Signs of Climate Warming Through the Eyes of Yak Herders in Northern Bhutan

Authors: Kesang Wangchuk, and Jigme Wangdi
Source: Mountain Research and Development, 38(1) : 45-52
Published By: International Mountain Society
URL: https://doi.org/10.1659/MRD-JOURNAL-D-17-00094.1

Mountain Research and Development (MRD)
An international, peer-reviewed open access journal
published by the International Mountain Society (IMS)
www.mrd-journal.org

MountainResearch
Systems knowledge

Signs of Climate Warming Through the Eyes of Yak Herders in Northern Bhutan

Kesang Wangchuk[1] and Jigme Wangdi[2]*
** Corresponding author: kesangwangchuk@rocketmail.com*
[1] Research and Extension Division, Department of Livestock, Ministry of Agriculture and Forests, Thimphu, Bhutan
[2] Livestock Production Division, Department of Livestock, Ministry of Agriculture and Forests, Thimphu, Bhutan

A questionnaire survey was conducted to understand how a mountain ecosystem in northern Bhutan is perceived by local yak herders to be changing under climate warming. One hundred elderly herders were selected using a 2-stage sampling. The questionnaire sought information on herders' awareness and perceptions of weather patterns, climate changes, and their impact on vegetation, herding practices, and livelihoods. Most study participants were aware of global warming. They perceived that global warming has led to warmer and longer vegetation growing periods, increased rainfall, decreased water availability, more frequent droughts, the ascent of snow lines, and an increase in flash floods and landslides. Many herders also perceived that vegetation is growing faster, new vegetation is gradually becoming established in formerly barren lands, and meadows have been encroached on by rhododendrons, which has reduced grassland size and caused a decline in forage availability and quality. Warming was perceived to have caused difficulties in herding and transhumant migration. It was also perceived to have caused a decrease in milk production and increase in livestock predation, which affected the livelihoods of herders who rely on yak. The study concluded that yak herders' perceptions provide critical signs of warming and their vulnerability to changing climatic conditions in the alpine environment.

Keywords: *Alpine; environment; herders; perceptions; yak; climate warming; Bhutan.*

