known about the extent of climate change at the local level – particularly amongst the high mountain regions – and its impacts on local communities. The present study combines traditional knowledge of the local communities living in the high-altitude regions of Nepal with the scientific data acquired from various sources to document the changes in climatic patterns, climate-induced natural hazards, and ecological systems and agricultural practices.

In addition to the scientific basis of causes and consequences of climate change, there is a growing body of research on public perceptions of climate change at the global scale (Lee, Markowitz, Howe, Ko, & Leiserowitz, 2015; Lehner & Stocker, 2015). Perceptions of climate change are built either by means of communications (media, social networks, public discussions, political debates) or by one's own experience of living in a particular climate and being affected by climatic changes (Finnis, Sarkar, & Stoddart, 2015). However, there are several other factors that can influence people's response to climate change, such as experimental, physical, psychological, economic, ecological and socio-cultural factors (Borick & Rabe, 2010; Macchi et al., 2014). In remote areas such as the study sites of this research, where access to various means of communications is limited and dependency of individuals or communities on the local climate for subsistence livelihood (agriculture and livestock rearing) is high, community perceptions are based on personal experience and understanding of the local climate and its variability.

Traditional knowledge is a reliable source of information on climatic change (Galloway McLean, 2010; Lehner & Stocker, 2015; Reedy, Savo, & McClatchey, 2014). Local communities accurately perceive signs of climate change as it is crucial for developing effective coping strategies to reduce vulnerability (Alexander et al., 2011; Li, Tang, Luo, Di, & Zhang, 2013; Wang & Cao, 2015). The knowledge of local communities can be complemented by meteorological data (Sanchez, Fandohan, Assogbadjo, & Sinsin, 2012). Furthermore, previous studies on local perceptions of climate change in the Himalaya – including Nepal – showed that traditional knowledge on climate change was on par with scientific knowledge (Aryal et al., 2014; Becken, Lama, & Espiner, 2013; Byg & Salick, 2009; Chaudhary & Bawa, 2011; Macchi et al., 2014; Mishra et al., 2015).

This study has not only brought new insights but also contributed to the growing body of knowledge in the field of documenting perceptions of climate change in the Himalayan region. First, this study helps to enhance our understanding of the impacts of climate change on the mountain communities using the widely established approaches in both traditional and local knowledge system as well as the Western scientific knowledge system. This study identifies the changes in local climate and frequency of natural disasters as well as changes in ecosystems and agricultural practices by documenting the perceptions of local communities and by analysing the scientific records. We also analyse the trends in temperature, precipitation and incidence of natural disasters in the study area and compare them with the changes perceived by local communities. Previous studies (Byg and Salick, 2009; Chaudhary & Bawa, 2011) did not compare local perceptions with scientific data. Second, to our knowledge, this is the first study to analyse the long-term temperature and precipitation trends in the study area. Third, it examines climate change in three mountainous villages lying above 3000-m elevation and representing western, central and eastern regions of Nepal, whereas Macchi et al. (2014) conducted a study in western Nepal and India and Chaudhary and Bawa (2011) focused on moderate elevation zones of eastern Nepal and India. These study sites from three different regions with different climatic and ecological variations allowed us a meaningful comparison. Fourth, the local communities of these villages comprise dominant characteristics of mountain livelihoods such as remoteness, ecosystem fragility, frequent natural hazards and marginality. Fifth, this study analyses trends in frequency of natural disasters linking them with local perceptions of climate change as there are a growing number of evidence showing that human-induced climate change plays a critical role to extreme events such as droughts, heavy rains and winter storms (Herring, Hoerling, Kossin, Peterson, & Stott, 2015; Stott et al., 2016).

2. Methodology

2.1. *Study area*

This study was conducted in three Village Development Committees (VDCs) of three different districts of Nepal: Humla, Mustang and Taplejung, respectively located in western, central and eastern Nepal (Figure 1). The details of physiographic, climatic, topographic, socio-ecological features of the study sites are given in Table 1.

2.2. *Household survey*

We conducted household surveys in the Thehe VDC of the Humla district, Tukuche VDC of the Mustang district and Lelep VDC of the Taplejung district in September, November and October 2013, respectively. We selected elderly and experienced respondents for face-to-face interviews so that they would recall their long-term experience of climate, natural hazards, ecological changes and changes in agricultural practices. All the respondents interviewed were above 35 years old and interviews were conducted in the Nepali language. Despite the remoteness and poor accessibility of the study sites, the scattered distribution of households and the age criterion for selecting respondents, we were able to conduct face-to-face interviews with 42 individuals (15 from Humla, 15 from Mustang and 12 from Taplejung district).

We developed the questionnaire after careful review of the published research on public perceptions (Aryal et al., 2014; Byg & Salick, 2009; Chaudhary & Bawa, 2011; Macchi et al., 2014; Mishra et al., 2015) and climate change (Pandit et al., 2014; Shrestha et al., 2012; Xu et al., 2009). Questions were asked to the respondents to document their experience on climatic and other environmental changes. The questionnaire had two major sections. The first section dealt with the informant's socio-economic characteristics. The second section included 15 different multiple choice questions that dealt with changes in the local climate (extent and timing of warming, rainfall, snowfall events), incidence of natural hazards (fire, flooding and landslide), ecological changes (change in forested areas, wildlife population and timing of flowering of common plants) and changes in agricultural practices (timing of major crops planting, harvesting and incidence of pests) over last 15–20 years. Previous studies have shown that climatic events of the past 15–20 years are easily recalled by informants (Aryal et al., 2014; Byg & Salick, 2009; Chaudhary & Bawa, 2011; Macchi et al., 2014; Mishra et al., 2015).

2.3. *Climate data*

The study sites are located in remote mountainous areas without weather stations and for which local data on temperature and precipitation is lacking. Indeed, Nepal has few weather stations, especially in higher elevations (Macchi et al., 2014), and data typically have several missing values (Practical Action, 2009). Therefore, we used gridded datasets of Global Surface Air Temperature produced by the National Oceanic and Atmospheric Administration, National Centers for Environmental Prediction, Climate Prediction Center, Global Historical Climatology Network and Climate Anomaly Monitoring System, combining ground observations, satellite measurements and interpolation techniques (Fan & van den Dool, 2008). These gridded data of mean monthly temperature provide continuous data from 1948 to the present in 0.5° × 0.5° spatial resolution. Temperature values for the study area were extracted from the global dataset by overlaying fishnet grids of 0.5° size in ArcGIS 10.3 (ESRI, 2014). Altogether, there were three grids for Humla, one for Mustang and three for Taplejung based on the shape and area of the VDC. The values from multiple grids were averaged for a particular location. Averaging values from multiple grids in a gridded dataset normally increases accuracy in the mountain regions as the Himalaya because single grid cells may largely deviate from neighbouring cells in terms of elevation (Körner, Paulsen, & Spehn, 2011).

