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RESEARCH ARTICLE

Climate change, risk perception, and protection motivation among high-altitude residents of the Mt. Everest region in Nepal

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Abstract Mountain ecosystems are considered vulnerable to early impacts of climate change. Whether and how local residents of these areas perceive these changes, however, remain under-studied questions. By conducting a household survey in the Khumbu region of Nepal, this study assessed local residents' experience-based perception of changes in climate trends and patterns, perceived risk, and attitudes towards climate issues. Multivariate cluster analysis based on residents' climate change beliefs revealed three segments: "Cautious," "Disengaged," and "Alarmed." A comparison of these segments along key psychosocial constructs of Protection Motivation Theory (PMT) revealed significant inter-segment differences in residents' perception of severity, vulnerability, response efficacy, self-efficacy, and response cost associated with engaging in mitigating behavior. Results shed light on how residents of high elevation areas that are considered to be exposed to early impacts of climate change perceive the risk and intend to respond. These findings could also assist stakeholders working in other similar mountain ecosystems in understanding vulnerability and in working towards climate readiness.

Keywords Khumbu · Protection motivation · Respondent segment · Sherpa · Vulnerability · Weather pattern

INTRODUCTION

Climate change is a major global issue affecting human and natural systems across the world. Over the years, scientists have presented consistent evidence of changing climatic conditions, increasing incidents of catastrophic weather events, and changing local weather patterns. Nevertheless, there still exists some degree of skepticism regarding climate change in certain segments of society, partly because individuals have yet to witness or fully comprehend its actual impact on their surroundings or resources they depend on (Grotta et al. 2013). Moreover, climate change is sometimes viewed as local level environmental change rather than a global phenomenon (Anisimov and Orttung 2019). Communities in rural mountain ecosystems, particularly those located at high-altitude, are considered vulnerable to climate change because of their exposure to early symptoms of climate change, sensitivity of local life resources (e.g. subsistence farming, mountain tourism), and lack of access to adaptive resources (e.g. health facilities, government programming) (Basannagari and Kala 2013). Academics and practitioners alike can learn from the local experiences of such communities by gaining a greater understanding of risk perception and then designing the most appropriate climate readiness programs (Ford and King 2015; Liski et al. 2019; Xenarios et al. 2019).

One such mountain ecosystem currently facing rapid climate change is the Khumbu region located in the eastern Himalayas, which is widely known for the richness of its natural (highest mountain peaks, glaciers, alpine habitats) and social systems (ethnic tribes, mountain tourism industry). Communities in the eastern Himalayas are particularly vulnerable to climate change because of their reliance on the monsoon cycle for farming and the continuous threat of melting glaciers in the highest mountains

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including the Everest (National Research Council 2012; Wester et al. 2019). Historical climate evidence in some regions of the eastern Himalayas have shown remarkable warming trends at a rate of 0.06 °C $year^{-1}$, and average precipitation has increased by 6.52 mm $year^{-1}$ (Shrestha et al. 2012). Water availability, subsistence farming, the tourism industry, and overall livability in the Khumbu region may be in peril (Chaudhary and Bawa 2011; National Research Council 2012) because of melting glaciers, warming winters, extended periods of drought, more erratic rainfall patterns, and reduced biodiversity (Tse-ring et al. 2010; Devkota et al. 2013). These trends are projected to persist in the future (Shrestha et al. 2012), yet it is unclear how local residents perceive and relate with actual change in the region's climate, and whether they would consider taking adaptive action is an important research question.

While the vast majority of research on human dimensions of climate change has focused on developed countries, a few have recently examined how local residents in the rural landscapes of Southeast Asia perceive impacts of climate change (Vedwan and Rhoades 2001; Basannagari and Kala 2013; Palazzol et al. 2015; Anup and Parajuli 2015; Ali and Erenstein 2017; Shrestha et al. 2017; Tripathi and Mishra 2017). Findings from these studies generally suggest that communities are concerned with changing weather patterns and have experienced adverse effects on crop production and food security. However, very little attention has been paid to climate change adaptation on mountain ecosystems, particularly the high elevation landscapes of the subalpine to alpine region, which are most vulnerable (Basannagari and Kala 2013; Shrestha et al. 2017). In an interview of a small sample (7) of residents in the Khumbu region of Nepal, Nyaupane et al. (2014) reported that interviewees agreed that weather patterns in the region were changing, but cautioned that respondents could be repeating hearsay rather than stating their own experiences. In another recent study in the region, albeit conducted at lower elevation (a mostly temperate zone), Sherpa (2014) concluded that local residents are noticing climate change-related environmental changes and have received climate change information from nongovernmental organization (NGO) climate campaigns, but argued that a deeper investigation of local residents regarding their vulnerability, access to resources, and knowledge is needed.

Moreover, review of the literature reveals a knowledge gap in connecting climate change beliefs and risk perception with behavioral aspects of mitigation or adaptation. Hence, the objective of this study was to investigate (i) whether and how residents of communities in high elevation Himalayan landscapes perceive the risks associated with climate change, and (ii) how their climate change beliefs relate with their sources of climate-related information, and their climate change protection motivation. Our study is conceptualized on the underpinnings of the theory of protection motivation (Rogers 1975), which posits that engagement in risk-reducing behavior depends on how individuals perceive the risk and vulnerability and how they evaluate their behavioral confidence and behavioral control in mitigating the risk. This was achieved by developing and administering a household survey for data collection and then conducting statistical analysis to compare and contrast resident segments and evaluate the relationship between psychosocial constructs.

