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Exploring Community Perceptions Through Parallel Analysis in Rural Himalaya

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Human dimensions of climate change (HDCC) research overwhelmingly presents community perspectives on climate change and its impacts through single epistemic frameworks. This limits the possible platforms that community voices can access within scientific scholarship. Many HDCC interdisciplinary collaborations pursue the goal of data triangulation and attempt to address complex social–ecological problems through analytical integration. This raises questions about the comparative validity of different epistemologies and often leads to unequal power sharing between the different disciplinary practitioners. Our research addresses both of these issues by operationalizing a plural epistemological framework that depends on parallel analysis. This framework consists of a quantitative approach, inspired by hazards theory and land-change science research, and a qualitative approach, from political ecology. We explored perceptions of climate change in rural households in Uttarakhand in the Indian Himalayan region. While the results reveal a high awareness of climate change within the community, most individuals and households do not consider the impacts of climate change to be a significant worry. The results for each approach complement each other. They provide the community with more than one platform to voice their experiences and reveal the complex relationships producing climate change knowledge in the region. Future research should attempt such parallel analysis in other locations to validate its utility in addressing issues of equity and marginalization between research epistemologies, as well as between experts and local communities.

Keywords: *Climate change, community perceptions, epistemologies, Himalayas, political ecology, Uttarakhand.*

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Introduction

Knowledge of climate and climate change has been constructed through various methodologies (Murphy 2011). In recent years, some approaches have attempted to incorporate nonexpert community perspectives into the analysis (Becken et al 2013; Joshi et al 2013; Finnis et al 2015). However, community perspectives have been overwhelmingly marginalized in the production of climate knowledge (Jasanoff 2010). Additionally, physical science dominates the more interpretive social science approaches (Murphy 2011). There is growing interest in considering a plurality of ways of "knowing" the climate. This acknowledges the different conclusions that emerge from different epistemologies (the way we understand the world) (Brace and Geoghegan 2011; Burnham et al 2016; Nightingale 2016; Popke 2016). However, such efforts are a minority in human dimensions of climate change (HDCC) research, where transdisciplinarity is often superficially integrated (Carr and Owusu-Daaku 2016; Fernández-Llamazares et al 2017). Different epistemologies of HDCC research explore differing material realities. Thus, severing analytical techniques from their ideological roots can be functionally unproductive (Yeh 2016).

Background and goals

The construction of a reflexive and democratic research method requires rethinking traditional notions of transdisciplinarity, based on data validation and

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triangulation, and a shift to addressing different partial dimensions of the whole research problem. This movement away from resolution of epistemological differences broadens the field by refusing to privilege some to the exclusion of others (Nightingale 2016; Yeh 2016). Additionally, it provides multiple avenues of negotiation between experts and communities, beyond the commonplace practice of transforming embodied personal experiences into bounded "observations" to be statistically verified for significance (Cote and Nightingale 2012; Fernández-Llamazares et al 2017). Ultimately, it brings the ideological assumptions about "social" and "ecological" processes underlying the different epistemologies together to construct an analytical framework that supports a range of methodological combinations (Ahlborg and Nightingale 2012; Yeh et al 2017).

Our aim was to operationalize such a method through *parallel analysis*. We followed the analytical trajectories of different routes of climate change knowledge production; and after the analysis we interrogated their points of convergence and divergence. We visualized a plural epistemological framework, where individual approaches were not held accountable to each other's philosophical traditions, but remained honest to their own assumptions and biases. We argue that this addresses 2 issues: First, it allows HDCC research to be transdisciplinary, addressing interepistemological concerns of power inequalities (Murphy 2011). Second, it provides the community with more than one platform of expression. The growing body of work on this issue inspires us (Goldman et al 2016; Abegunde 2017; Satyal et al 2017). However, much of the analytical methodology utilized in these works does not integrate the final conclusions of the different epistemic pathways (Boissière et al 2013; Ford et al 2013), remaining discursive (Stone-Jovicich 2015). Our parallel analysis focused on this, exploring issues of equity, representation, and validity in the production of knowledge.

We used 2 analytical starting points. The first was a theoretical quantitative framework rooted in climate science and natural hazards research. It was based on a literature review of biophysical climate change impacts, instrumental surveys, and statistical analysis (Wisener et al 2003; Turner and Robbins 2008). The second was a qualitative framework that draws on political ecology and uses ethnographic fieldwork and discourse/grounded analysis (Castree and Braun 2001; Nightingale 2016). This methodology was applied to a case study from the Indian Himalayan region.

The Himalayan case study

Global climate change is predicted to have significant impacts on land use, livelihood security, and overall stability of social–ecological systems in the Himalayan region (Schild 2008; Chaudhary and Bawa 2011; Hartmann and Buchanan 2014). As for other mountainous regions, HDCC research has recently expanded in the area, leading to a plethora of terminologies and constructs (Kelkar et al 2008; Sharma et al 2009; Gentle and Maraseni 2012; Pandey and Jha 2012; Ford et al 2013; Hoy et al 2016; Pandey et al 2017; You et al 2017). However, the lack of groundtruthing of model data, the scalar bias of nonregional simulations, and the diversity of biocultural terrain that such studies seek to represent have been questioned (Hewitt and Mehta 2012; Singh and Thadani 2015). Additionally, impact assessments have failed to incorporate community perceptions of their utility (Cote and Nightingale 2012). Our project aimed to address these issues within the processes of regional knowledge production.

Our analytical goal was to understand holistic precarity within small farmer households situated at intersections of climate change, land-use change, and sociocultural change (Chakraborty et al 2019). The household experience and engagement with such changes provide insight into lived realities versus scientific discourse/analysis. We specifically explored how rural households in the region view climate change (awareness) and whether they are concerned about it (worry). Our concepts of awareness and worry are rooted in "knowledge as embodied practice" (Yeh 2016: 36). Thus, the daily encounter between humans and their environment and the subsequent perception of changes are regarded as valid observations (Goldman et al 2018). The form in which such observations have been used for analysis was inspired by specific methodologies.

Given this, our research questions were:

1. What does a parallel analysis using different methodological approaches reveal about community perspectives of climate change (awareness and worry) in rural Uttarakhand?
2. What do these revelations convey about the limitations of each approach, and can they be used to inform a more inclusive and equitable regional research agenda for HDCC?

Study site: Uttarakhand, India

The empirical information, coproduced with the community, came from 4 villages in the Indian Himalayan state of Uttarakhand. Villages here are social entities and the outcome of multilocal processes and networks; as such, they vary (Mines and Yazgi 2010). This diversity allows the social and ecological particularities that represent local realities to emerge in the analysis. The 4 villages, Ghargaon, Mana, Inari, and Kamu (names changed in accordance with Institutional Review Board rules), are in the eastern sociocultural region of the state (Kumaon), in the lesser Himalaya (1200–3000 m). They

differ in their connectivity to industrial markets, infrastructure access, livelihood spectrum, administrative realities, agrarian practices, and ecological characteristics.

The state has a heterogeneous topographic, climatic, and cultural terrain. Most of its 10.11 million inhabitants live in about 16,000 villages (World Bank 2012). About 70% of the regional population is dependent on agriculture, mainly subsistence (Negi et al 2009). Regional agriculture is characterized by small farm plots, often on steep gradients with river-valley and ridge-top agroclimates, with little mechanization and consolidation (Guha 2000; Goodman 2017). Additionally, agricultural production is highly gendered, with women taking primary responsibility, while men migrate to work in the armed forces, industrial manufacturing units, and the service industry (Jain 2010; Mamgain and Reddy 2016). In recent years, investments in industrial development, catalyzed by favorable business policies, have been significant, particularly in hydropower and manufacturing (Roy 2008; World Bank 2012). This rapid industrialization has seen a simultaneous decline in agriculture as part of the total gross domestic product (Tomozawa 2014). The state has extensive forestlands, managed by national, state, and local institutions (Singh 2013). The forests surrounding most villages provide sustenance for the household, but they also increase wildlife encounters (Ogra and Badola 2008).