Peer-reviewed: *January 2018* ***Accepted:*** *January 2018*

Introduction

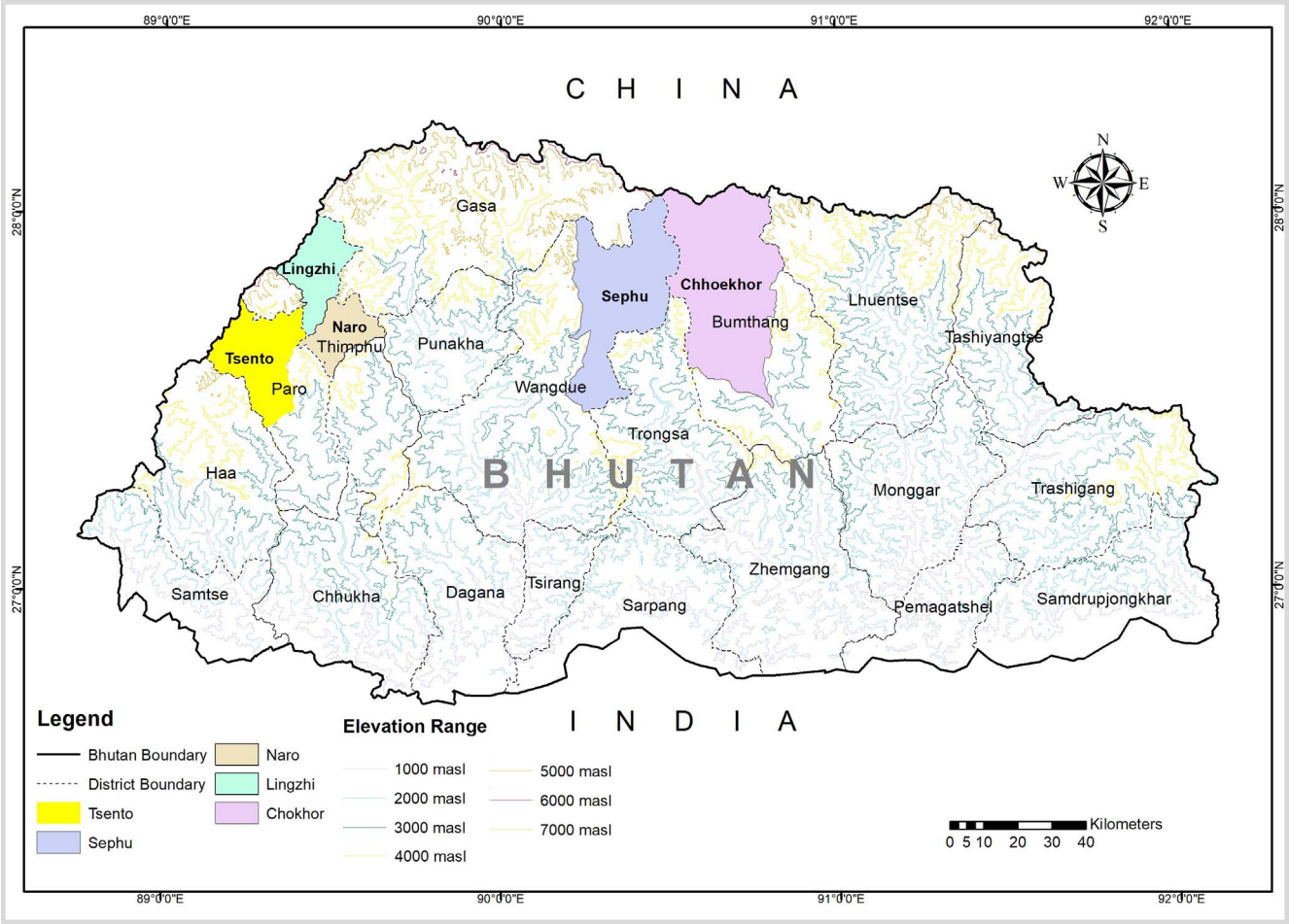
Mountain ecosystems, which play an important role in sustaining the livelihoods of mountain pastoralists, are under increasing pressure from stressors stemming from climate change. Climate change has added stress to the agriculture sector (IPCC 2007). Developing countries dependent on natural resources and with low capacity to fight the adversities of climate change will be affected; the poorest countries will be the most vulnerable (McCarthy et al 2001). Scientific communities have acknowledged that climate extremes threaten rural livelihoods. Yet the development strategies of least developed countries mostly overlook the risks of climate change, and this makes them more vulnerable.

In the Himalaya, millions of people living both upstream and downstream will face the burden of changing climate (Immerzeel et al 2010). The significance of the Himalaya in relation to global climate change and the likely impact of warming on the Himalaya and its ecosystems were discussed by Singh et al (2010). Academic debates on the changing climate in the Himalaya focus primarily on glacier melt (Ding et al 2006; Liu et al 2006) and the consequent negative impact on water resources (Xu et al 2009; IUCN 2011). However, until recently and with few exceptions, most climate change studies have ignored local knowledge (Byg and Salick 2009). Perceptions of climate change in the Himalayan environment have been studied recently (Vedwan and Rhoades 2001; Byg and Salick 2009; Salick and Ross 2009; Sharma et al 2009; Tse-ring et al 2010; Chaudhary and Bawa 2011; Islam et al 2014). A study of people's perceptions of climate change could improve understanding of how humans respond to climate change (Vedwan and Rhoades 2001).

Indigenous peoples are keen observers and have creative ways of interpreting and reacting to the impacts of climate change (Salick and Ross 2009). Traditional knowledge gained over many years is used to cope with changes in climate and environment. Thus, indigenous people have the ability to monitor the changing climate, adapt to it, and mitigate its effects. They provide innovative perspectives to strengthen climate change efforts and enhance ecosystem resilience. Indigenous

 http://dx.doi.org/10.1659/MRD-JOURNAL-D-17-00094.1

FIGURE 1 Location of the study villages in Bhutan. (Map by Pema Wangda, RNR Statistical Division)



knowledge also reinforces the available empirical evidence and increases our understanding of how shifts in climate may affect ecosystems and trigger cascading effects on livelihoods. Consequently, indigenous knowledge has benefited climate science (Cruikshank 1981; Reidlinger and Berkes 2001; Moller et al 2004). Such indigenous knowledge needs to be better understood, which could help scientific communities to design sound interventions aimed at alleviating the adverse effects of climate change.