We also downloaded the gridded monthly precipitation data (GPCC full-data reanalysis product version 7) produced by the Global Precipitation Climatology Center (GPCC) (Schneider, Fuchs, Meyer-Christoffer, & Rudolf, 2008) and extracted data for the study area. This global dataset, combining data from rain gauge stations and GPCC climatology models, is the largest monthly precipitation database in the world (Schneider et al., 2014). It covers the period 1901–2013 in 0.5° × 0.5° spatial resolution globally.

In this study, we used temperature and precipitation data of last four decades, from 1973 to 2012, one year prior to the survey period to match the period mentioned in our survey questions. We extended the climatic period to 40 years because minimum 30 years of climate data is recommended to study climate change (Smith et al., 1996).

2.4. *Disaster data*

We downloaded disaster data on the incidences of fires, floods, landslides and avalanches in the three studied districts from DesInventar (www.desinventar.net). DesInventar comprises national-level disaster data for Nepal for the years 1971–2011. The database, maintained with the support of the United Nations Office for Disaster Risk Reduction, was constructed by systematically reviewing the records on disasters published in major newspapers of Nepal and later verified from the disaster review series.

2.5. *Data analysis*

We counted the frequency and percentage of the responses of the survey data for each site and pooled the data for the whole area. We analysed the annual and seasonal trends in

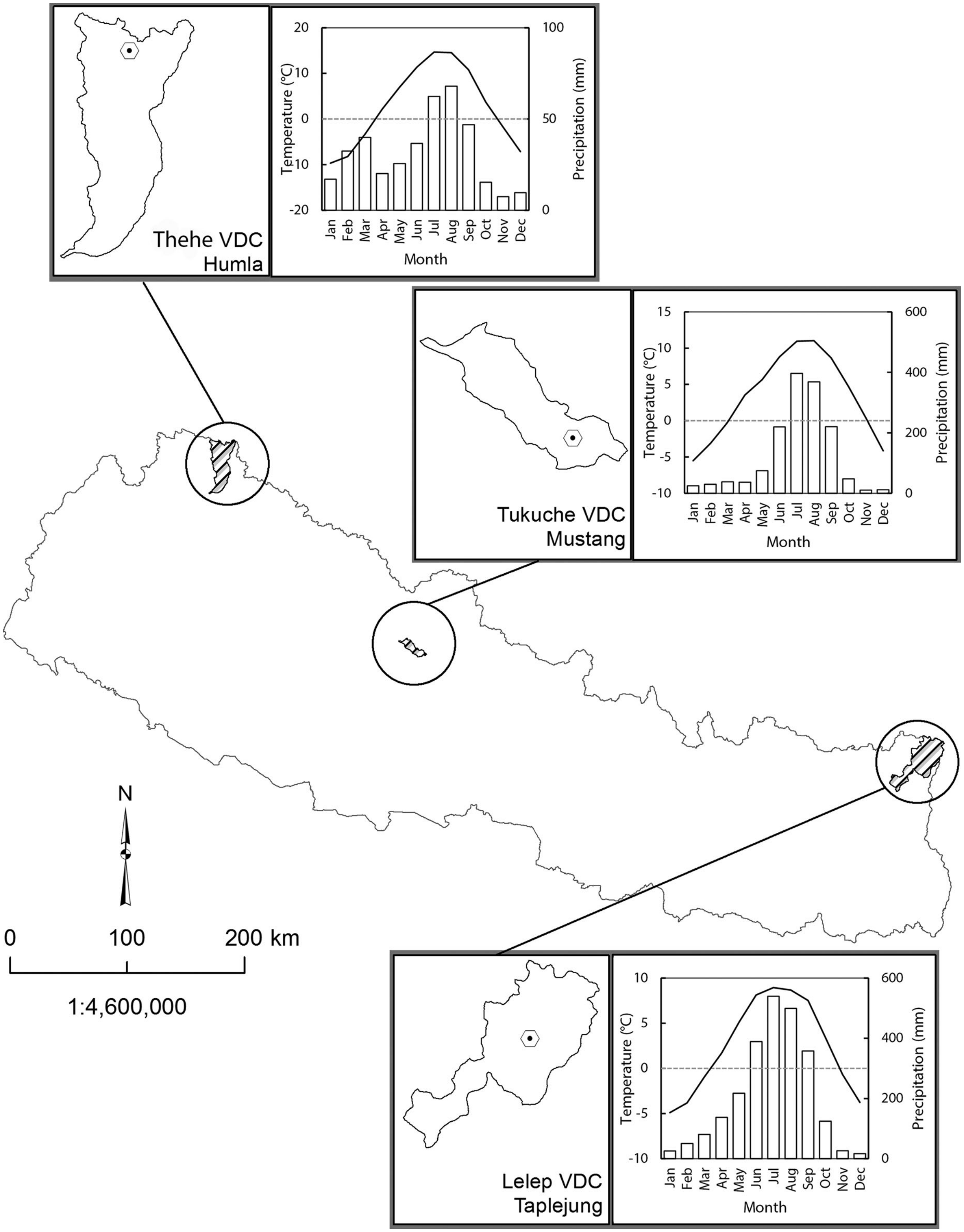

Figure 1. Study areas in eastern, central and western Nepal (Humla, Mustang and Taplejung districts, respectively). Mean monthly variations of temperature and precipitation are shown for each district.

temperature and precipitation and created a climatological profile (mean of monthly temperature and precipitation from 1972 to 2012) for each site (see Figure 1). From the climatological profile, we determined the points of maximum increase and decrease of monthly temperature to mark the months of onset of spring and winter,

Table 1. Climatic, topographic, physiographic and socio-ecological features of the study area.