Data collection

Data were gathered using a mixed-methods approach and included focused literature reviews, longitudinal regional rainfall data, and ethnographic and survey data from Uttarakhand. Field data were gathered over 24 months (2012–2016). These included 4 summer stints (3 months each) and one full year (2016). Months were spent with rural families, engaging with their daily activities. These included festivals, births, deaths, travel, family meetings, religious festivals, marriages, engagement with government institutions, and agropastoral activities. We built on relationships formed over a decade of engagement with these communities. This helped us to explore some vulnerable and personal topics. We present only those opinions families wished to reveal; households were not geotagged. Therefore, very different datasets were used to operationalize the 2 different approaches.

Quantitative approach

Literature review: A (nonexhaustive) list of scholarly articles analyzing historical, current, and projected changes in specific regional climatic features was compiled. This was used in the results to contextualize and triangulate the other datasets.

Long-term climatic data: We used two separate data repositories: the Indian Meteorological Division (IMD) gridded precipitation data at 0.25° and the Global Land Data Assimilation System (GLDAS). The former was purchased by one of the coauthors from IMD, and the latter was accessed through the GIOVANNI interface and averaged over the state of Uttarakhand (Acker and Leptoukh 2007; Pai et al 2014; Rodell and Beaudoing 2015). Rainfall, a proxy for precipitation, and temperature datasets, with the results of the literature review, were used as benchmarks for the biophysical rendition of regional climate.

Field data: Of the 500 surveys administered, 200 were completed. Households were surveyed using ICIMOD's poverty and vulnerability assessment (PVA) instrument, based on the Multidimensional Poverty Indicators framework (Gerlitz et al 2014). The surveys included ecological, socioeconomic, political, and demographic aspects, and they took 30–70 minutes to complete.

Qualitative approach

Literature review: Political ecology/economy case studies were reviewed (Turner 2004; Campbell 2007; Collins 2008; Robbins 2012; Birkenholtz 2016; Carey et al 2016). An extensive archive of local/regional news, analyses, and reports was compiled and used as a framing device.

Field data: Using a feminist epistemology approach, where the community was allowed to collaborate in defining the research objectives (Caretta 2017), ethnographic data were collected through participation in oral history sessions (10), focus groups (8), village government meetings (4), forest management cooperatives (3), district development workshops (5), social media profiles (120), video/photographic diaries (10), and semistructured interviews (500) with community members, district/state bureaucrats, regional scientists, civil society workers, and commercial business owners. Families and individuals decided when they wanted to communicate with us and to what extent.

Analytical tools and process

This project used 2, epistemologically different, analytical starting points:

Quantitative approach: The theoretical roots were drawn from extensive research traditions (Birkenholtz 2011). Frameworks considered included:

- Resilience frameworks: ecological and systems concepts;
- Land-change science: resource and behavioral economics, and ecological systems in dynamic models;
- Climatology/climate change science: physical dynamics of terrestrial and atmospheric systems.

Our approach was based on the latter 2, considering statistical relationships among the model outputs, literature, and survey variables. The aim was to

understand internal processes within the change experienced in the overall climatic profile on a regional scale (Turner and Robbins 2008; Muccione et al 2016).

This framework utilized measures of statistical significance and long-term spatio-temporal trends in biophysical variables for the region. The analysis was divided into 2 steps.

- Awareness (triangulation): The literature review, analysis of the IMD and GLDAS datasets for Uttarakhand, and the community survey data ($n = 188$) were compared. We explored how knowledge about bounded climatic events in the community (awareness) related to data from the literature and the IMD and GLDAS data.
- Worries (disaggregation): An inferential multivariate statistics model (ordinary least squares, OLS) was run on the survey data to visualize autocorrelations between climate change awareness and worries and other variables (gender, age, caste, economic wellbeing, debt, etc) for the surveyed households.

Qualitative approach: This approach is rooted in more "intensive traditions" (see Sayer 1984; Birkenholtz 2011), examining the particularity of processes of power and how these processes differentially affect human communities. The goal is to offer nuanced insights into aspirations and vulnerabilities within local communities and environments (Robbins 2012; Yeh 2016). These include insights from political ecology (Forsyth 2003; Turner 2014), and science and technology studies (Whatmore 2009; Rocheleau 2016). Our qualitative approach was based on political ecology and used testimonies of individuals, groups, and institutions to identify and qualify interactions across scales among higher-order processes, such as climatic transitions and local situations. This revealed the relationships within communities and the wider processes enmeshing them.

Results of the quantitative approach

Awareness

Table 1 summarizes our literature review. We also analyzed long-term climatic data and collated the surveys.

Long-term temporal variation (rainfall/temperature) is shown in Figure 1. There are strong multidecadal epochs of wetness and dryness in annual rainfall. The amplitudes in epochal variability have increased for summer rains and declined for winter rains (Figure 1A). Figure 2 shows pixel-wise changes in 30-year averages of different rainfall characteristics over the past century. Mean annual rainfall has declined in the western and southern parts of the state; by contrast, rainfall has increased in the eastern area (Kumaon) (Figure 2A). Seasonal variability is most pronounced in winter, with a sharp recent decline (1991–2016) in the greater Himalayan (Himadri) region in the north (Figure 2B). The total numbers of rainy days per year have declined in the lower elevations (Shivaliks) and have increased in the higher elevations in the east (Figure 2C). This suggests that the total volume of rain falls on fewer days at lower elevations, resulting in intensification of rainfall in the southern and western parts of the state (data not shown here). The frequency of high-intensity events (>150 mm d^{-1}) shows a tendency towards an even spread of fewer events across Uttarakhand in the last few decades (Figure 2D).

These observations were confirmed by a trend analysis using Sen slopes (Sen 1968), which estimates the pairwise rate of change in a time series calculated pixel-wise and aggregated for $\leq 5\%$ significance. The trend for total annual rainfall and number of rainy days decreases in the lower elevations in the south and increases in the higher elevations of northern Garhwal (Figure 3E, F). Seasonally, winter rainfall and duration has declined across elevations (Figure 3A, B). In monsoon and summers, reduction in rainfall and increase in number of rainy days has led to lowering of maximum daily rainfall and large storms (maximum 5-day cumulative rainfall) (Figure 3C, D), concentrated in west and south Uttarakhand (Figure 3G, H). Incidentally, the frequency of such large storms has increased in the Upper reaches of Garhwal, which are home to the highest peaks and glaciers in Uttarakhand (Figures 3G, H).

Temperature trends obtained from GLDAS data show clear warming trends in annual and winter minima (Sen slope: trend = 1.17°C, slope = 0.02, intercept = 2.6) and winter maxima (Sen slope: trend = 0.90°C , slope = 0.01, intercept = 8.59). The trends in mean annual temperature (trend = 0.31°C, slope = 0.006, intercept = 14) and maximum daily temperature (trend = –0.19°C , slope = –0.001, intercept = 23.8) were not significant (Figure 1B).

Figure 4 illustrates responses to questions about changes observed over the last 10 years. To summarize our climate-related conclusions, there have been:

- A reduction/change in winter precipitation and increase in winter temperature;
- A slight increase in overall temperature as well as an increase in maximum and minimum temperatures; and
- Change in the intensity/occurrence of extreme/erratic (precipitation) events.

Additionally, there has been a slight increase in mean annual rainfall in the eastern region of the state. Note: All our study villages were located within this region. However, the precipitation changes noted by respondents showed divided opinions, with 8% stating an overall increase and 11% stating a decrease. This could be due to the reduction in winter precipitation being the dominant narrative, biasing their experiences, and also the increase in fluctuations in precipitation. The increase in fluctuations, and the onset of a "climate of extremes," is evident in the high percentage of erratic events observed

TABLE 1 Summary of literature review of the biophysical climatic changes over the Hindu Kush–Himalaya (HKH) mountains and the Tibetan Plateau over different time periods of the present climate. (Table continued on next page.)