Climate studies in the Himalaya have been confined to only a few countries (Chaudhary and Bawa 2011), which are not representative of the overall Himalayan scenario. The Himalaya's diverse topography offers a variety of climatic conditions, leading to large differences in farming practices. Perceptions of climate change and its effects have been found to differ significantly between sites in the Himalaya (Byg and Salick 2009). These geographic complexities suggest that local perceptions in one region may be of less value for another. To help address this gap in knowledge, we conducted a questionnaire survey with the main aim to investigate yak herders' perceptions on the effects of climate warming in the alpine environment of Bhutan.

Material and methods

Study area

Yak farming in Bhutan is found only in the alpine region in the northern part of the country. Five villages in that region, all major yak farming communities and all located in remote areas on rugged terrain, were selected as the study sites: Naro (27°21′24″N, 89°35′24″E), Lingzhi (27°52′48″N, 89°28′12″E), Soi Yaksa (27°40′48″N, 90°27′30″E), Sephu (27°33′36″N, 90°18′36″E), and Khangdang (27°48′36″N, 90°45′0″E) (Figure 1). The villages are in the districts of Thimphu, Bumthang, Paro, and Wangdue. Average temperatures range from 20 to –10°C.

Questionnaire design

Survey questions were framed as closed-ended with 3 possible answers: "agree," "disagree," and "neither." The

http://dx.doi.org/10.1659/MRD-JOURNAL-D-17-00094.1

questionnaire was pretested to ensure that the questions were easy to understand and did not influence participants' responses.

The survey questionnaire, which used a 3-point Likert scale (Likert 1932), gathered information on informants' perceptions of changes in the environment, weather patterns, herding practices, and livelihoods. It was divided into 6 sections. The first section consisted of questions on the herders' general awareness of changes in the climate and environment over the last 15 years. The second section sought information on their perceptions of specific signs of climate change, such as changes to the tree line, seasons, and soil conditions. The third section focused on weather patterns, the fourth on water and vegetation, and the fifth and sixth on the impacts of warming on herding practices and herders' livelihoods, especially in regard to transhumant migration and animal health.

The full questionnaire is presented in the *Supplemental Material*, Table S1; (http://dx.doi.org/10.1659/MRD-JOURNAL-D-17-00094.S1).

Interviews

An official approval was sought for the sampling and selection of villages and questionnaire survey of participants. Yak herders were selected because their heavy dependence on natural resources makes them sensitive to environmental changes and thus the best informants on the effects of warming in the alpine environment. A questionnaire survey was administered in the 5 study villages.

Villages and respondents were selected in 2 stages. In the first stage, researchers, development workers, and local government bodies were consulted and villages were selected for surveying. In the second stage, village leaders were consulted and households and elderly herders were identified as potential respondents. Interviews were conducted with 100 elderly herders. Elderly herders were interviewed because they had witnessed the past climate and environmental changes over several years.

Data analysis

Yak herders' perceptions on the effects of warming were identified through their responses to different questions. These responses were categorized and codified for statistical analysis and are displayed as percentages. Differences in responses were tested with nonparametric chi-square tests. The software SPSS 23 (Landau and Everitt 2004) was used to analyze the dataset.

Results

Perceptions of changes to weather and climate

Herders' perceptions of climate change are presented in Table 1. The majority of respondents were aware of the changing climate. When asked to compare the current climate to that of 15 years ago, the vast majority of respondents agreed that temperatures have risen and the climate is warmer at present. According to a large majority of respondents, this has led to a gradual change in the environment over the last 15 years. Most respondents perceived that weather patterns are changing; the vast majority agreed that the weather was worsening and becoming more unpredictable and was likely to worsen further in the future.