Features	Village development committee (district)			Data source
	Thehe VDC (Humla)	Tukuche VDC (Mustang)	Lelep VDC (Taplejung)	
Average annual temperature (1973–2012)	2.84 ± 0.28°C	3.40 ± 0.22°C	2.45 ± 0.14°C	Fan and van den Dool, (2008)
Average annual precipitation (1982–2012)	381.45 ± 37.50 mm	1481.08 ± 55.02 mm	2466.58 ± 72.53 mm	Schneider et al. (2008)
Elevation	2121–6169 m	2547–6995 m	1311–8387 m	ASTER, Global Digital Elevation Model
Physiographic zone	High mountain	High mountain	High mountain	Physiographic map of Nepal
Total number of households	443	206	511	Central Bureau of Statistics (CBS, 2014)
Total population	2344	743	2205	CBS (2014)
Ethnic groups	Chhetree, Tamang, Kami, Damai, Thakuri	Thakali, Magar, Kami, Chhetree, Brahmin, Damai, Gurung, Tamang, Sherpa	Limbu, Walung, Rai, Sherpa, Gurung, Chhetree, Brahmin, Tamang, Newar	CBS (2014)
Distance to the district headquarter	5–7 hours walk from district headquarter; no road access to the district	11 km; access road	25 km; no road access to the VDC	Field visit
Major occupation of the villagers	Agriculture, livestock	Agriculture, tourism	Agriculture	Field visit
Vegetation types	Alpine Mats and Scrub, Alpine pasture, Birch-Rhododendron forest, Blue Pine-Birch forest, Deciduous Walnut-Maple-Alder forest, Fir forest, Nival Zone, Pine-Spruce-Fir forest	Alpine pasture, Blue Pine-Cypress forest, Cypress forest, Fir-Blue pine forest, Mixed blue pine-oak forest, Nival Zone, Trans-Himalayan Steppe, Upper Temperate Blue pine forest	Dwarf Rhododendron scrub, East Himalayan Oak-Laurel forest, Fir forest, Larch forest, Mixed broad leaved forest, Nival zone, Rhododendron Shrubberies, Schima-Castanopsis forest	Barnekow Lillesø et al. (2005)
Area	576 km^2	123 km^2	806 km^2	

respectively, as well as the points of maximum increase and decrease of rainfall to mark the months of onset and completion of monsoon, respectively. We compared average June precipitation (beginning of monsoon) between the periods 1973–1992 and 1993–2012, to ease comparison with the community perceptions of climate now and 15–20 years ago. Likewise, we compared average March temperature (beginning of spring) and frequency of disasters between the periods 1973–1992 and 1993–2012.

3. Results

3.1. *Perceived changes in the local climate*

The respondents acknowledged that there were notable changes in local climatic conditions, the frequency of natural disasters and ecological changes (Table 2). They also experienced changes in agricultural practices in last 15–20 years. Most of the respondents (88% in total) agreed that 'it is generally warmer these days compared to 15–20 years ago.' A few respondents of Humla (13%) disagreed with the statement on warming. Along with the overall change in temperature, respondents expressed their familiarity with the change in temperature seasonality, both in the duration of winter and onset of summer; 74% of the total respondents mentioned that summer starts earlier now than 15–20 years ago. Similarly, 71% of the total respondents felt that winter is now shorter than it was 15–20 years ago.

Views of the respondents were more variable on the trends of annual rainfall and onset of rainfall. Almost two-thirds of the respondents (62%) mentioned that the amount of rainfall is higher now than 15–20 years ago. Responses also varied between sites: 40% of the Humla respondents mentioned that the amount of rainfall decreased, whereas 33% said the opposite. Similarly, 67% of the Mustang respondents and 92% of the Taplejung respondents stated that rainfall was higher now than 15–20 years ago, as opposed to a perception of decreased rainfall for 33% and 8% of the respondents in Mustang and

Table 2. Percentage of informants in each VDC with different perceptions on various indicators of climate change.

Statements	Responses (%)	Localities			
		Thehe (Humla)	Tukuche (Mustang)	Lelep (Taplejung)	Total
QN 1. It is generally warmer these days compared to 15–20 years ago					
	Agree	67	100	100	88
	Disagree	13	0	0	5
	No change	7	0	0	2
	Don't know	13	0	0	5
QN 2. The onset of summer these days occurs earlier, later or at the same time compared to 15–20 years ago					
	Earlier	73	67	83	74
	Later	7	13	0	7
	No change	7	20	17	14
	Don't Know	13	0	0	5
QN 3. Duration of winter these days is longer, shorter or equal compared to 15–20 years ago					
	Longer	7	7	0	5
	Shorter	53	67	100	71
	No change	13	27	0	14
	Don't know	27	0	0	10
QN 4. The amount of rainfall these days lower, higher, or unpredictable compared to 15–20 years ago					
	Less	40	33	8	29
	More	33	67	92	62
	Unpredictable	13	0	0	5
	Don't know	13	0	0	5
QN 5. The onset of rainfall these days occurs earlier, later or at the same time compared to 15–20 years ago					
	Earlier	27	13	17	19
	Later	7	20	0	10
	No change	60	67	83	69
	Don't know	7	0	0	2
QN 6. Snowfall these days starts earlier, later or at the same time compared to 15–20 years ago					
	Earlier	60	73	67	67
	Later	13	7	0	7
	No change	27	20	25	24
	Don't know	0	0	8	2
QN 7. Incidence of drought these days is higher, lower or the same compared to 15–20 years ago					
	Higher	7	73	92	55
	Lower	73	0	0	26
	No change	7	27	8	14
	Don't know	13	0	0	5
QN 8. Incidence of fire these days is higher, lower or the same compared to 15–20 years ago					
	Higher	60	27	33	40
	Lower	20	73	17	38
	No change	13	0	0	5
	Don't know	7	0	50	17
QN 9. Incidence of floods and landslides these days is higher, lower or the same compared to 15–20 years ago					
	Higher	73	73	83	76
	Lower	27	27	17	24
	No change	0	0	0	0
	Don't know	0	0	0	0
QN 10. Incidence of avalanches these days is higher, lower or the same compared to 15–20 years ago					
	Higher	33	40	50	40
	Lower	13	53	0	24
	No change	27	7	0	12
	Don't know	27	0	50	24
QN 11. Amount of forested area these days is higher, lower or the same compared to 15–20 years ago					
	Higher	13	20	67	31
	Lower	60	67	33	55
	No change	20	13	0	12
	Don't know	7	0	0	2
QN 12. Populations of wildlife species these days are higher, lower, or the same compared to 15–20 years ago					

(*Continued*)

Table 2. Continued.

Statements	Responses (%)	Localities			
		Thehe (Humla)	Tukuche (Mustang)	Lelep (Taplejung)	Total
	Higher	7	20	75	31
	Lower	73	53	0	45
	No change	13	0	0	5
	Don't know	7	27	25	19
QN 13. Blooming time of common plants these days occurs earlier, later or at the same time compared to 15–20 years ago					
	Earlier	27	47	58	43
	Later	0	0	0	0
	No change	27	33	42	33
	Don't know	47	20	0	24
QN 14. Plantation of major crops these days occurs earlier, later or at the same time compared to 15–20 years ago					
	Earlier	7	13	17	12
	Later	0	20	25	14
	No change	60	0	58	38
	Don't know	33	67	0	36
QN 15. Harvesting of major crops these days occurs earlier, later or at the same time compared to 15–20 years ago					
	Earlier	20	7	33	19
	Later	0	13	8	7
	No Change	40	40	50	43
	Don't know	40	40	8	31
QN 16. Incidence of pests in major crops these days is higher, lower, or equal compared to 15–20 years ago					
	Higher	40	100	100	79
	Lower	20	0	0	7
	No change	20	0	0	7
	Don't know	20	0	0	7

Taplejung, respectively. Most respondents (69%) mentioned that there was no change in the onset of rainfall. About two-thirds of the respondents (67%) noted that snowfall starts later now than 15–20 years ago.