MATERIALS AND METHODS

Study area

This study was conducted in the Khumbu region, located in and around the Sagarmatha (Mt. Everest) National Park in Nepal (ranging from 27° 45′ to 28° 07′ in latitude and 86° 28′ to 87° 07′ in longitude), which is one of the most fragile ecosystems in the eastern Himalayas. The Khumbu region ideally represents the Himalayan landscape for studying public perceptions of early impacts of climate change because of its location and sociocultural diversity. The region's elevation ranges from 3300 m above mean sea level to 8848 m at the top of Mt. Everest, the tallest mountain in the world. In addition, the region is home to several more of the world's highest mountains [e.g. Lhotse (8516 m), Makalu (8485 m), Cho Yyou (8201 m)], Sagarmatha National Park (SNP, a world heritage site designated in 1979), and thousands of ethnic Sherpa people. The remoteness of the region is evident in the fact that the study area, representing the rural mountainous region of Nepal, can only be accessed after several days of hiking from the nearest motorable road or airport. Most of the Khumbu region is managed by Nepal's federal government as a strictly protected national park within which human settlements are managed as designated buffer zones. Land use restrictions are partially relaxed in these buffer zones to accommodate the lifestyles and culture of the local residents (SNP 2016). Subsistence agriculture—which includes cattle herding and the cultivation of potatoes, wheat, barley, and buckwheat—depends heavily on a favorable climate (Byers and Thakali 2016). Farming remains a common livelihood practice among residents because of the seasonality of the tourism industry (Sherpa et al. 2019).

Recognizing the region's climate vulnerability, government agencies and NGOs have undertaken various community-based education and outreach efforts in Khumbu. In a broader effort to help develop a Local Adaptation Plan

of Action (LAPA)—a six-step framework adopted by Nepal's government to integrate climate change resilience into governance and the planning process—Byers and Thakali (2016) conducted a stakeholder survey in the region. The assessment concluded that local residents have concerns over increasing temperatures and catastrophic weather events, irregularity in the floristic behavior of plant communities, and the growth of microbial activities.

Household survey

By working closely with SNP officials, the investigators selected five communities (Namche, Thame, Khumjung, Phortse, and Laushasa) that cover the most of populated areas within the Khumbu region. These settlements are similar in ethnic composition but differ in population, elevation, and level of tourism activities. After reviewing recent literature in the human dimensions of climate change and preliminary discussion with some key conservation officials at SNP, a four-page survey questionnaire was prepared. Scales used in the survey regarding perception of risk, knowledge of climate, and perceived impacts on farming and life conditions were adapted from other similar studies (Barnes and Toma 2012; Arbuckle et al. 2013; Ali and Erenstein 2017; Rainear and Christensen 2017). The questionnaire (Appendix S1), initially developed in English, was translated to the Nepali language while paying particular attention to the accuracy of scientific terms related to climate science. Survey protocols were reviewed and approved by the University of Tennessee's Institutional Review Board (IRB-18-04457-XP).

The household survey was conducted during the first 2 weeks of June 2018. No specific sampling scheme was adopted because of the relatively small household population in the region. Instead, the research team attempted to visit each household in five villages and to interview the head of household or next available adult in the household. Since the study was undertaken right after the peak of tourism season and before major crop plantation or the harvesting season, investigators were able to locate an adult in all households on the first or second attempt. Completed surveys from 298 households were obtained, which is considered big enough for generalizing to the estimated population of 1500 households in the study area at a 95% confidence level with a 5% margin of error (Vaske 2008). The authors themselves conducted the interviews whenever possible, but locally recruited research assistants also conducted interviews so a greater sample size could be obtained. To ensure consistency among all interviews, authors trained the research assistants in how to conduct the interview process and how to complete the questionnaire. They were also adequately trained to communicate the concept of climate change in a plain language that relatively uneducated local residents could easily understand. The hiring of local research assistants improved the efficiency of the fieldwork, as they knew how to best navigate local routes to visit as many households as possible over a short period.

Measurement

Climate change beliefs

A set of seven scales was used to measure respondents' beliefs regarding the occurrence of climate change and perception of impact, which included "There have been more extreme weather events recently," "Weather patterns in the region will be less reliable in the future," "Talk of changing weather patterns is exaggerated," "Weather conditions in the region have been less reliable over the years," "Changing weather patterns are hurting my farms/pastures," "Changing weather patterns will make my living conditions worse," and "Changing weather patterns will cause more floods and landslides." They were measured in a 3-point scale (1: disagree, 2: neutral, and 3: agree) because of convenience and practical advantage considering the interview nature of data collection. Admittedly, a broader scale (e.g. 5-point) is typically preferred specially if higher precision in measurement is critical, but given the conceptual complexity associated with the topic of climate change and the cognitive burden on audiences with relatively low levels of education, investigators realized a 3-point scale would provide the best tradeoff between conceptual simplicity and precision.

Personal experience of climate change

Because of the conceptual complexity in understanding the meaning of climate change, it was important to frame survey questions in simpler terms (e.g. extreme weather, change in weather patterns) that possess similar conceptual meaning. Scholars argue that changes in local weather patterns or seasons is the way people experience, understand, or relate with the very idea of climate change (Akerlof et al. 2013). Following recent practices (Ali and Erenstein 2017; Elum et al. 2017), respondents' perceptions of long-term change in climatic conditions were measured by asking them to indicate how they have experienced trends (1: increasing, 2: no change, 3: decreasing) in eight different elements of climatic conditions since they started living in the region: snowfall frequency, snowfall intensity, rainfall frequency, rainfall intensity, temperature, drought, length of winter season, and windy days. Similarly, in an effort to learn where they obtained their climate-related information from, they were presented with a list of seven possible sources (media, own

experience, friends, school teachers, tourists, NGO/project staff, and government staff) and were asked to indicate their primary source.