Regarding the signs of changing climate, most respondents agreed that snow and glaciers are melting faster, causing the snow line to ascend. The majority of respondents said that the frequency of landslides and flash floods has increased and the warm period has become longer. Many also said that water sources are drying gradually and water availability has declined. Despite agreeing that the amount of rainfall has increased, the vast majority of respondents said there is increasing water scarcity due to warming and soil fertility has declined. Over half of the respondents said that the changing climate and warming have led to more droughts and desertification; less than half perceived that the tree line has ascended. Respondents were divided on whether warming has led to changes in the amount of soil moisture content and number of lake outbursts. Respondents felt that the frequency of hailstorms has not increased. According to less than half of the respondents (statistically not significant), the size of rivers is perceived to have decreased.

Perceived impact of warming on vegetation

Yak herders' perceptions of the impacts of warming on vegetation are presented in Table 2. Many agreed that the barren lands are gradually being colonized by plants. Grassland size and fodder availability were perceived to have decreased. According to over half of the respondents, rhododendrons are encroaching on alpine meadows at a faster rate and forage quality has declined. Just under half reported that vegetation has started to grow faster, yet no new plant species have been found in the meadows.

Perceived impact of warming on herding practices and livelihoods

Table 3 shows respondents' perceptions of the impact of warming on herding. According to most respondents, climate warming has made herding difficult. Yaks were reported to feel discomfort during transhumant migration and livestock health is declining. Most respondents said that unlike in the past, transhumant migration has become difficult and the timing of migration has changed over the recent years. However, respondents were evenly divided on whether the prevalence of gid disease (*Coenurus multiceps multiceps*) in

TABLE 1 Yak herders' awareness of perceived changes in weather pattern and signs of climate warming as reported by 100 respondents of 5 villages in northern Bhutan.

Perceptions	Response (%)			Significance (*P*)
	Yes	No	Do not know	
General awareness of climate change				
The temperature has increased.	95	3	2	≤0.001
The environment has changed in the last 15 years.	90	5	5	≤0.001
I have heard of climate change.	77	21	2	≤0.001
The climate is warmer now.	74	26	0	≤0.001
The climate was colder in my area 15 years ago.	52	16	32	≤0.001
Weather patterns				
Weather patterns are changing.	91	8	1	≤0.001
The weather is becoming more unpredictable.	89	6	5	≤0.001
The weather is becoming worse.	88	2	10	≤0.001
The weather will worsen in future.	82	5	13	≤0.001
Signs of climate change				
The snow is melting earlier.	89	6	5	≤0.001
The snow line is ascending.	83	4	13	≤0.001
The glaciers are melting.	80	9	11	≤0.001
There are more landslides.	74	12	14	≤0.001
The warm period is becoming longer.	73	11	16	≤0.001
There are more flash floods.	68	24	8	≤0.001
Water sources are drying up.	65	18	17	≤0.001
Water availability is declining.	65	18	17	≤0.001
Rainfall is increasing.	64	25	11	≤0.001
Water scarcity is increasing.	62	31	7	≤0.001
Soil fertility is declining.	61	14	25	≤0.001
Drought and desertification are increasing.	59	34	7	≤0.001
The tree line is ascending.	46	18	36	≤0.01
The size of the river is decreasing.	43	26	31	Not significant
Soil moisture is declining.	36	33	31	Not significant
There are more lake outbursts.	35	38	27	Not significant
There are more hailstorms.	31	43	26	Not significant

yak is increasing. The majority felt that warming has not contributed to rural–urban migration of yak herders. Only a smaller proportion said that the transhumant migration route itself has changed or become longer.

Table 4 presents the perceived impact of warming on herders' livelihoods. The majority agreed that milk production has declined and that their livelihoods have been affected by warming. Many have lost animals to

http://dx.doi.org/10.1659/MRD-JOURNAL-D-17-00094.1

TABLE 2 Perceived impacts on vegetation due to changing climate as reported by 100 respondents of 5 villages in northern Bhutan.