3.2. *Comparison with meteorological data*

The local perceptions of climate change gathered from the survey data showed the same trends as the climatic records. Mean annual temperature in Humla, Mustang and Taplejung increased significantly from 1973 to 2012, by 0.02°C/year ($P < .05$), 0.04°C/year ($P < .01$) and 0.01°C/year ($P < .05$), respectively (Figure 2(a)). Temperature records showed that the magnitude of winter warming is higher than that of annual warming; winter temperature in Humla, Mustang and Taplejung has increased by 0.04°C/year ($P < .05$), 0.05°C/year ($P < .01$) and 0.03°C/year ($P < .01$), respectively, in the same period (Figure 2(c)). The change in annual temperature, predominantly in winter, could be the underlying factor for perceived warming and observed advancement in the onset of snowfall. Mean temperature of March (corresponding to spring onset) increased between the periods 1993–2012 and 1973–1992 but only significantly so in Mustang (Figure 2(b)).

We noticed a disparity between the trends of annual rainfall and the community perceived trend of more rainfall now than 15–20 years ago. Although the trends of annual precipitation in Humla (−2.26 mm/year), Mustang (−2.33 mm/year) and Taplejung (−0.17 mm/year) were decreasing, none of them was statistically significant (Figure 3(a)). We also did not see a difference in mean June precipitation (onset of rainfall) between the most recent 20 years and the previous 20 years (Figure 3(b)). In that sense, community perceived change in the onset of rainfall matched with the precipitation patterns. Contrastingly, increasing trends were observed in pre-monsoon rainfall in Mustang and Taplejung, as well as in winter rainfall in Humla, but none of the trends was statistically significant. The seasonal trends of precipitation are given in Figure 4.

3.3. *Change in natural hazards*

Natural hazards witnessed by the local communities expressed in the surveys were fires, floods, landslides and avalanches. There was no clear uniformity among the responses regarding the incidence of fire, as 40% of the total respondents indicated an increase in incidence, whereas 38% indicated a decrease now compared to 15–20 years ago. However, a majority of the total respondents (76%), mostly from Taplejung, mentioned that the frequency of floods and landslides was now higher than 15–20 years ago. Similarly, slightly more respondents felt that avalanche incidence had increased (40% vs. 24%).

Community perceptions of frequency or incidence of natural disasters were compared to the disaster record

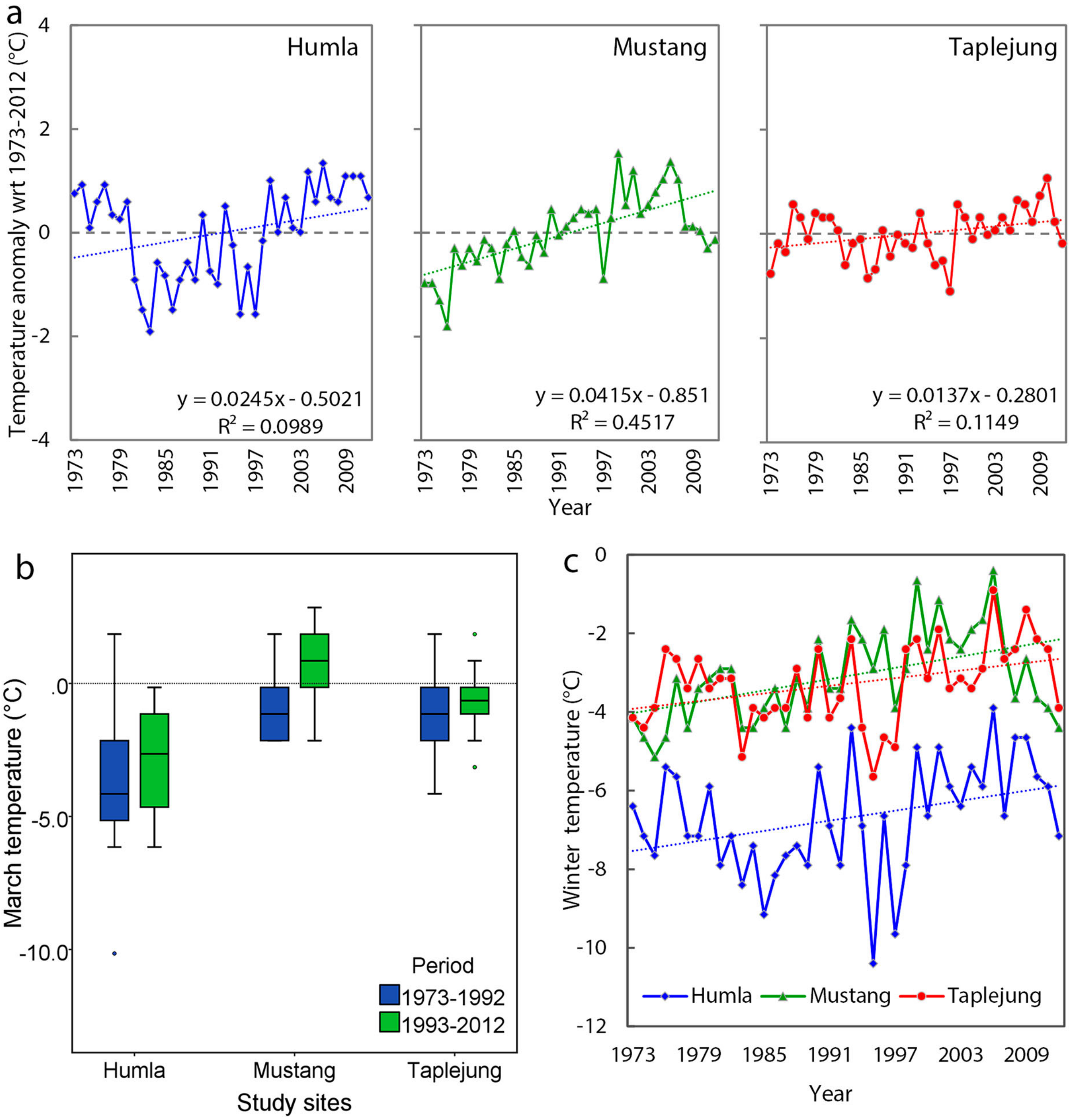

Figure 2. (a) Temperature anomaly with respect to 1973–2012 for the Humla, Mustang and Taplejung districts. (b) Differences in March temperature (corresponding to spring onset) between the 1973–1992 and the 1993–2012 period, for each district. (c) Trend in mean winter temperature from 1973 to 2012 for each district.

derived from DesInventar. While comparing disaster data between two periods – the most recent 20 years (1992–2011) with previous 20 years (1972–1991), it was found that the average frequency of natural hazards including fire, flooding, landslide and avalanche has increased significantly from 1.5 ± 0.61 (95% CI) incidences per year in 1972–1991 to 10.4 ± 2.91 (95% CI) incidences per year in 1992–2011 ($t = -6.02$, $P = .00$) (Figure 5). In the same period, site-specific incidences of natural hazards have also increased from 0.05 ± 0.09 to 2.65 ± 1.30 incidences per year in Humla ($t = -3.92$, $P = .00$), 0.35 ± 0.26 to 1.55 ± 0.70 incidences per year in Mustang ($t = -3.14$, $P = .00$) and 0.85 ± 0.59 to 6.20 ± 2.32 incidences per year in Taplejung ($t = -4.38$, $P = .00$).