Climatic change	Literature	Region	Conclusion
Temperature	You et al (2017)	HKH and Tibetan Plateau	Increase in temperature
	Ren et al (2017)	HKH	
	Sun et al (2017)		
	Zhan et al (2017)		
	GOU (2014)	Uttarakhand	
	Shrestha et al (2015)	Ganges River basin	
	Bhutiyani et al (2010)	Northwestern Himalayas	
	Bhutiyani et al (2007)		
	Dimri and Dash (2012)	Western Himalayas	
	Dash et al (2007)		
	Brohan et al (2006)		
	Diodato et al (2012)		
	Kothawale and Kumar (2005)		
Precipitation	Palazzi et al (2013)	HKH and Himalaya	Precipitation decrease in winter
	Dimri and Dash (2012)	Western Himalayas	
	You et al (2017)	HKH and Tibetan Plateau	Precipitation increase
	Ren et al (2017)	HKH	
	Sun et al (2017)		
	Zhan et al (2017)		
	Mishra (2014)	Uttarakhand	Precipitation decrease
	Basistha et al (2009)		
	Bhutiyani et al (2010)		
	Guhathakurta and Rajeevan (2008)		
Rainfall	Shrestha et al (2015)	Ganges River basin	Increase in rainfall
	Stewart (2009)	Himalayas	
	Bhutiyani et al (2010)	Northwestern Himalaya	Decrease in rainfall
	Sontakke et al (2008, 2009)	North mountainous India	
	GOU (2014)	Uttarakhand	
	Basistha et al (2009)		
	Naidu et al (2009)		
Snowfall	GOU (2014)	Uttarakhand	Decrease in snowfall
	Zhao and Moore (2006)	Himalayas and Tibetan Plateau	
	Bhutiyani et al (2010)	Northwestern Himalayas	
	Stewart (2009)	Himalayas	

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TABLE 1 Continued. (First part of Table 1 on previous page.)

Climatic change	Literature	Region	Conclusion
Extreme events	Hartmann and Buchanan (2014)	HKH	Increase in extreme precipitation
	Roy (2009)	HKH	
	Ren et al (2017)	HKH	
	Sun et al (2017)		Decrease in extreme cold events; increase in extreme warm events
	Singh and Mal (2014)	Uttarakhand	Higher variability in rainfall in all seasons

FIGURE 1 (A) Long-term spatio-temporal trends in annual and seasonal rainfall (1901–2016) from IMD data for Uttarakhand. (B) Long-term spatio-temporal trends in surface temperature plotted as annual mean, maxima, and minima using GLDAS data for Uttarakhand (1948–2010).