Perceived impact	Response (%)			Significance (*P*)
	Yes	No	Do not know	
Vegetation is expanding into formerly barren lands.[a)]	82	0	18	≤0.001
Grassland size and fodder availability are decreasing.	82	11	7	≤0.001
Encroachment by rhododendrons is faster.	58	24	18	≤0.001
Forage quality is declining.	55	36	9	≤0.001
Vegetation is growing faster.	49	27	24	≤0.010
There are new plant species in the meadows.	32	45	23	≤0.050

[a)] Refers to barren soil without vegetation.

TABLE 3 Perceived impact of climate warming on yak-herding practices.

Perceived impact	Response (%)			Significance (*P*)
	Yes	No	Do not know	
Warming is making herding difficult.	85	12	3	≤0.001
Animals feel discomfort during transhumant migration.	61	13	26	≤0.010
Livestock health is declining.	58	20	22	≤0.010
Transhumant migration is becoming difficult.	52	18	30	≤0.050
Transhumant migration time has changed.	49	39	12	≤0.050
Gid disease prevalence is increasing.	42	43	15	≤0.010
Warming has contributed to herders' migration to the city.	18	65	17	≤0.010
Transhumant migration route has changed.	15	58	27	≤0.010
Transhumant migration route has become longer.	7	22	71	≤0.001

TABLE 4 Perceived impact of climate warming on yak herders' livelihoods.

Perceived impact	Response (%)			Significance (*P*)
	Yes	No	Do not know	
Milk production is decreasing.	89	11	0	≤0.001
I have been affected by warming.	77	14	9	≤0.001
I have lost animals to predation.	62	31	7	≤0.010
I have lost animals to flash flooding.	41	52	7	≤0.050
I have lost animals to landslides.	33	60	7	≤0.010
Annual income is decreasing.	27	63	10	≤0.010
I have taken steps to adapt to warming.	0	90	10	≤0.001

http://dx.doi.org/10.1659/MRD-JOURNAL-D-17-00094.1

predation, whereas few have lost animals to flash floods or landslides. Only about a quarter reported a decline in annual income. The large majority said that they have not taken steps to adapt to warming.

Discussion

This study investigated yak herders' perceptions of environmental conditions in the alpine rangelands of northern Bhutan under climate warming. The results of the study have relevance for sustainable development in mountains. Mountain countries, organizations, and communities have emphasized the importance of including mountains in the Sustainable Development Goals of the United Nations (FAO 2014). This study highlights some of the ways that climate warming may affect the wellbeing of mountain communities. Thus, the study findings contribute to the discussion on negative effects of climate change and on alleviating poverty, which are 2 of the 17 key issues addressed in the Sustainable Development Goals.

Perceptions of changes to weather and climate

Yak herders' responses provide important insights into their local knowledge on the changing climate in the alpine region of northern Bhutan. The widespread awareness and perceptions of herders not only demonstrate their ability to view the changing climate holistically through various indicators but also reflect their fears and concerns. The herders' ability to assess the changing climate probably arises from the long and dynamic human–environment relationship that structures perceptions of climate change (Vedwan and Rhoades 2001). The findings of our survey reinforce the empirical evidence of several studies that warming in the alpine environment causes erratic weather patterns, increasing glacial melt, and reducing snow cover (Baker and Moseley 2007; Eriksson et al 2009), increasing frequency of drought (Dai 2013), and increasing water scarcity (Morrison et al 2009). Our findings are consistent with those of Carney et al (2007) and Baker and Moseley (2007), who reported a decrease in soil fertility and ascent of snow and tree lines under warming, respectively. Sudmeier-Rieux et al (2012) also reported an increase in the frequency of landslides and flash floods under warming.

The perceived drying up of water sources is consistent with the findings of Chaudhary and Bawa (2011). Yak herders associate declining water availability with drying up of water sources due to increasing frequency of drought. This conforms with the projection by Bhutan's Gross National Happiness Commission (2011) that temperature change will influence overall rainfall patterns and increase droughts. Perceived decline in water availability likely indicates drinking water shortages, which are a prominent effect of global warming (Sudmeier-Rieux et al 2012). Decline in water availability could also be due to changes in seasonality and increases in variability, increases in demand, and increases in temperature and evapotranspiration.