Perceived impact on farm and responsive actions

Since a majority of residents depend on subsistence farming for food security and livelihood, a separate question asked them to indicate whether or not they have experienced impacts on farming. Respondents could check all applicable items from the list, which included reduction in crop yield, crop failure, crop damage, reduction of forage in pasture, more weeds on farm, more pests/disease on farm, and wildfire. A follow up question also asked them to indicate whether they have adopted any of the practices on the list to cope with the impact on their farms. The list of possible responsive actions included change planting time, reduce planting, switch crops, new in-field practice, modify grazing, apply more fertilizer, quit farming, change harvest time, shift cultivation, change crop variety, reduce cattle herd size, apply more insecticides, access public lands (i.e. National Park) for collecting produce, sell/rent land, and buy produce from others. For this study, these actions are loosely described as adaptive responses because adaptation broadly could mean much more than these actions. On the other hand, adaptation could also be situational to level of risk and local context. Nevertheless, this list was developed by reviewing recently published literature on climate change adaptation studies in an agricultural context. For example, change in planting time, changing crops or adopting a new crop, and changing to a new (climate-tolerant) variety of the same crop were adopted from Ali and Erenstein (2017) and Elum et al. (2017). Similarly, intensifying farming by heavier application of input (e.g. fertilizer), adopting a different crop, selling or renting land, and quitting farming were adopted from Mase et al. (2017).

Climate change protection motivation

As postulated in the protection motivation theory, an individuals' behavior relative to a risk such as climate change is shaped by his/her "appraisal of the threat" and "coping ability" (Rogers 1975). Appraisal of threat is further conceptualized in terms of the *Severity* (i.e. perceived seriousness of the issue) and *Vulnerability* (i.e. likelihood of experiencing negative impact from the risk). Similarly, the appraisal of coping is characterized by *Self-efficacy* (i.e. perceived confidence in behavior), *Response efficacy* (i.e. perceived effectiveness of behavior), and *Response cost* (i.e. perceived constraints from engaging in the behavior). By adapting the items used in the literature (Rainear and Christensen 2017), "Unreliable weather conditions are a serious issue for my area" was used to measure perception of *Severity*, whereas "I will likely experience negative impacts of climate change in my lifetime" and "My children will likely experience negative impacts of climate change in their lifetime" were used to measure respondents' perception of *Vulnerability*. Similarly, "If I help conserve forests and the environment now, it will help minimize extreme weather impacts" was used to measure perceived *Response efficacy*, and "I am confident I can contribute to conserving forests if I wanted" was used to measure *Self-efficacy*. Finally, "For me, doing anything to mitigate climate effect takes too much of time and money" and "I don't know how to protect myself from negative effects of extreme weather conditions" were used to measure *Response costs*. For the same reason stated above, a 3-point Likert scale (1: disagree, 2: neutral, and 3: agree) was used.

Data analysis

Survey responses were coded in IBM SPSS package for summarizing and cross-tabulation of item responses. While the overall results were summarized using mean sample scores and graphs, a multivariate cluster analysis was used to identify the typology of residents (i.e. segments) according to their beliefs regarding climate change occurrence and risks. Multivariate cluster analysis is a statistical technique that classifies respondents into a number of distinct groups in such a way that similarity in survey responses are maximized between the members of a group, but differences in responses are maximized between members of different groups. The basis of segmentation was survey data recorded on scales used in measuring respondents' climate change beliefs (the list of seven items were presented earlier in "Climate Change Beliefs" section under "Measurement"). The *k*-means cluster analysis method was used because of its intuitiveness, ease of interpretation of results (Hair et al. 2006), and the fact that it has been previously used in climate-related audience segmentation (Barnes and Toma 2012). In this tool, Euclidean distancing is used to develop the algorithms, which then create audience segments by using the following formulae (Hair et al. 2006):

$$J(V) = \sum_{i=1}^{b} \sum_{j=1}^{b_i} \left(x_i - y_j\right)^2. \quad (1)$$

In the above equation, $(\|x_i - y_j\|)$ represents the Euclidean distance between data point x_i and centroid y_j, which is defined as the mean of the points in the clusters, b_i is the number of data points in ith cluster, and b is the number of cluster centers in the k-means partition $J(Y)$ of a given data set.

While the cluster analysis algorithm has mathematical foundation on data-based classification of observations, it still involves researcher's subjective interpretation to give intuitive meaning to the resulting clusters (Tunved and Strom 2019). In other words, researchers typically have to use an iterative process to determine what level of partition provides the *d* clearly distinguishable clusters in the sample. By the same token, we analyzed and compared cluster results with various values of *k* (2, 3, 4, 5,…) in *k*-means clustering. The 2-cluster solution did not offer fine enough contrast to uniquely describe each cluster regarding climate change belief, whereas 4- or more cluster solutions yielded thinly spread segments where at least 2 segments look mostly identical in most belief statements. Hence, we determined that the 3-cluster solution (i.e. 3 segments) provided the most distinguishable sub-groups of respondents, each of which could be uniquely described and contrasted with the remaining based on their climate beliefs. In this solution, the Euclidean distance between the clusters was highest and clusters were significantly different in terms of each of the climate belief statement used in the clustering (see Appendix S2). It is worth noting that *F*-test, which reveals the statistical difference between final clusters, was only used for descriptive purposes as clusters are designed to have a maximum difference between each other. Resulting clusters were then compared by a series of statistics tests of difference (χ^2) on their demographics, their own experiences of change in climatic conditions, sources of climate information, and protection motivation constructs.

RESULTS AND DISCUSSION

Characteristics of respondents

About 75% of the 298 completed surveys were from Namche, Phortche, and Thame (generally evenly split between three), whereas the remaining 25% were from Khumjung and a nearby small settlement (Laushasa). Over half (51%) of the respondents were male, and the average age of the respondents was 42 years (min 18, max 90). About 77% indicated they were native to the Khumbu region (i.e. born in), whereas the remaining 23% had migrated in. On average, self-claimed migrants reported having lived in the region for 18 years (min 1, max 85). The average size of household for the respondents was 4.54 (min 1, max 24). Large household size is not uncommon in joint family culture in Nepal, particularly in rural areas where each pair has multiple children and three or more generations live under the same roof. While farming is mostly subsistent, about 34% of respondents also reported selling produce for income.