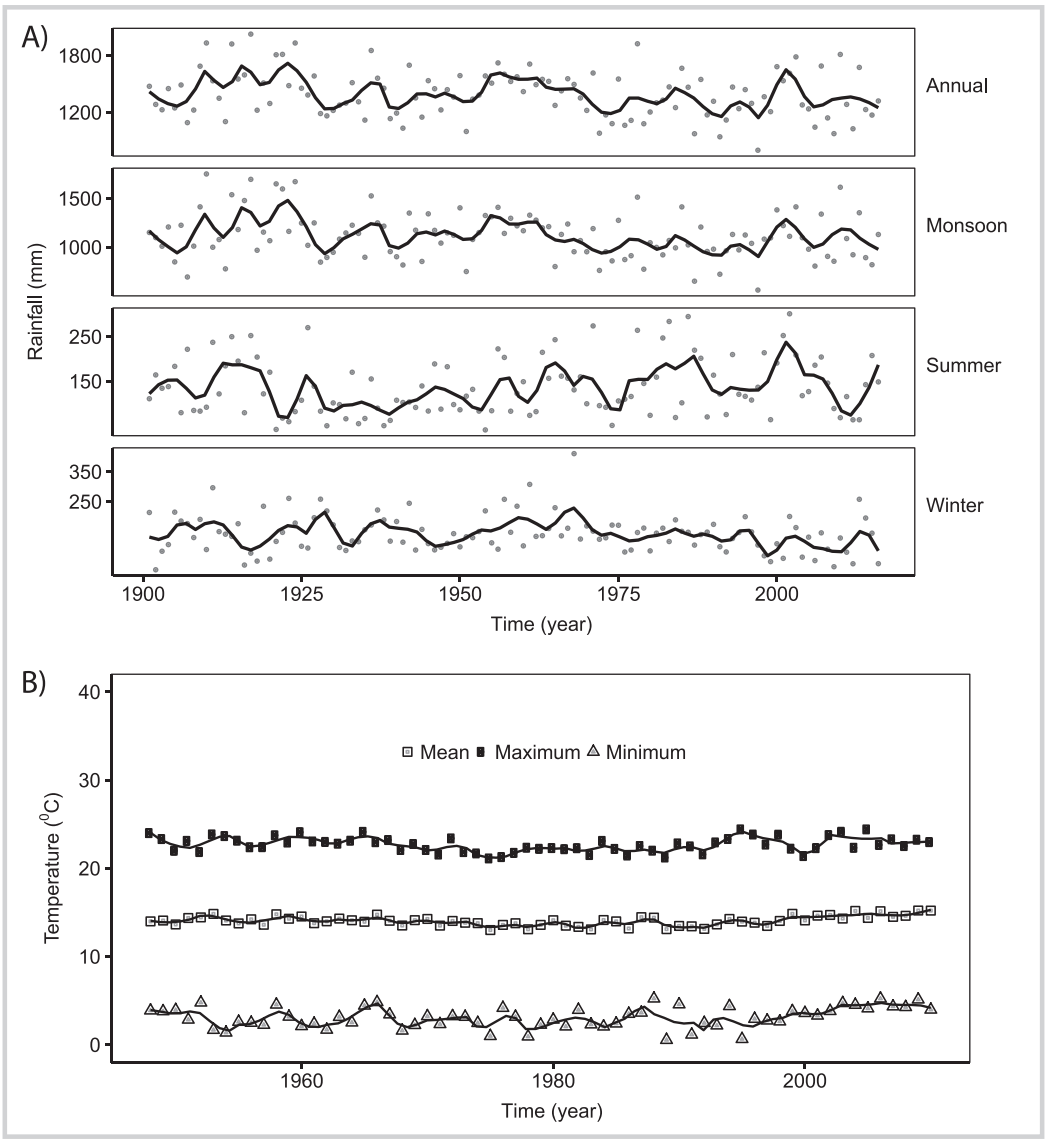

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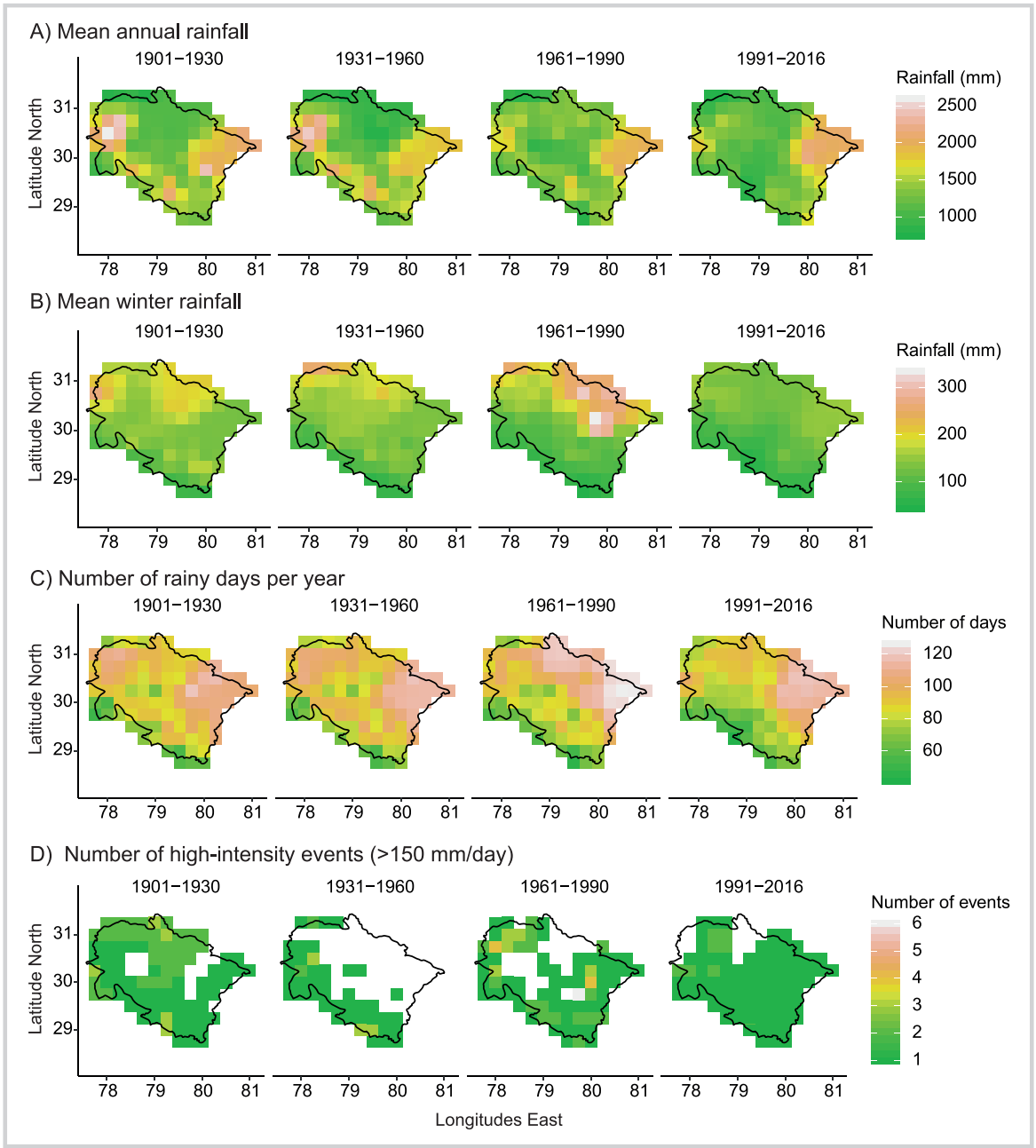
FIGURE 2 Spatial rainfall patterns at multidecadal scale (1901–2016).



by the community in Figure 4B and C. The community related these to the changing nature and quantity of winter precipitation and, to a lesser extent, to an increase in the intensity of precipitation during monsoon seasons. The climate-related conclusion of the total volume of rain falling over fewer days was corroborated by about half the survey sample (48%).

The rather strong response (67%) to "new animal species observed" (Figure 4C) does not represent an increase in the number of species; instead, it echoes increases in "pest" animals in the area and the corresponding increase in numbers of interactions with humans. The most-mentioned species are the most destructive to regional agriculture and livestock: rhesus macaques (*Macaca mulatta*), porcupines (*Hystrix indica*), wild boars (*Sus scrofa cristatus*), and leopards (*Panthera pardus fusca*).

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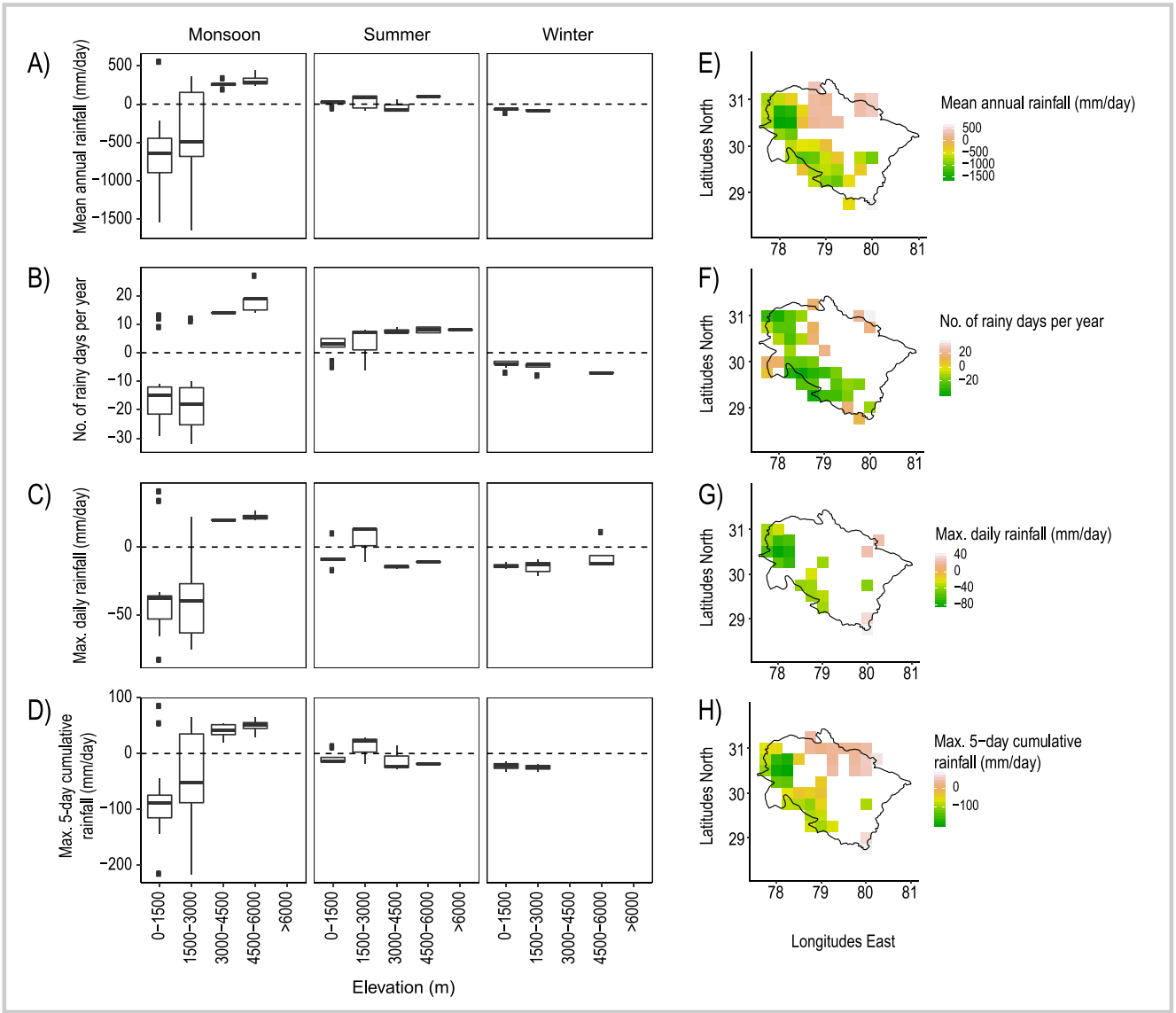
FIGURE 3 Changes in Sen slope trends in rainfall characteristics across seasons and elevations (left) and spatial patterns.