Perceived impact of warming on vegetation

Alpine vegetation is perceived to have undergone considerable changes, including growing faster than the normal pace because of warming. Study participants stated that the impacts of climate change have included new vegetation growth on formerly barren land and rapid encroachment on meadows by rhododendron shrubs. The perceived changes in vegetation growth conform to reports that warming stimulates the growth of herbaceous and woody plant species (Bazzaz 1996). The perception of encroachment on meadows by rhododendrons indicates both horizontal and vertical movement by this species. It explains the decline in grassland size, availability, and quality, as perceived by yak herders. It is widely accepted that, with rising temperature, alpine plant species shift their elevational ranges to stay within the most favorable climatic zones and habitats. Aryal et al (2014) found a decrease in the size of agricultural fields, grassland, and forest due to shrub encroachment in the alpine region of Nepal. Studies conducted elsewhere have also highlighted denser and higher shrub infestation due to climate warming (Tape et al 2006; Hudson and Henry 2009; Brandt et al 2013). In northeastern Yunnan in Himalayan China, about 39% of alpine meadows are reported to have been encroached on by shrubs from 1990 to 2009 (Brandt et al 2013). In Bhutan, an estimated 22% of the grazing area has been lost to shrub encroachment from 1998 to 2008 (Chophyel 2009).

Increased growth of alpine vegetation could reduce soil erosion, improve water storage and quality, and provide hydrological benefits to the hydropower industry. However, in terms of herders' livelihoods and conservation, shrub encroachment appears less desirable. Alpine meadows sustain yak farming, and the expansion of shrubby vegetation would reduce meadows' size and carrying capacity, which would exacerbate the existing forage shortage. Thus, shrub encroachment may pose a major threat to herders' livelihoods, as well as to the many endemic plants and animal species living in alpine meadows. Bush encroachment is reported to alter habitat structure and decrease herbaceous production and may threaten livestock production and natural resource conservation (O'Connor and Crow 1999).

Perceived impact of warming on herding practices and livelihoods

Because of changes in the alpine environment caused by warming, herding is becoming increasingly difficult. This is reflected by the decline in animal health, increasing difficulty of transhumant migration, and increasing

discomfort of migrating yaks. It is also reflected in changes to the time of year at which migration takes place. According to study participants, such changes show the sensitivity of yak to high temperatures. Nardone et al (2010) reported that livestock experience physical discomfort at high temperatures. Decline in overall livestock health is probably explained by the fact that the rise in temperature causes physiological stress in yak and leads to reduced feed intake and altered physiological functions and impaired health (Beede and Collier 1986). However, herders were divided on the increased prevalence of gid disease, which causes high mortality in yaks. Although the rangeland ecology in northern Bhutan seems to be undergoing a change unfavorable to yak farming, warming has not contributed to rural outmigration of yak herders.

Most yak herders have been affected by warming, but few have lost their animals to flash floods and landslides. Although a detailed assessment of yak mortality due to predation was not covered by this study, respondents revealed during informal discussions that predators have increased in number and that they have sighted new species of wild animals. Survey respondents mentioned a recent increase in predation by snow leopards near village settlements. The ascent of the tree line has most likely reduced the size of the alpine area and thus the habitat of snow leopards (Lovari et al 2013), which has probably increased their presence near grazing fields and thus their encounters with and predation of livestock. The ascent of the tree line may also have increased the habitat of other predators that previously remained at lower elevations. Another possible explanation is that, because of shrub encroachment, grasses are less abundant, and livestock might have moved in search of forage to more distant places where they are more vulnerable to predators. Livestock predation adversely impacts local livelihoods (Aryal et al 2014).

Warming is also perceived to have resulted in a decline in milk production, which is explained by the reduced size, productivity, and quality of grasslands. Declining milk production and predation pose major challenges to yak farming. However, warming has not resulted in a decline in annual income for the majority of herders. Alternative income sources—in particular, the collection and sale of *Cordyceps* (caterpillar fungus) (Wangchuk and Wangdi 2015)—appear to have made up for the losses from yak farming.