Personal experience of climate change

When asked about changes in various measures of climatic conditions, the vast majority (more than 70%) reported witnessing increases in temperature and drought in the Khumbu region (Fig. 1). More than three-quarters of respondents noticed decreases in both the intensity and frequency of snowfall and increases in temperature and drought. A qualitative interview of limited residents in the Khumbu region by Nyaupane et al. (2014) also revealed general agreement over changing weather patterns, including decreases in snow frequency and amount. Further, recently completed general household surveys in Nepal (Shrestha et al. 2019) and other studies of farming communities in the Indian Himalayas (Vedwan and Rhoades 2001; Basannagari and Kala 2013) and lower-elevation ranges of northern Thailand (Shrestha et al. 2017) also reported similar observations regarding perceptions of changing weather patterns. In addition, slightly more than half (55%) of the respondents in this study indicated that the frequency as well as intensity of rainfall had declined over the years. This is not surprising because studies have warned that higher elevation areas in the Himalayan region are likely to experience significant alterations in water flow and shifts in the location, intensity, and variability of rain due to climate change (National Research Council 2012). Slightly less than one-third indicated having seen an increase in windy days. Overall, climate change perceptions as described by the respondents in our study area are consistent with climate trend data reported in recent assessments in the Hindu Kush Himalayan region (Wester et al. 2019).

Beliefs regarding occurrence and perceived impacts of climate change

Respondents were asked to indicate whether they agreed or not with statements about the occurrence of and impact from climate change in their lives and communities. More than three-quarters (76%) asserted that there were more extreme weather events recently, whereas only 35% agreed that talks of changing weather patterns are exaggerated (Fig. 2). Over 80% agreed that weather conditions in the region have been less reliable over the years and will continue being so in future. More than half (58%) reported that changing weather patterns are already hurting their farms and pastures. As the land stability and floods are major issues in the mountainous regions, 68% indicated that changing weather conditions would lead to more floods and landslides. The same concern was also shared by many residents recently surveyed in a similar study in the region (Sherpa et al. 2019). About 72% agreed that changing weather patterns would also hurt the tourism

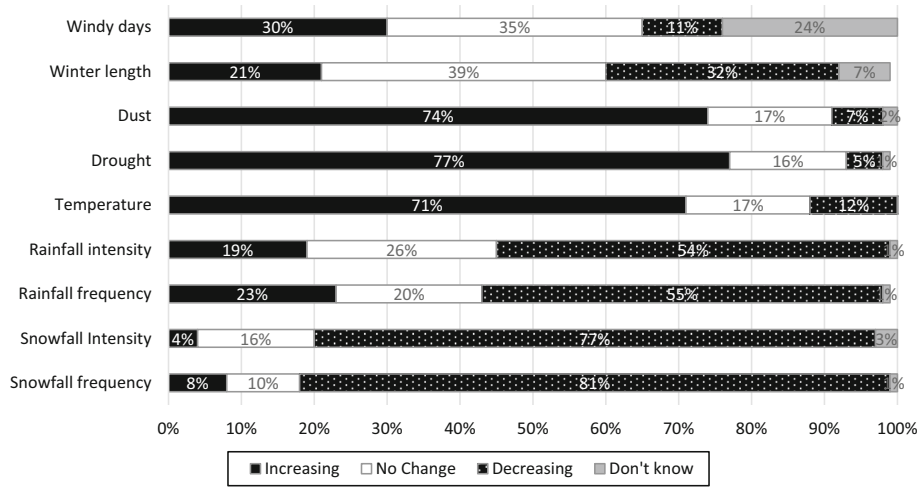

Fig. 1 Respondents' personal experience of change in regional climatic conditions since they started living in Khumbu ($N = 295$)

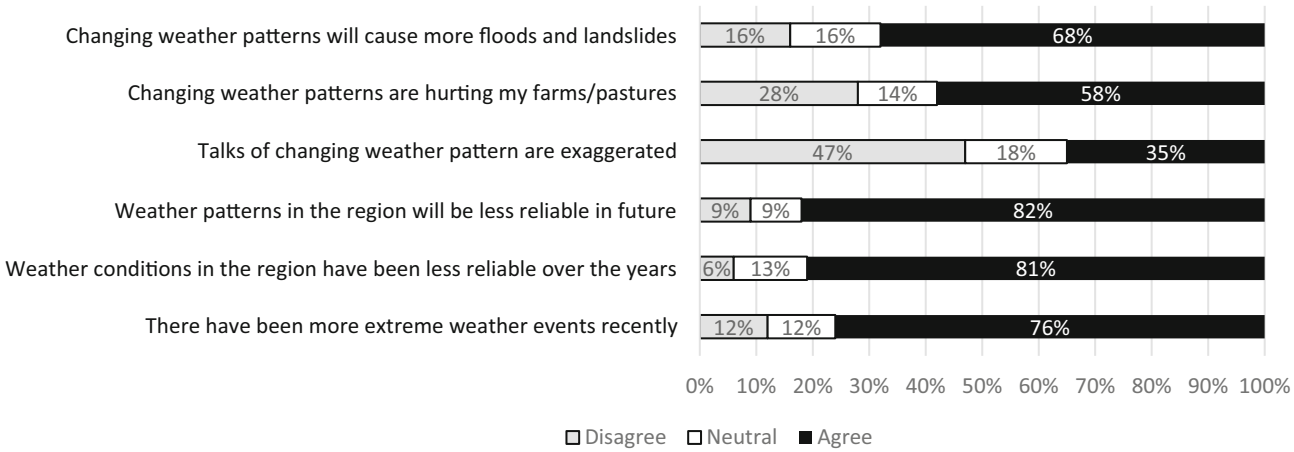

Fig. 2 Percentage of respondents according to their agreement or disagreement with beliefs regarding occurrence and perceived impacts of climate change in Khumbu region ($N = 295$)

business, the major economic engine in the Khumbu region.