3.4. *Changes in ecosystems, biology of flowering plants and agricultural practices*

Responses of local people on their perceived changes in forested areas, wildlife populations and flowering time of common plants are given in Table 2. There was no clear pattern among the responses regarding these ecological

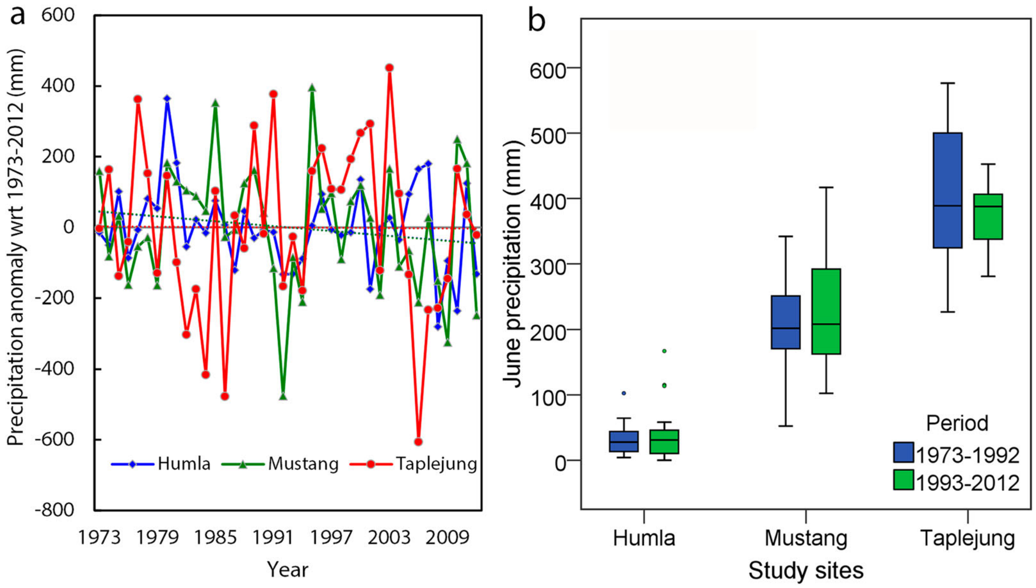

Figure 3. (a) Precipitation anomaly with respect to 1973–2012. (b) Differences in June precipitation (corresponding to monsoon onset) between two different periods.

changes, except for forested areas. A little more than half of the total respondents (55%) mentioned that the forested area decreased, most of them from Humla and Mustang. Responses to the change in the flowering time of common plants varied largely. Nevertheless, a majority of respondents from Taplejung (58%) perceived that flowering time had shifted earlier. Similarly, we did not find consistency in the responses about agricultural changes except for the statement on the incidence of pests and insects affecting major crops. Most respondents (79%) perceived that the incidence of pests and insects increased compared to 15–20 years ago.

4. Discussions

This study documented perceptions of climate change in mountain communities and compared them with measured climatic records. A long-term increase in mean temperature in the study sites coincides with the local perception of warming. Our findings on warming trends are similar to those reported in previous studies conducted elsewhere in Nepal (Practical Action, 2009; Shrestha et al., 1999; Shrestha & Aryal, 2011). However, local perceptions on average rainfall trends varied between communities. The likelihood of reporting an increase in rainfall decreased from east to west Nepal. It might be associated with the higher amount of rainfall in the east than in the west of Nepal; eastern Nepal is generally wetter compare to western Nepal. Howe, Thaker, and Leiserowitz (2014) also reported that respondents of northeast India, a wet region close to eastern Nepal, were the most likely to report increasing rainfall. Our findings of no consistent trend in the magnitude and seasonality of rainfall reaffirm previous studies, which did not find a consistent trend in precipitation throughout Nepal (Duncan, Biggs, Dash, & Atkinson, 2013; Shrestha, Wake, Dibb, & Mayewski, 2000).

The respondents' perception of increasing incidence of floods and landslides was strongly associated with the increasing number of floods and landslides over the past 20 years in the study sites. Our results on local perceptions on ecological changes are comparable with those reported in previous studies (Byg & Salick, 2009; Chaudhary & Bawa, 2011) and show inter-site variability. Ecological change is a complex process to recall unless there is a signature event in an ecological phenomenon that directly affects local livelihoods or traditional practices. Cherry blossoms in Japan are considered as culturally significant events and dates of cherry blossoms were recalled and documented very well (Primack & Higuchi, 2007; Sakurai et al., 2011). For example, if there is a particular species of flower needed for a certain tribe to celebrate a festival that occurs at a fixed date, the community would easily notice a change in the flowering time of that particular species. Therefore, a nuanced view in this regard is necessary and further studies are needed, focusing on individual plant and animal species. Nevertheless, traditional knowledge is known for its high local precision (Asselin, 2015), and it is thus normal that different trends are noted at the local scale, compared to the apparent homogeneity of scientific, large-scale studies.

The respondents mentioned increased occurrence of pests and diseases in valuable crops such as cardamom, maize, wheat, millet and potatoes. Previous research in Nepal (Chaudhary & Bawa, 2011; Macchi et al., 2014) and other parts of the Himalaya (Byg & Salick, 2009; Li