Worries

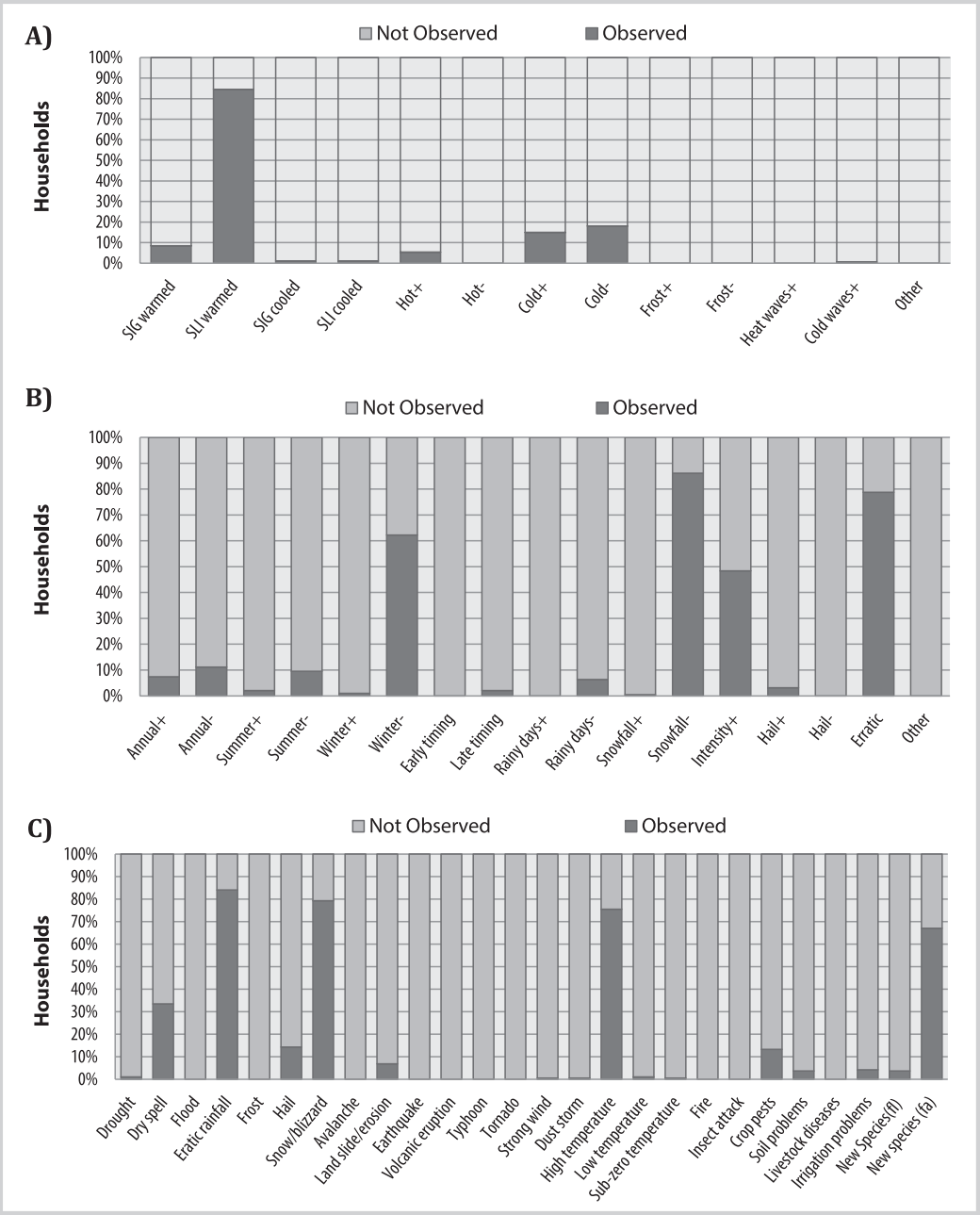
This segment consisted of 2 connected steps. Question 42.3 of the PVA survey tool (Gerlitz et al 2014) asked families to identify and rank the most important problems/shocks the household had faced in the past 12 months. These worries were tabulated to rank their significance based on number of responses. The 48 options given for local shocks/problems (worries) were drought, dry spell, flood, erratic rainfall, frost, hail, snow/blizzard, avalanche, landslide/erosion, earthquake, volcanic eruption, typhoon/hurricane, tornado, strong wind, dust storm, high temperatures, low temperatures, subzero temperatures, fire, insect attack, crop pests, lack of fertilizer/too expensive, bad seeds, soil problems, livestock disease/death, irrigation problems, labor shortage, theft, low market prices crop/livestock, poor market access, family sickness, death of family member, debt, *bandh* (strike), local conflict, national conflict, taxes, unemployment, loss of house, business failure, personal violence, intimidation, corruption, imprisonment, electricity shortage, human–wildlife encounters, divorce or separation, and other (specify).

The most important worries identified (n =188) were:

1. Other (21.80%);
2. Human–wildlife encounters (20.21%);
3. Unemployment (19.14%);
4. Corruption (12.34%).

Figure 5A ranks the number of times these shocks were mentioned by households as the most important, second

FIGURE 4 Awareness of disparate biophysical climatic variables: (A) observations of precipitation events; (B) observations of temperature events; (C) observations of unprecedented climatic/ecological events. The percentages represent the number of respondents from the total survey set of 188. Therefore, when reduction in snowfall is at 85% in graph A, 160 families observed the occurrence. (In C, the high responses to snow/blizzard represent the reduction observed and not the actual occurrence of the event.) In C, for the New Species category: fl, flora; fa, fauna.



most important, and so on. Climatic/ecological problems or shocks (other than the human–wildlife encounters) were absent from the top 4 ranks of the most critical problem/shock list; however, they are visualized in Figure 5B.

While most households were acutely aware of climatic changes and events, none of them included climatic/ecological factors in their most significant household worries. The "other" category was the overarching worry expressed by households. This can be broken down into 9 different factors: education, healthcare, roads, telecommunication, alcohol/drug addiction, extramarital affairs, inability to sell land, migration of youth, and production of cold storage units. However, the majority of this category (72%) was dominated by 4 variables: education, healthcare, roads, and telecommunication. Different combinations of these variables dominated the overall identification of worries within the household.

Among the climatic/ecological factors, the main concern was human–wildlife encounters, which respondents claimed caused 25–80% yield losses. The next largest worry was that of erratic rainfall, which was generally the third or fourth most-pressing worry.

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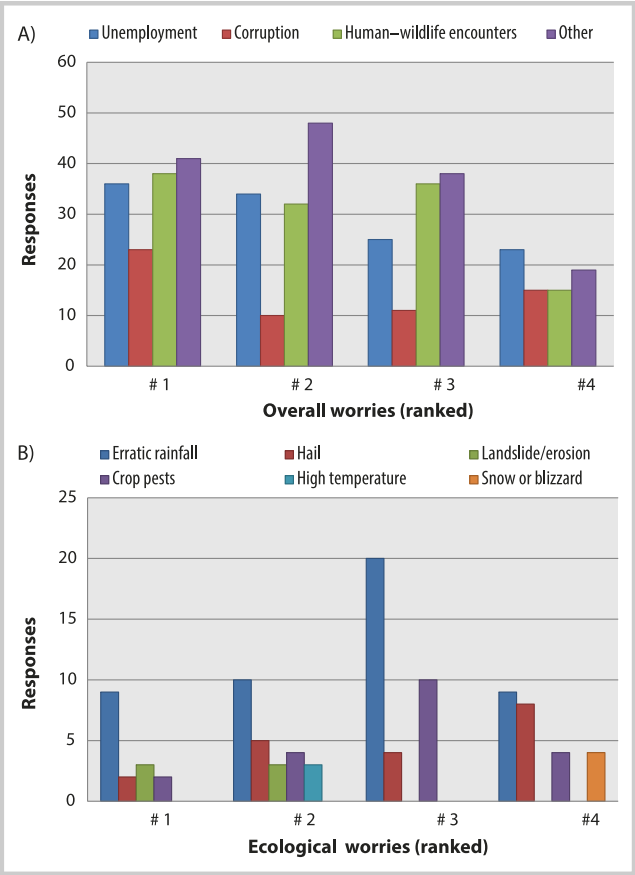
FIGURE 5 Ranked worries for households: (A) overall worries; (B) climatic/ecological worries. The households were asked to choose and rank their top 4 worries from the list provided. The "other" category represents variables that were not part of the original survey but were added in responses by the community. The snow/blizzard responses in B represent a "reduction in snow or blizzard" and not the increase in or presence of it.