Sources of information

In response to the question concerning climate-related information, most respondents (82%) indicated that their primary source is media such as radio and TV (Fig. 3). Slightly less than half (47%) indicated having learned about climate change from their own experience, and about one-third (33%) indicated having learned from friends and neighbors. Some also mentioned having heard about climate change from school teachers (17%) and tourists (15%). Very few (less than 10%) mentioned having received information from NGO, project, or government staff. This was surprising considering the number of grassroots campaigns and projects run by several NGOs and government agencies. However, while they probably did not directly hear from these government or NGO officials, many of the programs aired on TV or radio could have been sponsored by these institutions. Government agencies and NGOs in Nepal commonly air sponsored messages and documentaries through local and national radio and TV stations.

Perceived impacts on farming

Since not all in the sample had farmland, about 70% of respondents answered questions about the perceived impact of climate change on farming practices. Of the 208 that had

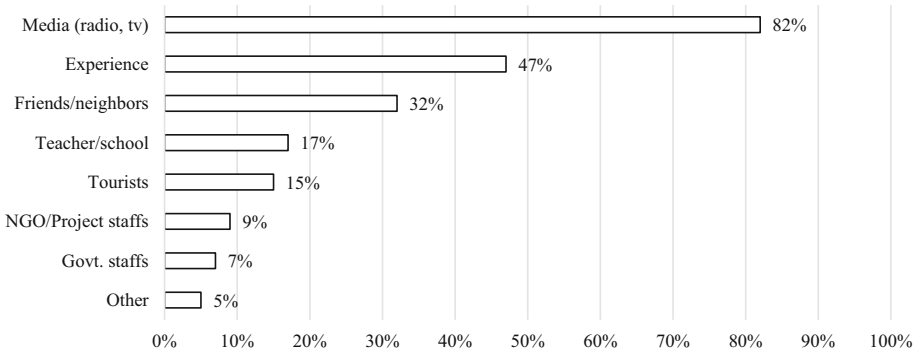

Fig. 3 Respondents' reported source of climate-related information (N = 295)

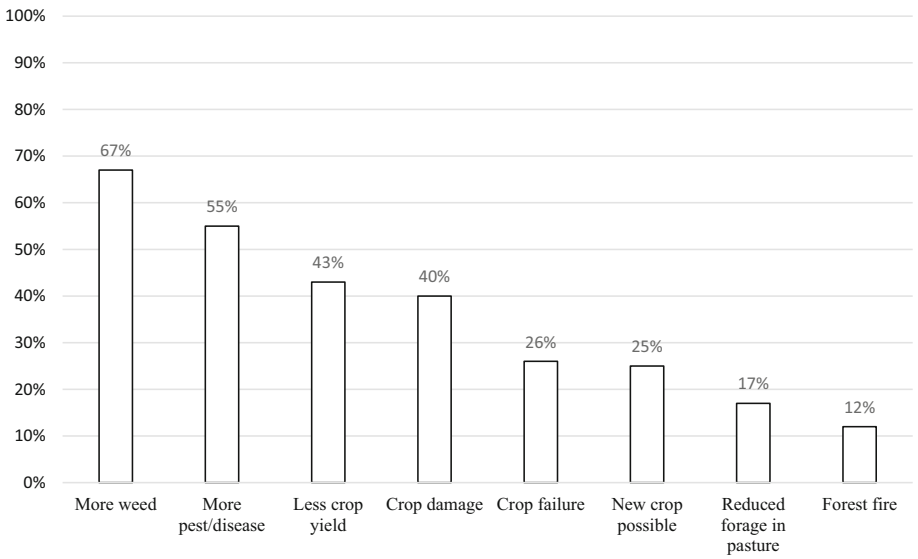

Fig. 4 Percentage of respondents indicating the type of climate change damage on farming (N = 208)

farmland, 98% reported to have experienced at least 1 type of damage and over 30% reported more than 3 types of damage. As shown in Fig. 4, the most frequently recorded impacts included more weeds (67%), increased pests/disease (55%), crop damage (40%), and declines in crop yield (43%). A reduction in agricultural production due to the warming climate has also been documented in recent social and environmental assessments of the Hindu Kush Himalayan region (Wester et al. 2019). A similar study by Elum et al. (2017) reported that crop failure, reduction in yield, and increased pest and disease incidents are major impacts from climate change experienced by South African farmers. Moreover, a survey of farmers in the Midwestern United States found that increased weeds and insect pressures were two of the major concerns regarding climate change impacts on farm operations (Mase et al. 2017). In our study, about 28% indicated that new crops were becoming feasible in the region, corroborating findings by Byers and Thakali (2016) who noted that new kitchen vegetables were becoming available at various tourist markets along the Everest Base Camp (EBC) trail. The same study also found that residents in higher elevation communities (including Namche) reported seeing unprecedented levels of insect activity in recent years. In a recent community survey (Byers and Thakali 2016), fewer reported having noticed crop failure, forest fire, or reduced forage in pasture, which is consistent with the above-reported results.

When asked how they have dealt with the impacts of climate change on farming, respondents indicated having adopted a variety of strategies. Of the 208 who had farms, 97% indicated to have performed at least 1 action, whereas 37% reported performing more than 3. As shown in Fig. 5, the most commonly reported actions were applying more fertilizer (58%), buying from others (52%), and accessing SNP/buffer zone forests to collect products (39%). A modest number also reported applying more insecticides (29%), reducing cattle herd size (27%), and changing crop