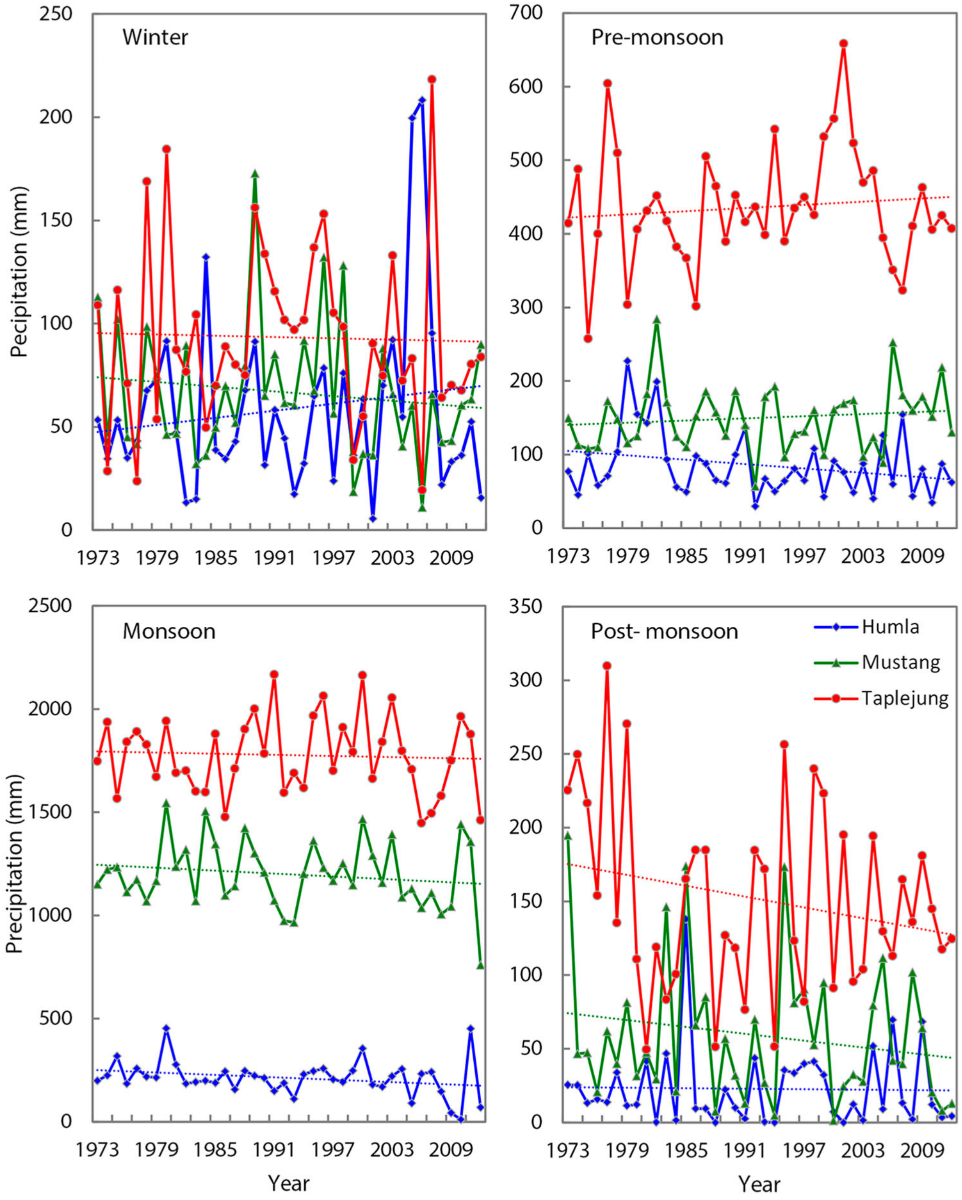

Figure 4. Trends in seasonal precipitation in the three study sites.

et al., 2013) found similar results while documenting local perceptions of climate change. With the increase in temperature, pests and insects are thought to be active in environments that used to be too cold (Li et al., 2013).

Although we did not document details of local adaptive measures to climate change, it was evident that local communities had developed adaptive livelihood strategies to respond to the changes in climate and environment. These adaptive responses are spontaneous rather than planned. For example, increased incidence of pests has impacted traditional agricultural practices, as respondents said they are now using pesticides and wearing mosquito nets for protection against mosquitos that had never been seen in these areas before. Similarly, climate change has impacted the traditional transhumances practised by these communities for livestock rearing. They now spend more time in upper rangelands, as the amount of snowfall and the thickness of the snow cover have decreased.

Our study on climate change in high-altitude areas of Nepal adds to past research conducted in Nepal by analysing long-term precipitation and temperature trends and by including data on natural disasters, which were lacking in previous studies. Studies showed that the social, cultural and economic conditions within which people experience the risk have a high influence on the perceptions of climate (Patt & Schröter, 2008). However, we did not test for possible differences in responses based on social-political affinity, education, ethnicity, age and gender as well as

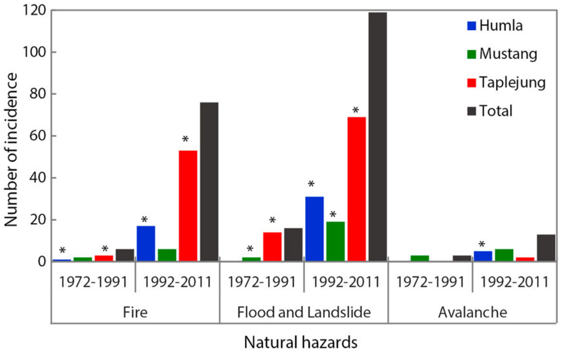

Figure 5. Frequency of natural disasters in the Humla, Mustang and Taplejung districts for the periods 1972–1991 and 1992–2011 (* = statistically significant).

other socio-economic characteristics due to the small sample size. Nevertheless, we presented a broad perspective of three geographically distinct isolated local communities living in mountainous areas of western, central and eastern Nepal. Only 4 out of 15 respondents in Humla, 4 out of 15 respondents in Mustang and 6 out of 12 respondents in Taplejung mentioned they had heard the term ‘climate change’ before (*Jalabayu Pariwartan* in the Nepali language) through the radio or discussions with local NGO workers. This level of awareness about the term ‘climate change’ among villagers represented in this study reinforces the findings of Gallup survey, which showed that 49% of Nepalese citizens do not know about ‘climate change’ and the proportion of people who do not hear the term ‘climate change’ is higher in the rural areas (Gallup, 2009). This might be due to the lack of appropriate terminology for ‘climate change’ in their native language that is linked to the phenomenon of increase in temperature, change in precipitation pattern and increasing frequency of disasters. Nevertheless, they have experienced environmental and climatic changes in recent years which were clearly expressed in their responses. Therefore, their responses documented here were mainly based on their own experience rather than on prior knowledge of climate change and thus describe genuine trends.