Ultimately, from a list of 48 worries, across communities, the main worries congregated around the same few variables: *employment, corruption, wildlife encounters, and dissatisfaction/lack of the services of education, healthcare, roads, and communication.*

Correlations

To explore statistical relationships between the awareness of climate change impacts and worries about it, we performed a multiple regression analysis using an OLS model. The goal was to examine correlations between worries and awareness about climate change and socioeconomic variables. The category of worries was constructed by summing the 6 most-reported climatic/ecological shocks from Figure 5B across all the households. The category of awareness was constructed by summing the same 6 climatic/ecological shocks mentioned by the households (Figure 4). These were used as dependent variables, with independent variables from the PVA list of critical socioeconomic variables for the Himalayan region (Gerlitz et al 2014; Table 2).

Worries and awareness were used as dependent variables, in sequence. We attempted to run the multivariate models for individual villages, but given the lower sample sizes, the tests did not highlight any significance.

The regression analysis (Table 3) points to age being a significant factor in worries and awareness about climatic/ecological events. This highlights the worries of the older generation, especially older men, within a transitioning world (see Chakraborty 2018). Furthermore, caste seemed to display a weak negative coefficient with worries, implying that lower-caste families are more likely to fear changes in climate. Lower-caste families were a minority in the villages (11% overall), and, therefore, along with historical marginalization (see Polit 2006), they also formed a minority within the dataset. Most families with higher livelihood overdependence were clustered around 2 livelihood types (salaried/wage work and agriculture). Therefore, families that were more dependent on agriculture and local wage labor to provide livelihood security were more aware of climatic/ecological events,

TABLE 2 Variables used in statistical analysis.

Variable	Explanation
Age	Age of the survey respondent
Gender	Gender of the survey respondent
Household debt	Amount of household debt owed to various institutions/individuals
Household expenditure	Annual expenditure for the household (including medical costs, education, food, shelter, fuel, loan repayments, agricultural input costs, etc)
Caste (high)	Caste of the respondent, two possible options—high or low
Positive economic change	Positive economic change in overall household finances in the past 12 months
Negative economic change	Negative economic change in overall household finances in the past 12 months
Livelihood overdependence	If more than 50% of annual household income came from just one source, the household was categorized as overdependent
Livelihood diversity	Total number of livelihoods within the household

TABLE 3 Coefficient comparison of OLS results between awareness and worries ($n = 188$, the R^2 values are unadjusted).

Variable	Worries	Awareness
Age	66.624012***	3.222094***
Gender (male)	−0.004939	0.002864
Debt (yes)	−5.922066	0.028279
Expenditure	−3.844936	−0.151108
Agriculture	0.00102	−0.000007
Caste (high)	−0.17773***	0.005329
Positive economic change	−2.34397	0.250932
Negative economic change	9.725392**	0.918546***
Livelihood overdependence	6.871819*	1.491728***
Livelihood diversity	7.602502	−0.277394
R^2	13	19

*** Significant at 1%.
** Significant at 5%.
* Significant at 10%.

since they often had to react to daily and seasonal changes. For farmers, this meant understanding changing precipitation regimes and invasive pest management. For wage laborers, it meant the availability of local contract work. For both dependent variables, families that were experiencing economic insecurity seemed to be important, suggesting broader issues of unemployment, livelihood instability, and economic exclusion were driving climatic relationships.

Results of the qualitative approach

The intensive ethnographic data collection, its coding, and trend analysis, along with the literature review, revealed that community worries and awareness of climate change in rural Uttarakhand were connected to certain discursive and material events/processes. These are listed in Table 4.

Awareness

The events and processes identified above interacted differently in different villages to inform awareness of climate change in households.

Access and mobility: For households in villages with unreliable road and telecommunication infrastructure (Kamu and Inari), accessing state development schemes was almost impossible. However, this remoteness also meant a lack of state regulation and allowed most families to participate in the informal/illegal medicinal plant and *Cannabis indica* economy. Among the medicinal plants collected, *Cordyceps sinensis* (caterpillar fungus) was the most valuable, and, according to the community members, its collection in spring months from high-altitude pastures (>3000 m) was supported by a reduction in the winter snow and its faster melt rate. Additionally, the lack of winter snow in higher mountain passes also increased the ease of access for traders buying plants and transporting them to Nepal and the Tibetan Autonomous Region. Senior community members (>60 years) recalled that winter snow amounts between 1.6–2 m were commonplace. However, in the past 15 years, there has been less snow. Senior members validated their memories of winter snow by pointing to the present-day availability of medicinal plants in early spring (March, April), which in the past would have been unavailable due to the snow cover.

Commercial agriculture: Households in villages with significant commercial agriculture, especially horticulture, were transforming their agrarian practices most dramatically. A reduction in winter snow and erratic spring hailstorms were causing significant damage to their fruit crops—peaches, plums, apples, and apricots. Simultaneously, local nongovernmental organizations (NGOs) were supporting the construction of polyethylene greenhouses to produce supplementary vegetables to reduce household dependency on markets and bolster the nutritional value of diets. Most families had coupled the knowledge of greenhouse construction and the burgeoning market for vegetables in nearby cities, which was now accessible through newly constructed roads, and converted their subsistence operations into commercial ones. This allowed them to deal with the threats to their fruit crops—reduced winter precipitation, erratic spring hailstorms, and increasing crop pests. Most farmers identified this climatic change as it directly related to their valuable fruit trees, but they also directly related their ability to maintain greenhouses through the winter due to the reduction of snowfall. In the past, most such structures collapsed under the weight of the accumulated snow.

Kedamath floods: In all villages, most households were acutely aware of the threat from floods. They related the recent increase in this threat to climate change. However, this knowledge seemed to defy actual experiences of floods. Just 10% of the 500 individuals interviewed mentioned that their households or relatives had been adversely affected by floods; however, close to 30% of these same individuals also mentioned applying for government natural disaster relief funds. Therefore, knowledge of flash floods and their threat due to changing precipitation regimes was intrinsically tied to the availability of relief funds from the state. Despite filing claims for flood events and having in-depth knowledge of the Kedarnath flood (Table 4), *most households had never experienced such floods*. This was because much of the land in

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TABLE 4 Analysis of important processes/events from Uttarakhand.