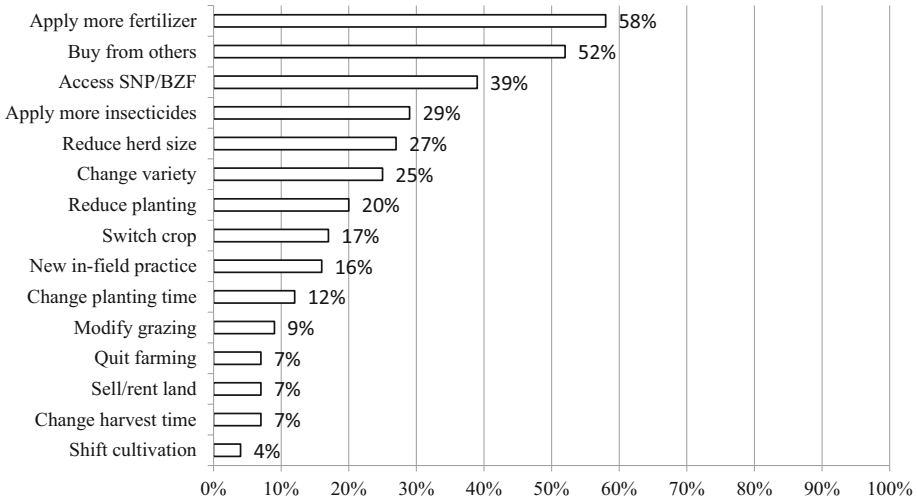

Fig. 5 Percentage of respondents that have taken alternative actions to cope with climate change impacts on farming ($N = 208$)

varieties (25%). Interestingly, a small but significant proportion indicated switching crops (17%) or changing planting time (12%). Very few (4%) reported shifting their cultivation practice, a major problem in other parts of the Himalayas, or quitting farming altogether (7%) in response to climate change impacts. A study of Midwestern farmers (Mase et al. 2017) found that while a majority of farmers (> 60%) were implementing in-field conservation practices or purchasing crop insurance to mitigate loss due to climate impact, some were intensifying current operations by applying more fertilizer (20%) or diversifying production through the adoption of difference crops (10%). A small portion (7%) reported selling or renting the property, whereas another 2% reported quitting farming altogether. The study by Elum et al. (2017) also found that over half of the farmers surveyed in South Africa reported applying integrated pest management, planting drought tolerant varieties, and relocating crops. Nevertheless, our findings regarding perceived climate impacts on farming systems are in line with the limited evidence scientists have established on climate change phenomenon in the region (Shrestha et al. 2012) and conclusions on the agronomic impact of climate change (Shrestha et al. 2019). As a recently conducted systematic review of over 170 adaptation studies attested, the farmers in mountain agroecosystems worldwide are taking adaptive actions in response to what they locally experience as climatic impact and lack proper guidance in adopting formal adaptation plans (McDowell et al. 2019).

Respondent segments

Results from *k*-means clustering showed that classifying the sample into three segments provided clearly distinguishable segment of respondents based on their climate change beliefs (Table 1). Segments were significantly different in terms of their mean response to all seven belief statements. Segments were given appropriate descriptive labels after a relative comparison of mean scores for belief statements (Appendix S2). Specifically, the first segment was labeled "Cautious" because respondents in this segment generally agreed that weather patterns are becoming

Table 1 Mean response of respondent segments according to their beliefs regarding climate change and perceived risk in Mt. Everest region ($N = 279$)

Belief statement	Segments		
	Cautious (20%)	Disengaged (17%)	Alarmed (51%)
There have been more extreme weather events recently***	2	2	3
Weather conditions in the region have been less reliable over the years***	3	2	3
Weather patterns in the region will be less reliable in future***	3	2	3
Talks of changing weather pattern are exaggerated***	3	1	2
Changing weather patterns are hurting my farms/pastures***	2	1	3
Changing weather patterns will make my living conditions worse***	2	2	3
Changing weather patterns will cause more floods and landslides***	2	2	3

1 Disagree, *2* neutral, *3* agree

***, ** and * indicate significance of difference between clusters as determined by two–tailed test at 1%, 5%, and 10% respectively

Table 2 Socio-demographic characteristics of respondent clusters

Characteristics	Segments		
	Cautious (%)	Disengaged (%)	Alarmed (%)
Male**	35	58	55
Native (i.e. born in the region)	86	74	74
Young (below 29 years)*	21	22	27
Adult (30–58 years)*	70	51	57
Senior (59 years and more)*	9	27	16
Education below high school)	100	100	95
Hotel occupation	49	43	56

***, ** and * indicate significance of difference between clusters as determined by two–tailed test at 1%, 5%, and 10% respectively

less reliable and will continue being so in future, but they also had a tendency to agree that ongoing talks of changing weather patterns are exaggerated. Even though they did not have a strong opinion regarding climate change impact, they acknowledged perceiving changing weather conditions and expressed caution regarding its future. This segment represented about 20% of total respondents. The famous "Six Americas of Climate Change" study also found that 16% of Americans held similar attitudes regarding climate change (Goldberg et al. 2020), and a related internet panel study in the Netherlands found 30% of the sample to be in this category (Wonneberger et al. 2020).

The second segment, which made up 17% of the respondents, was labeled "Disengaged" because they had no clear indication regarding any of the belief statements. A similar study segmenting dairy farmers on similar scales of climate attitudes in the United States found 23% of the sample to be in this category (Barnes and Toma 2012), whereas the Netherlands study found 26% of the sample to have similar attitudes (Wonneberger et al. 2020). Also, the Six Americas study cited above found 7% of the American population to belong in this category. However, another 10% of the sample was also described as "doubtful."

Finally, the third segment from the cluster analysis result was named "Alarmed" because the respondents not only overwhelmingly agreed with most belief statements, but also believed that climate change talks are warranted. This segment made up the largest (51%) portion of total respondents. Wonneberger et al. (2020) found 16% of respondents in the Netherlands study to have similar beliefs. The Goldberg et al. (2020) study in the United States classified 28% of the sample as "Alarmed" or "Concerned." The fact that half of the respondents in our sample are in this category shows that concern is comparatively higher in these high-altitude villages compared to other places around the world.

Despite their differences in climate change beliefs, respondent segments did not differ much in terms of their demographics (Table 2). Notably, compared to the other two segments, the Cautious segment included a significantly lower proportion of males. In terms of age cohorts, the Alarmed segment contained a significantly higher proportion of younger cohorts (below 29 years), the Cautious segment included a significantly higher proportion of adult cohorts (30–58 years), and the Disengaged segment contained a significantly higher proportion of senior cohorts (59 years or more). No statistical differences were observed in terms of their native (born in the region) vs. migrant status, education level, or occupation in the hotel business. This is not surprising considering that almost everyone in the region has less than a high school level of formal education, and a fair proportion of the residents are to some extent associated with hotel-related businesses to serve the region's tourism industry.