Conclusions

This study investigated the perceptions of yak herders in the alpine region of northern Bhutan. These perceptions provide critical signs of rising temperature and herders' vulnerability to climate change. The yak herders' perceptions are consistent with the findings of empirical studies, except on the issue of water availability. Warming is expected to cause discomfort to yaks and make migration and herding more difficult, and might reduce grasslands through shrub encroachment. As an adaptation strategy, herders may have to reduce herd size, which might affect their livelihoods. Herders are likely to confront increasing difficulties in coping with the changing climate and sustaining their livelihoods, which will compel them to seek alternative economic opportunities. Challenges lie ahead in designing interventions to make yak farming sustainable and attractive under changing environmental conditions.

REFERENCES

Aryal A, Brunton D, Raubenheimer D. 2014. Impacts of climate change on human–wildlife–ecosystem interactions in the Trans-Himalayan region of Nepal. *Theoretical and Applied Climatology* 115:517–529.

Baker BB, Moseley RK. 2007. Advancing treeline and retreating glaciers: Implications for conservation in Yunnan, P.R. China. *Arctic, Antarctic, and Alpine Research* 39:200–209.

Bazzaz FA. 1996. *Plants in Changing Environments: Linking Physiological, Population and Community Ecology*. Cambridge, United Kingdom: Cambridge University Press.

Beede D, Collier RJ. 1986. Potential nutritional strategies for intensively managed cattle during thermal stress. *Journal of Animal Science* 62:543–554.

Brandt JS, Haynes MA, Kuemmerle T, Waller DM, Radeloff VC. 2013. Regime shift on the roof of the world: Alpine meadows converting to shrublands in the southern Himalayas. *Biological Conservation* 158:116–127.

Byg A, Salick J. 2009 Local perspectives on a global phenomenon—Climate change in eastern Tibetan villages. *Global Environmental Change* 19:156–166.

Carney KM, Hungate BA, Drake BG, Megonigal JP. 2007. Altered soil microbial community at elevated CO_2 leads to loss of soil carbon. *Proceedings of the National Academy of Sciences of the United States of America* 104:4990–4995.

Chaudhary P, Bawa KS. 2011. Local perceptions of climate change validated by scientific evidence in the Himalayas. *Biological Letters* 7:767–770.

Chophyel P. 2009. *Rangeland Management in Bhutan: A Consultancy Report*. Thimphu, Bhutan: Royal Government of Bhutan, Ministry of Agriculture.

Cruikshank J. 1981. Legend and landscape: Convergence of oral and scientific traditions in the Yukon Territory. *Arctic Anthropology* 18:67–93.

Dai A. 2013. Increasing drought under global warming in observations and models. *Nature Climate Change* 3:52–58.

Ding Y, Liu S, Li J, Shangguan D. 2006. The retreat of glaciers in response to recent climate warming in western China. *Annals of Glaciology* 43: 97–105.

Eriksson M, Xu J, Shrestha AB, Vaidya RA, Nepal S, Sandstrom K. 2009. *The changing Himalayas—Impact of climate change on water resources and livelihoods in the Greater Himalayas*. Kathmandu, Nepal: International Centre for Integrated Mountain Development.

FAO [Food and Agriculture Organization of the United Nations]. 2014. *Mountains and the Sustainable Development Goals—A Call for Action*. Rome, Italy: FAO. www.mountainpartnership.org/fileadmin/templates/mountain_partnership/doc/POLICY_BRIEFS/Mountains_and_the_Sustainable_Development_Goals_-_NY_-_8Jan.2014.pdf; accessed on 22 February 2018.

Gross National Happiness Commission. 2011. *Bhutan National Human Development Report 2011—Sustaining Progress: Rising to the Climate Challenge*. Thimphu, Bhutan: Royal Government of Bhutan.