Event	Explanation
Kedarnath floods of summer 2013	In June 2013, nearly 600 mm of rainfall fell in the Mandakani catchment over a period of 36 hours. This led to deadly and widespread flooding, lake outbursts, and landslides, which occurred near an important religious tourism site. Estimates of lives lost range from 7000–30,000 people and property loss around US$700 million (Ziegler et al 2014). While some touted this as a "natural" disaster, others pointed to the rampant dam construction that had altered the hydrology of the region. These dams, once breached, sent large amounts of construction silt, boulders, and other debris downstream; these greatly increased erosion. Additionally, significant deforestation in the highland areas for hydropower and mining had changed the absorption capacity of the hillside soils while removing constraints to runoff. Ultimately, massive road construction and urbanization had weakened hillsides while creating large population spaces within prominent floodplains and on fragile riverbanks. In short, scholars and activists claimed the rainfall event had only played a cursory role in a disaster that was produced by human modification of the landscape (Taylor 2015; Huber 2019). While our study villages were far away from the disaster site, they had to deal with significant flooding and landslide events of their own. However, there was no loss to life and very minimal loss to property. Due to the large number of people affected that season, the state government set up a compensation portal where people could file claims for loss of life or property and get financial assistance. These schemes were well publicized all over the state, and most households in our study villages knew about them (Bhatt et al 2013).
Livelihood transitions	In recent years, driven by the rapid increase in schools, colleges, and vocational training institutes, there has been a rapid surge in the number of educated youth looking for nonagrarian jobs (Government of India 2013). Additionally, catalyzed by a robust traditional medicine industry, a clandestine supply chain of medicinal plants from the high-altitude meadows has emerged (Pauls and Franz 2013). Finally, with the increase in industrial investment in the state, many new manufacturing and service operations have materialized, offering thousands of informal, low-paying, temporary jobs (PHD Chamber of Commerce 2015).
Public distribution systems	With the spread of roads and changing consumption cultures, state-subsidized grains are now the cornerstones of the diet of most families. This system has made the practice of cultivating subsistence volumes of cereal grain and lentils redundant (Nichols 2015). Most households in our study villages depend on this food supply as their major nutritional component, which they supplement with seasonal vegetables.
Disputes around forest/ pastureland	Forest and pastureland in and around many villages in Uttarakhand are contested due to competing claims by local, state, and federal agencies and individuals over their management and ownership (Agrawal 1996; Singh 2013). These disputes lead to constant surveillance of forest and pastureland to check for intruders and unprecedented land-management activities.
Development presence of nongovernmental organizations (NGO)/aid agencies	There are many NGOs and aid agencies in the rural areas of Uttarakhand. Most focus on rural development, which they claim to be a supplemental service to the state's projects (Pandey et al 2012; Nickow 2015). Many work on project-based time lines, and, therefore, their area and interventions are tied to donor time lines, which are usually short-term constructs. While the overall impact of these institutions on Uttarakhand is highly debated (Jakimow 2012), our study villages received training and funds, and some locals were employed.
Circular migration	With transforming aspirations and access to development, households in Uttarakhand often contained one or more circular migrants. These were young men moving frequently between their village and the city, for temporary labor contracts, taking care of both household responsibilities and aspirations of modernity (Koskimaki 2017; Chakraborty 2018).

river valleys had been abandoned by households due to: its distance from roads, which are usually on ridge tops; the marked reduction in rice cultivation, which requires heavy irrigation and was grown next to rivers; and the fear of landslide debris, which had greatly increased in the past decade due to road construction. Additionally, most households (75%) had stopped the practice of transhumance—seasonal migration with livestock across elevations—and, therefore, their experience of climatic events is currently limited to specific elevations. For example, in the past, a majority of families in the villages of Mana, Kamu, and Inari (92%) used to spend the winters in the river valley and ridge located at 1500–1900 m and summer/monsoon with livestock in the meadows/ forestland located at 2450–3600 m. This practice is currently restricted to only 5% of households.

Migrant subjectivities: Migration was ubiquitous in the households, and 90% of all interviewed community members claimed to have migrants in the household. Most migrants moved between the mountains and the plains with varying degrees of frequency. Their periodic absence from the village allowed them to provide a different view of climatic transformations. Furthermore, they were also exposed to climatic and land-use changes outside of the village. The migrants described the mountain communities slowly becoming more like the plains communities, with electricity, roads, schools, and markets. Furthermore, just like their version of the plains, there was also a rise in temperatures, the appearance of mosquitoes, and changes in the dependability of weather. Therefore, while many families remained rooted to their agricultural land, industrial markets and motor roads were bringing the plains to them. Additionally, due to their interaction with media and discourses in cities that included migrants from many other parts of the country, they learned about similar changes occurring elsewhere. Thus, when they returned to the villages, they would universalize the transformation that the village elders saw in the community and relate it to broader transformations in climate and agricultural livelihoods beyond Uttarakhand and the Himalayas.

Worries

Public distribution system and horticulture: In villages, climatic changes in precipitation caused little worry in relation to food production. Interviewees made this connection just 4 times out of 500. While the awareness of the result of a change in precipitation regime was high (as noted above), the actual transformation of agricultural yields was seen to be more causally related to pest/storage/transport-related damage, labor shortages, and quality of inputs (seeds, fertilizers, pesticide). Additionally, the public distribution system, which made cheap, industrially produced food grain available in most village grocery shops, had further reduced the cultivation of subsistence grains. None of the interviewees reported incidences of hunger or food insecurity. Commercial horticultural production was seen to be detrimentally impacted by locally rising temperatures, a reduction in winter snow, and erratic spring precipitation; however, greenhouse agriculture, especially focused on vegetables, was an adaptation practice that all households were transitioning toward. Despite the lower return on vegetable sales versus fruit sales, greenhouse agriculture made unpredictable weather events and pest damage much easier to control for most households.

Unpredictable futures: Diversification of livelihoods is a well-documented adaptation strategy in many rural parts of the world (Gautam and Andersen 2016; Martin and Lorenzen 2016). However, in this case, the rapid social–ecological transformation of rural Uttarakhand due to various sociopolitical factors, along with the climatic ones, made many young people wary of investing completely in any novel adaptation practice. Driven by widespread unemployment, illegal acquisition of village land by outsiders, and the dissolution of the village moral economy, the youth found it hard to trust anyone. In the past, diversification was pursued by many families, with an underlying faith in the processes that sustained legal, political, and ecological justice. However, the youth—having been relatively more exposed to urban life beyond the village—were overwhelmingly invested in short-term practices, with the understanding that the material conditions of their lives would change very soon, and they would have to change along with them. As Ramesh of Ghargaon village put it:

> *Today we are farming cabbage, tomorrow we may have to grow peas, and, who knows, maybe in a few years, we will go back to my grandfather's apple trees. I don't see this as a bad thing. Unlike our ancestors, we don't stick to a certain crop regime, or even livelihood regime. This uncertainty in the environment has forced us to experiment and be prepared for anything.*

Here, Ramesh refers to the "environment" not just as a biophysical entity, but also as a sociocultural one. Therefore, effects of climatic change were understood as one of the many dynamic processes affecting their lives. Given their short-term focus on the material needs of the household and for personal wellbeing, their aspirations for the future were few. They believed the future to be highly unpredictable, compared to the social, cultural, and ecological predictability of the previous generations (see Smith 2013). *Therefore, devoid of this trust in the benevolence of the larger socioecological systems around them, the youth appeared to be actually more fearful of the impacts of climate change than the elders.*

When asked why the impacts of climatic change did not worry them relative to other mentioned factors, answers coalesced around 3 arguments. First, over half of the respondents (265/500) relegated the climate and ecological systems to a realm that was beyond the management of people and communities like to them. While they believed that "more powerful" entities, such as national governments or large corporations, could have an impact on the climate, such actions were beyond the purview of rural Himalayan farmers. They chose to focus their actions on worries that they could address. In this sense, the physical climate was inseparable from their religious and mythological renditions of it, which defined climatic realities as a manifestation of the whims of different sacred deities (see Gergan 2017). However, there was a marked difference in the faith in such "supernatural" explanations between older generations without a formal education and educated younger people. The youth were often more worried about natural disasters, having more access to media that regularly

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highlights the human cost and unpreparedness of regional institutions to deal with such events.

Culture of agriculture: Most respondents (452/500) saw agriculture as a dying tradition in their community/household. None of the senior respondents interviewed wanted their children to be farmers. With the spread of formal schooling, temporary manufacturing, and service industry labor, and the increasing monetization of daily life, subsistence security-driven food production was seen as inadequate. Additionally, the growing incidence of commercial horticulture was often being pursued in the climate-controlled environments of the greenhouses. Potentially negative climatic effects on field crops were mitigated through crop insurance schemes, state-subsidized inputs, and cross-breeding. However, according to most respondents (490/500), while animal pests—monkeys, wild boars, porcupines, and bears—caused the greatest damage to fields, their populations and behavior were mediated through state laws, representatives, and management. This included the transport of feral animals from cities to rural Himalayan areas, the corrupt forest rangers that deforested and sold trees from government-owned forests, and strict fines tied to hunting. Therefore, the problem was not the wildlife encounters, but essentially a loss of community control over the management of local natural resources and mismanagement of such resources by the state guardians.