Table 3 Respondent personal experience of change in regional climatic conditions since they started living in the Khumbu

Conditions	Segments								
	Cautious			Disengaged			Alarmed		
	Decreasing (%)	No change (%)	Increasing (%)	Decreasing (%)	No change (%)	Increasing (%)	Decreasing (%)	No change (%)	Increasing (%)
Snowfall frequency**	84	14	2	84	13	4	78	9	13
Snow intensity	83	14	3	84	11	5	73	23	4
Rainfall frequency**	68	16	16	67	18	15	48	21	31
Rain intensity**	66	16	18	67	18	15	46	32	22
Temperature	10	21	70	11	20	69	13	15	73
Drought	5	18	78	9	20	71	4	16	79
Winter length**	33	40	27	20	46	34	36	50	14
Windy days	18	54	29	9	67	24	9	59	32

***, ** and * indicate significance of difference between clusters as determined by two–tailed test at 1%, 5%, and 10% respectively

Table 4 Reported sources of climate information by respondent clusters

Sources	Segments		
	Cautious (%)	Disengaged (%)	Alarmed (%)
Media (radio/TV)	76	78	87
Own experience	54	35	50
Friends	35	35	28
School teachers***	10	6	24
Tourists	11	18	15
NGOs/project staff***	2	6	13
Government staffs	11	4	6

***, ** and * indicate significance of difference between clusters as determined by two–tailed test at 1%, 5%, and 10% respectively

In terms of their personal experiences of changing climatic conditions during their time in the region, respondent segments showed striking similarity in most measures (Table 3). Despite their differences in climate beliefs, the segments did not report to have perceived differences in the way climate conditions have changed. The only exceptions were snowfall frequency, frequency and intensity of rainfall, and the length of winter seasons. Compared to other segments, a significantly higher proportion of the Alarmed segment reported to have experienced a decrease in snowfall frequency since they started living in the region. Similarly, a higher proportion in this segment also reported an increase in both the frequency and intensity of rainfall. Compared to the Disengaged, significantly more in the Cautious and Alarmed segments reported to have observed the length of the winter season decreasing over the years. These observations are in line with findings observed elsewhere concluding that residents' perception of climate risk significantly relates to their own experience (Sund et al. 2015; Ngo et al. 2019).

Notable variation was observed between respondent segments in terms of their external sources of climate-related information (Table 4). For example, a significantly higher proportion of the Alarmed segment indicated receiving their climate-related knowledge from school teachers and NGO/project staff. A recent study conducted in nearby villages, albeit at lower elevation, concluded that local residents receive their climate knowledge mostly from NGOs (Sherpa 2014). In Nepal, many local or non-local NGOs operate their externally funded projects on a temporary basis, and local residents often interchangeably use these two terms (i.e. NGO and Project) to refer to non-government entities that work at the community level to implement externally funded programs. Of all the sources mentioned here, schoolteachers and NGO or project staff are generally highly regarded and trusted for their academic and professional reputation in local communities. Taken together, the fact that those receiving information from these two sources are significantly more alarmed than the other groups is not surprising. Unlike in western

Table 5 Comparisons of respondent segments regarding psychological constructs describing protection motivation

Statements	Segments								
	Cautious			Disengaged			Alarmed		
	Disagree (%)	Neutral (%)	Agree (%)	Disagree (%)	Neutral (%)	Agree (%)	Disagree (%)	Neutral (%)	Agree (%)
^{S}Unreliable weather conditions are a serious issue for my area***	25	10	65	33	25	42	13	3	85
^{V}I will likely experience negative impacts of climate change in my lifetime***	20	15	65	29	11	60	11	6	83
^{V}My children will likely experience negative impacts of climate change in their lifetime***	18	18	64	23	22	55	7	8	85
^{RE}If I help conserve forests and environment now, it will help minimize impacts of extreme weather***	18	16	66	11	15	74	8	11	81
^{SE}I am confident I can contribute in conserving forests if I wanted**	27	23	50	20	16	64	15	12	73
^{RC}For me, doing anything to mitigate climate change takes too much of time and money	8	19	73	9	15	76	6	21	73
^{RC}I don't know how to protect myself from negative effects of extreme weather conditions***	26	32	42	29	9	62	27	42	31

S, V, RE, SE, RC respectively refers to the corresponding scales used in measuring Severity, Vulnerability, Response Efficacy, Self-efficacy, and Response Cost

***, ** and * indicate significance of difference between clusters as determined by two–tailed test at 1%, 5%, and 10% respectively

societies, rural areas in the Himalayas do not have the presence of ideologically aliened media programming (e.g. talk shows, opinion panels), and may not have a significant impact on how people form their climate attitudes.

Inter-segment difference in protection motivation constructs

Respondent segments were found to have significantly different responses to items of psychological constructs related to protection motivation (Table 5). The proportion that agreed that climate change is an issue for the region was highest for the Alarmed segment followed by Cautious. In other words, the perceived severity was consistent with the level of concern. A similar pattern in responses was observed in vulnerability items, as a higher proportion of the Alarmed and Cautious segments agreed that climate change will have a negative impact during their own and children's' lifetimes.

Similarly, a higher proportion of the Alarmed segment indicated that their immediate effort to conserve forests could have long-term impacts on mitigating climate risk. Interestingly, compared to Cautious, a higher proportion of the Disengaged agreed with the statements corresponding to response efficacy and self-efficacy. An intuitive explanation for this observation is that both statements are related to contributing to forest conservation, which may bring other co-benefits to communities that still heavily depend on forest products for firewood, fiber, fodder etc. Despite their activism in forest conservation for broader place-based benefits, not everyone may see its relationship to mitigating climate risk, an issue often viewed as global phenomenon. Regarding the statements of response costs, there was no significant difference between the segments in terms of their perception of time and money required to help mitigate climate change. However, they did differ significantly in their perceived ability to protect themselves from the negative effects of extreme weather conditions. In particular, a significantly higher proportion of respondents in the Disengaged and Cautious segments compared to those in the Alarmed segment agreed that they do not know how to protect themselves.