Various factors such as perceived impact, perceived responsibility, various biases (e.g. ‘confirmation bias’) and personal experiences or memories of climatic events influence climate change perceptions (Becken et al., 2013; Patt & Schröter, 2008). Howe, Markowitz, Lee, Ko, and Leiserowitz (2012) showed that respondents’ personal experiences are influenced by seasonality, for example, individuals more likely to perceive recent warming during the local warm season. Culture is a crucial factor for framing people perception, understanding and experience on key elements in which they live (Becken et al., 2013). Despite these biases and factors that influence people’s perception and experience, studies demonstrated that locals, who are highly dependent on environment and developed a symbiotic relationship with nature, can identify changes in their environment precisely (Goebbert, Jenkins-Smith, Klockow, Nowlin, & Silva, 2012; Laidler, 2006; Marin, 2010). We tried to minimize biases while constructing and asking questions, for example, questions were semi-structured and the questions directly related to climate change were asked at the end. Interviews were conducted in local languages and by the persons who are known by the villagers to reduce local biases on sharing information with ‘outsider’ as suggested by Becken et al. (2013) and Laidler (2006). Nevertheless, this study might possess inherent biases such as ‘recall bias’ as our results on documenting local perceptions of climate change are dependent on the respondent’s previous experience. Bias might be present in the disaster data; disasters records in the earlier years might not be as good as it was kept these years. However, we used the most salient, credible and updated database so far available for this region. Along with the biases in the data sources, this study is based on the limited sample size that may have some impacts on the results.

5. Conclusion

The local communities from the high mountain regions of Humla, Mustang and Taplejung (Nepal) have been experiencing changes in the local climate and environment. The perceived changes of climate change are generally aligned with scientific records of temperature and precipitation, indicating overall warming but no clear pattern of precipitation. Climate change has already affected local communities in these areas and they were responding by spontaneously developing adaptive livelihood strategies. Therefore, more planned adaptation strategies are needed to reduce their vulnerability to climate change and post climate-induced impacts. Strengthening institutional networking and collaboration among institutions in the Himalayan region is necessary to increase the adaptive capacity of local communities. Caution should be taken while documenting community perceptions of complex environmental changes such as changes in ecological processes, as local people often recall more easily observable changes such as signature events that have a direct effect on their livelihood. Like other social surveys, community perceptions of climate change might hold a recall bias and judgmental prejudice. Nevertheless, community perceptions of climate change can complement scientific climate records and provide valuable information at the local scale for advancing scientific research and developing adaptation strategies to climate change.

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References

Aase, T. H., Chaudhary, R. P., & Vetaas, O. R. (2010). Farming flexibility and food security under climatic uncertainty: Manang, Nepal Himalaya. *Area*, *42*(2), 228–238.

Alexander, C., Bynum, N., Johnson, E., King, U., Mustonen, T., Neofotis, P., … Weeks, B. (2011). Linking Indigenous and scientific knowledge of climate change. *BioScience*, *61*(6), 477–484.

Aryal, S., Cockfield, G., & Maraseni, T. N. (2014). Vulnerability of Himalayan transhumant communities to climate change. *Climatic Change*, *125*(2), 193–208.

Asselin, H. (2015). Indigenous forest knowledge. In K. Peh, R. Corlett, & Y. Bergeron (Eds.), *Routledge handbook of forest ecology* (pp. 586–596). New York: Earthscan, Routledge.

Barnekow Lillesø, J. P., Shrestha, T. B., Dhakal, L. P., Nayaju, R. P., & Shrestha, R. (2005). *The map of potential vegetation of Nepal: A forestry/agro-ecological/biodiversity classification system*. Hørsholm: Center for Skov, Landskab og Planlægning/Københavns Universitet (Development and Environment; No. 2/2005).

Bawa, K. S., Koh, L. P., Lee, T. M., Liu, J., Ramakrishnan, P. S., Yu, D. W., … Raven, P. H. (2010). China, India, and the environment. *Science*, *327*(5972), 1457–1459.

Becken, S., Lama, A. K., & 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.

Borick, C. P., & Rabe, B. G. (2010). A reason to believe: Examining the factors that determine individual views on global warming. *Social Science Quarterly*, *91*(3), 777–800.

Byg, A., & Salick, J. (2009). Local perspectives on a global phenomenon—climate change in Eastern Tibetan villages. *Global Environmental Change*, *19*(2), 156–166.

Central Bureau of Statistics. (2014). *National Population and Housing Census 2011 (Village Development Committee/Municipality)*, Government of Nepal, National Planning Commission Secretariat, Central Bureau of Statistics, Kathmandu, Nepal.

Chaudhary, P., & Bawa, K. S. (2011). Local perceptions of climate change validated by scientific evidence in the Himalayas. *Biology Letters*, *7*(5), 767–770.

Duncan, J. M., Biggs, E. M., Dash, J., & Atkinson, P. M. (2013). Spatio-temporal trends in precipitation and their implications for water resources management in climate-sensitive Nepal. *Applied Geography*, *43*, 138–146.

ESRI. (2014). ArcGIS 10.3 Desktop, Redlands, CA: Environmental Systems Research Institute, CA, USA.

Fan, Y., & van den Dool, H. (2008). A global monthly land surface air temperature analysis for 1948–present. *Journal of Geophysical Research*, *113*, D01103. Retrieved from http://onlinelibrary.wiley.com/doi/10.1029/2007JD008470/abstract

Finnis, J., Sarkar, A., & Stoddart, M. C. (2015). Bridging science and community knowledge? The complicating role of natural variability in perceptions of climate change. *Global Environmental Change*, *32*, 1–10.

Galloway McLean, K. (2010). *Advance guard: Climate change impacts, adaptation, mitigation and Indigenous peoples – a compendium of case studies*. Darwin: United Nations University – Traditional Knowledge Initiative.

Gallup. (2009). *High risk, low awareness of climate change in Nepal*. Retrieved January 25, 2017, from http://www.gallup.com/poll/124658/high-risk-low-awareness-climate-change-nepal.aspx

Goebbert, K., Jenkins-Smith, H. C., Klockow, K., Nowlin, M. C., & Silva, C. L. (2012). Weather, climate, and worldviews: The sources and consequences of public perceptions of changes in local weather patterns. *Weather, Climate, and Society*, *4*(2), 132–144.

Herring, S. C., Hoerling, M. P., Kossin, J. P., Peterson, T. C., & Stott, P. A. (2015). Explaining extreme events of 2014 from a climate perspective. *Bulletin of the American Meteorological Society*, *96*(12), S1–S172.

Howe, P. D., Markowitz, E. M., Lee, T. M., Ko, C. Y., & Leiserowitz, A. (2012). Global perceptions of local temperature change. *Nature Climate Change*, *3*(4), 352–356.

Howe, P. D., Thaker, J., & Leiserowitz, A. (2014). Public perceptions of rainfall change in India. *Climatic Change*, *127*(2), 211–225.

Intergovernmental Panel on Climate Change. (2007). Climate change 2007: The physical sciences basis. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hansen (Eds.), *Contribution of working group I to the fourth assessment report of the IPCC*. Cambridge: Cambridge University Press. Retrieved from www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-frontmatter.pdf

Körner, C. (2003). *Alpine plant life: Functional plant ecology of high mountain ecosystems*. Berlin: Springer

Körner, C., Paulsen, J., & Spehn, E. M. (2011). A definition of mountains and their bioclimatic belts for global comparisons of biodiversity data. *Alpine Botany*, *121*(2), 73–78.