http://dx.doi.org/10.1659/MRD-JOURNAL-D-17-00094.1

Hudson J, Henry G. 2009. Increased plant biomass in a High Arctic heath community from 1981 to 2008. *Ecology* 90:2657–2663.
Immerzeel WW, van Beek LPH, Bierkens MFP. 2010. Climate change will affect the Asian water towers. *Science* 328:1382–1385.
IPCC [Intergovernmental Panel on Climate Change]. 2007. Summary for policy makers. *In:* Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, editors. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom: Cambridge University Press, pp 1–18.
Islam ARMT, Tasnuva A, Sultana S, Rumana S. 2014. Climate change impact: Food production and local perception. *American Journal of Environmental Protection* 3:45–50.
IUCN [International Union for Conservation of Nature]. 2011. *Community Perceptions on Climate Change in Bagrote Valley, Pakistan—A Case Study*. Karachi, Pakistan: IUCN.
Landau S, Everitt B. 2004. *A Handbook of Statistical Analyses Using SPSS*. Boca Raton, FL: Chapman and Hall/CRC.
Likert R. 1932. A technique for the measurement of attitudes. *Archives of Psychology* 140:1–55.
Liu SY, Ding YJ, Li J, Shangguan DH, Zhang Y. 2006. Glaciers in response to recent climate warming in western China. *Quaternary Science* 26:762–771.
Lovari S, Ventimiglia M, Minder I. 2013. Food habits of two leopard species, competition, climate change and upper treeline: A way to the decrease of an endangered species? *Ethology, Ecology and Evolution* 25:305–318.
McCarthy J, Canziani OF, Leary NA, Dokken DJ, White KS, editors. 2001. *Climate Change 2001: Impacts, Adaptation, and Vulnerability*. Cambridge, United Kingdom: Cambridge University Press.
Moller H, Berkes F, O'Brian LP, Kislalioglu K. 2004. Combining science and traditional ecological knowledge: Monitoring populations for co-management. *Ecology and Society* 9:2.
Morrison J, Morikawa M, Murphy M, Schulte P. 2009. *Water Scarcity and Climate Change: Growing Risks for Businesses and Investors*. Boston, MA: Pacific Institute.
Nardone A, Ronchi B, Lacetera N, Ranieri MS, Bernabucci U. 2010. Effects of climate changes on animal production and sustainability of livestock systems. *Livestock Science* 130:57–69.
O'Connor TG, Crow VRT. 1999. Rate and pattern of bush encroachment in Eastern Cape savanna and grassland. *African Journal of Range Forage Science* 16:26–31.
Reidlinger D, Berkes F. 2001. Contributions of traditional knowledge to understanding climate change in the Canadian Arctic. *Polar Record* 37:315–329.
Salick J, Ross N. 2009. Traditional peoples and climate change. *Global Environmental Change* 19:137–139.
Sharma E, Chettri N, Tse-ring K, Shrestha AB, Jing F, Mool P, Eriksson M. 2009. Climate change impacts and vulnerability in the Eastern Himalayas. Kathmandu, Nepal: International Centre for Integrated Mountain Development.
Singh SP, Singh V, Skutsch M. 2010. Rapid warming in the Himalayas: Ecosystem responses and development options. *Climate and Development* 2:221–232.
Sudmeier-Rieux K, Gaillard JC, Sharma S, Dubois J, Jaboyedoff M. 2012. Floods, landslides, and adapting to climate change in Nepal: what role for climate change models? *In:* Lamadrid A, Kelman I, editors. *Climate Change Modeling for Local Adaptation in the Hindu-Kush-Himalayan Region*. Bingley, United Kingdom: Emerald, pp 119–140.
Tape K, Sturm M, Racine C. 2006. The evidence for shrub expansion in northern Alaska and the Pan-Arctic. *Global Change Biology* 12:686–702.
Tse-ring K, Sharma E, Chettri N, Shrestha A. 2010. *Climate Change Vulnerability of Mountain Ecosystems in the Eastern Himalayas*. Kathmandu, Nepal: International Centre for Integrated Mountain Development.
Vedwan N, Rhoades RE. 2001. Climate change in the Western Himalayas of India: A study of local perception and response. *Climate Research* 19: 109–117.
Wangchuk K, Wangdi J. 2015. Mountain pastoralism in transition: Consequences of legalizing *Cordyceps* collection on yak farming practices in Bhutan. *Pastoralism: Research, Policy and Practice* 5:1–10.
Xu J, Grumbine RE, Shreshtha 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.

Supplemental material

TABLE S1 Survey questionnaire.

Found at DOI: http://dx.doi.org/10.1659/MRD-JOURNAL-D-17-00094.S1 (119KB PDF).