CONCLUSIONS

Findings from this study uniquely contribute to human dimensions of climate change as it differs from earlier studies in many aspects. First, it focused on understanding the perspectives of residents in one of the highest human-inhabited landscapes in the world, which is believed to have higher exposure and sensitivity to climate change and possess less adaptive resources. Second, moving beyond just assessing perceptions and attitudes, it offers new insights on how farmers perceive the impacts of climate change and respond with adaptive measures to cope. Third, it identifies typologies of residents based on their climate beliefs and compares and contrasts resident segments regarding their demographics, personal experience of climate change, and protection motivation.

Findings have several implications in understanding public perceptions of climate change and for designing outreach and communication to strengthen community readiness in Khumbu and other similar regions worldwide. First, respondents in general agreed that they have personally experienced temporal change in climatic conditions in terms of unreliable and unstable weather patterns. This evidence of human perception corroborates the recorded climatic data presented in recent assessments of the region's climate (Wester et al. 2019), and our findings help fill the gap between what climatic data shows and how humans perceive climate change. As it is often said "seeing is believing:" personal experience of changing climatic conditions have led local residents to develop beliefs regarding its risk and impact. Unlike the existing notion in human dimensions of climate change that public beliefs are largely influenced by mass media rather than experience, our study finds evidence that climate beliefs are also influenced by their own personal experience of regional climatic conditions as well as information obtained from socially credible external sources such as teachers and NGOs staff rather than mass media.

Second, respondents also linked their knowledge and personal experience of climate change with specific impacts they have witnessed in farming systems over the years. If the causality is established in this relationship, farm service agencies may need to design and implement programs to help farmers adopt climate-resistant crops or practices so the region's subsistence farming can be sustained. Respondents also noted that because of changing climatic conditions, nontraditional crops that previously could not be grown in the region are becoming feasible. This perhaps indicates an opportunity for growing alternative produce that can thrive in changing climates. Although investigating any direct relationship in production processes was not within the scope of this study, a high number of incidents concerning rapid changes in weather patterns warrants deeper agronomic investigation into how specific changes in climate patterns impact the feasibility of new crops in areas like Khumbu. Identifying crops that are compatible with the native ecosystem and climate-resistant may open up opportunity to mitigate food security issues in mountain communities that depend on subsistence farming.

On the other hand, farmers' adaptive response to climate impact with the planting of new crops could have undesired

consequences in fragile mountain ecosystems. This is because new crops may possess the risk of possible invasion in mountain ecosystems like Khumbu, which are highly regarded for their conservation value. Further, while structural change in traditional farming practices was a not major concern in Khumbu, farmers intensifying farming operations with the application of fertilizers and pesticides could have long-term impacts on the health of this fragile mountain agroecosystem. Yet another alarming note from a conservation viewpoint is that almost half of the respondents reported to have increased their access to national park and protected buffer zone forest areas for forage, food (e.g. non-timber forest products), fodder etc. Since these forests are protected for their pristine biodiversity and wildlife habitat, access by the public for harvesting purposes is illegal and detrimental to the ecosystems therein. This indicates that a continuous impact of climate change on farms in the region may gradually lead to a spillover effect on nearby protected lands causing irreversible damage to the ecosystems. Government and non-government agencies working on park management may see benefit in taking preemptive action through education, outreach, and even law enforcement to mitigate potential human pressure inside the national park and buffer zone forests. All of this evidence suggests that the regions facing climate impact on farming and livelihoods require developing a systematic adaptation plan to avoid impacts on social and natural systems. As McDowell et al. (2019) reported, adaptive action taken by mountain farmers across the world lack proper guidance or adaptation plans. Hence, government institutions interested in sustaining farming systems in Khumbu and similar regions have an important role to play in helping communities develop science-based adaptation plans that meet local needs and challenges.

Third, findings from our segmentation analysis revealed that even though a large portion of residents are alarmed, there still are segments of the population that are either not entirely accepting the occurrence of or appreciating threats from climate change to their community, or are totally disengaged from conversations on the topic. The fact that half of the respondents are cautious or disengaged suggests there is a critical need for outreach on climate education in the region. Further, observed differences between segments in terms of their own experience of change in climatic conditions and their external sources of climate information lends support to the notion that climate change risk perception is shaped by personal experience. Climate education campaigns interested in broader climate awareness programs may see benefit in helping residents connect their own experience of climate change with the risk and possible consequences of long-term changes to local conditions.

Finally, the segments of various levels of risk perception were found to exhibit different protection motivations. Compared to those that are currently disengaged from climate conversation or appear to be cautious, alarmed residents not only revealed a higher perception of the severity of climate change and vulnerability to climate risk, but also expressed higher self-efficacy and lower response cost. Taken together, these findings suggest that personal experience and access to informed external sources for climate information leads to higher risk perception, which in turn may help improve their understanding of vulnerability and response efficacy and also bolster their confidence when taking mitigation actions. According to theories of human behavior (e.g. theory of planned behavior, Ajzen 1988), individuals with positive beliefs who intend to take action for risk mitigation could be persuaded to take behavioral actions. One limitation to be noted in our findings is that perception of response cost was relatively high across the segments, suggesting that the lack of resources (time and money) required for mitigation action could be a significant barrier. This may only be alleviated with proper outreach and education to help communities engage in joint projects that can reduce participation cost (i.e. time, financial resource needed) to individual households. The key lessons learned from this case study can assist other vulnerable communities in understanding perception–attitude relationship among residents and developing climate readiness programs (e.g. education, outreach, adaptive strategies).

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