Kreft, S., Eckstein, D., Junghans, L., Kerestan, C., & Hagen, U. (2014). *Global Climate Risk Index 2015*.

Kulkarni, A., Patwardhan, S., Kumar, K. K., Ashok, K., & Krishnan, R. (2013). Projected climate change in The Hindu Kush–Himalayan region by using the high-resolution regional climate model PRECIS. *Mountain Research and Development*, *33*(2), 142–151.

Laidler, G. J. (2006). Inuit and scientific perspectives on the relationship between sea ice and climate change: The ideal complement? *Climatic Change*, *78*(2), 407–444.

Lee, T. M., Markowitz, E. M., Howe, P. D., Ko, C. Y., & Leiserowitz, A. A. (2015). Predictors of public climate change awareness and risk perception around the world. *Nature Climate Change*, *5*, 1014–1020.

Lehner, F., & Stocker, T. F. (2015). From local perception to global perspective. *Nature Climate Change*, *5*(8), 731–734.

Li, C., Tang, Y., Luo, H., Di, B., & Zhang, L. (2013). Local farmers' perceptions of climate change and local adaptive strategies: A case study from the middle Yarlung Zangbo

River Valley, Tibet, China. *Environmental Management*, *52*(4), 894–906.

Macchi, M., Gurung, A. M., & Hoermann, B. (2014). Community perceptions and responses to climate variability and change in the Himalayas. *Climate and Development*, *7*(5), 414–425.

Marin, A. (2010). Riders under storms: Contributions of nomadic herders' observations to analysing climate change in Mongolia. *Global Environmental Change*, *20*(1), 162–176.

Ministry of Environment. (2010). *Nepal National Adaptation Programme of Action (NAPA)*. Kathmandu: Government of Nepal.

Mishra, S. R., Bhandari, P. M., Issa, R., Neupane, D., Gurung, S., & Khanal, V. (2015). Climate change and adverse health events: Community perceptions from the Tanahu district of Nepal. *Environmental Research Letters*, *10*(3), 034007.

Mittermeier, R. A., Gils, P. R., Hoffman, M., Pilgrim, J., Brooks, T., Mittermeier, C. G., … daFonseca, G. A. B. (Eds.). (2004). *Hotspots revisited. Earth's biologically richest and most endangered terrestrial Ecoregions*. Mexico City: CEMEX/ Agrupación Sierra Madre.

National Planning Commission/United Nations Development Programme. (2014). *Nepal human development report: Beyond geography, unlocking human potential*. Nepal: National Planning Commission, Government of Nepal and United Nations Development Programme.

Pandit, M. K., Manish, K., & Koh, L. P. (2014). Dancing on the roof of the world: Ecological transformation of the Himalayan landscape. *BioScience*, *64*(11), 980–992.

Patt, A. G., & Schröter, D. (2008). Perceptions of climate risk in Mozambique: Implications for the success of adaptation strategies. *Global Environmental Change*, *18*(3), 458–467.

Practical Action. (2009). *Temporal and spatial variability of climate change over Nepal (1976–2005)*. Kathmandu: Practical Action Nepal Office.

Primack, R., & Higuchi, H. (2007). Climate change and cherry tree blossom festivals in Japan. *Arnoldia*, *65*(2), 14–22.

Reedy, D., Savo, V., & McClatchey, W. (2014). Traditional climatic knowledge: Orchardists' perceptions of and adaptation to climate change in the Campania region (southern Italy). *Plant Biosystems*, *148*(4), 699–712.

Sakurai, R., Jacobson, S. K., Kobori, H., Primack, R., Oka, K., Komatsu, N., & Machida, R. (2011). Culture and climate change: Japanese cherry blossom festivals and stakeholders' knowledge and attitudes about global climate change. *Biological Conservation*, *144*(1), 654–658.

Sanchez, A. C., Fandohan, B., Assogbadjo, A. E., & Sinsin, B. (2012). A countrywide multi-ethnic assessment of local communities' perception of climate change in Benin (West Africa). *Climate and Development*, *4*(2), 114–128.

Schneider, U., Becker, A., Finger, P., Meyer-Christoffer, A., Ziese, M., & Rudolf, B. (2014). GPCC's new land surface precipitation climatology based on quality-controlled in situ data and its role in quantifying the global water cycle. *Theoretical and Applied Climatology*, *115*(1–2), 15–40.

Schneider, U., Fuchs, T., Meyer-Christoffer, A., & Rudolf, B. (2008). *Global precipitation analysis products of the GPCC*. Global Precipitation Climatology Centre (GPCC), DWD, Internet Publication 112.

Sharma, R. (2012). Impacts on human health of climate and land use change in the Hindu Kush–Himalayan region. *Mountain Research and Development*, *32*(4), 480–486.

Shrestha, A. B., & Aryal, R. (2011). Climate change in Nepal and its impact on Himalayan glaciers. *Regional Environmental Change*, *11*(1), 65–77.

Shrestha, A. B., Wake, C. P., Dibb, J. E., & Mayewski, P. A. (2000). Precipitation fluctuations in the Nepal Himalaya and its vicinity and relationship with some large scale climatological parameters. *International Journal of Climatology*, *20*, 317–327.

Shrestha, A. B., Wake, C. P., Mayewski, P. A., & Dibb, J. E. (1999). Maximum temperature trends in the Himalaya and its vicinity: An analysis based on temperature records from Nepal for the period 1971–94. *Journal of Climate*, *12*, 2775–2786.

Shrestha, U. B., Gautam, S., & Bawa, K. S. (2012). Widespread climate change in the Himalayas and associated changes in local ecosystems. *PLoS One*, *7*(5), e36741.

Smith, J. B., Huq, S., Lenhart, S., Mata, L. J., Nemesová, I., & Toure, S. (Eds.). (1996). *Vulnerability and adaptation to climate change: Interim results from the US country studies program* (Vol. 8). Berlin: Springer.

Stott, P. A., Christidis, N., Otto, F. E., Sun, Y., Vanderlinden, J. P., van Oldenborgh, G. J., … Zwiers, F. W. (2016). Attribution of extreme weather and climate-related events. *Wiley Interdisciplinary Reviews: Climate Change*, *7*(1), 23–41.

Wang, S., & Cao, W. (2015). Climate change perspectives in an Alpine area, Southwest China: A case analysis of local residents' views. *Ecological Indicators*, *53*, 211–219.

Xu, J., Grumbine, R., Shrestha, A., Eriksson, M., Yang, X., Wang, Y., & Wilkes, A. (2009). The melting Himalayas: Cascading effects of climate change on water, biodiversity, and livelihoods. *Conservation Biology*, *23*, 520–530.