Corruption and institutional mismanagement: Many respondents (473/500) related the increased occurrence of events such as floods, landslides, forest fires, and invasive species to political corruption and management failure. While most agreed that the changing climate was impacting such events, they saw the major cause as being local and national governmental mishandling and neglect of development in the region. As Sita Devi, a 67-year-old female farmer from Kamu village, said:

> *In this country, the lives of mountain people are very cheap. The lives of farmers are very cheap. We are both. The politicians, the scientists, the administrators, treat us like pawns in their powerful games, and when they screw up and there is a disaster, they blame everyone and everything but themselves.*

While most respondents had heard of and even experienced the Kedarnath floods, massive forest fires in the region, and landslides during the monsoon season, they overwhelmingly blamed illegal deforestation, dynamite blasting used for road construction, and overcrowded tourism sites that ignored safe building practices and the biophysical characteristics of the land. Despite concerns about corruption and the material impacts, produced in conjunction with regional climate change, very few individuals saw migration as a long-term adaptation practice (3/500). This worldview was influenced by circular migrants that disseminated stories and experiences of the pollution, overpopulation, heat, and virulent corruption in the cities. Thus, in spite of their feelings of abandonment and exploitation by public officials and services, most locals preferred to retain their homes in the villages (see Korzenevica and Agergaard 2017; Koskimaki 2017).

Discussion

The parallel analysis, incorporating 2 approaches, leads to significant disciplinary-situated insights about regional climate knowledge. Here, we consider these with the goal of analyzing how the results of each approach converge with or diverge from the other. We explore how such a methodological exercise informs our understanding of community perceptions of regional climate change. The parallel analysis emerges as significant in 2 ways.

Supplementary conclusions

The results generated from both approaches irrespective of whether they seem to converge or diverge enhance our understanding of the other. A major impetus of HDCC research is pursuing complementary resolutions to mixed-methods research (Weatherhead et al 2010; Manandhar et al 2011; Fernández-Llamazares et al 2017). However, by maintaining the epistemic integrity of each method and addressing the inherently different goals of analysis, the conclusions of each approach provide contextual scaffolding for the other.

When the results converge: The climate is changing and has changed in the past decade: Both the quantitative approach and the qualitative approach identified the specific climatic parameters that appear to have transformed: winter precipitation, erratic and intense rainfall events, and temperature. However, the triangulation done through our IMD data analysis revealed that the responses of community members, though limited by certain scalar and temporal factors, reflect the broader changes in the region (Kwan and Schwanen 2009). The location of the villages at higher elevations on the eastern edge of the state provides a caveat to the overall experience of climate change. This allows the community experience to find validation at more than just the household or individual scale (Vincent 2007; Ahlborg and Nightingale 2012). Correspondingly, the awareness of erratic rainfall events, which emerged prominently in the quantitative approach, is situated within the politics of disaster relief and the socioeconomic valuation of particular socioecological experiences (floods) over others (reduction in winter snow). Thus, the awareness of climatic changes is produced by more than just the biophysical experience of the actual event (Goldman et al 2016), and often even in the absence of material experience. Instead of challenging the validity of community perceptions of knowledge, this fact reveals the myriad intersectional engagements with the spectrum of processes, both human and nonhuman,

that together shape the experience of climate change (Nguyen et al 2016; Vedwan 2006). Furthermore, it challenges the framing of community knowledge as temporally/spatially static and existing in relative isolation (Goldman et al 2018).

When the results diverge: Generationally biased worries about the impacts of climate change and narratives of human–wildlife encounters: While the quantitative analysis assigned an age-based significance relationship to worries about climate change, the qualitative analysis apparently countered this insight, finding the youth more fearful about the impacts of climate change. However, eschewing the need for evaluation based on triangulation and instead following the parallel analysis, we posit that both these insights are true, albeit with caveats.

One of the reasons why older members of the community appear to be more worried in the statistical analysis is their relationship with state scientists and planners. Younger community members mistrust survey-based data gathering, given their similarity to census operations and NGO work, about which they have very ambivalent feelings (see Gergan 2014; Smith and Gergan 2015). The older members that grew up with more faith in the public bureaucracy versus private institutions, often due to the ubiquity of the former, responded to survey instruments with a sense of despair. This despair, according to their children, is a performative tool used to access development aid from the state. Another reason could be the insecurity that many older respondents feel in what they see as a rapid and vast transformation of their agrarian lifeworlds (Smith 2013). They ascribed this to the incursion of the state/private institutions through industrial investment, telecommunication infrastructure, formal schooling, and availability of cheap mass-produced goods, along with changes in sociocultural institutions and ultimately climate change. Thus, these generationally tethered relationships to different types of institutions stem from the region's history of ubiquitous colonial/state institutions, which have seen a wave of private capital/industrialization in the last 2 decades (Mathur 2015; PHD Chamber of Commerce 2015; Whitmore 2018).

On the other hand, the youth, in informal settings with their peer group and unencumbered by the survey instrument, are more apt to discuss their fears and aspirations (Langevang 2008; Smith 2012). These differential reactions—in essence performances—are place based and are rooted in the strategies that different community members utilize to relate to both the state and scientific evaluations of their lives and environments (Mahony and Hulme 2016). The youth, with their access to formal education, better understanding of telecommunication, and transportation, aspire to futures that provide more freedom from communal and state institutions. However, the older members of the community, who are better versed in accessing state welfare schemes, represent themselves in a certain way (vulnerable/precarious) when they encounter scientific methodologies that mirror state evaluation programs. (In rural Uttarakhand, intergenerational relationships within the household are complex and require further context and unpacking. Unfortunately, this is beyond the scope of this paper. For a better understanding, see Chakraborty [2018], Nichols [2016], and Jeffrey and Dyson [2014].)

The different views on human–wildlife encounters also echo similar caveats. The survey instruments leave little room to unravel the conditions producing such views, such as the state catch-and-release program that moves monkeys from urban to rural areas (see Govindrajan 2015). While most individuals identified increasing animal populations as a menace to agricultural livelihoods, they added a significant addendum during more intimate interviews about poaching for smuggling into Tibet, corrupt practices of state forest officials, and transformations in agricultural/forestland management. The animals were a problem, but as Sher Singh of Inari put it, "*a proximate effect, not the root cause*."

The parallel analysis revealed that each approach inherently pursued and explored knowledge about something different. The divergences and convergences were valuable insights, but what emerged were the limitations of both and their critical value in addressing alternative dimensions of the same problem. Furthermore, data production tools allowed specific sections of the community to voice their fears. The opinion of rural youth, which is often missing from such community perception datasets, emerged when we moved past the survey instruments.

While it is impossible to construct an unbiased, impartial perspective of social–ecological processes, this adherence to epistemic pluralism "produce(d) a richer understanding of the research problem, and in the process help(ed) unsettle the analytical boundaries between society and nature, science and social science" (Nightingale 2016: 46).

Democratic coproduction

Writing about her experiences of doing mixed-methods HDCC research with Tibetan herders, Yeh (2016) stated that knowledge itself can be thought of as 2 different entities. The first is a factual observation—a substance of evaluation that is acquired and static—while the second is embodied practice—a dynamic outcome of people's daily engagement with their environment. In much of HDCC research with local communities, this second idea of knowledge is marginalized (Popke 2016). While interpretive social science disciplines—anthropology, human geography, sociology, etc—have generated a significant scholarship countering such reductionist attempts, within the HDCC community, and especially in the Himalayan region, such attempts are rare (for

exceptions, see Vedwan and Rhoades 2001; Cote and Nightingale 2012; Gagné 2016). Our work attempted to involve the community as coproducers of knowledge and thus required fieldwork that stretched across many years. The researchers lived and worked with over 1000 families in the region. They spent almost a decade engaging with the individuals beyond the geographical boundaries of the village and beyond the present research agenda. This allowed for a disaggregated view of local communities that transcended their reductionist representation as victims of a "remote and fragile landscape" (Gergan 2017).

Furthermore, community members often questioned the utility of our work, the need for this project, and its ability to honestly portray their complicated lifeworlds. The impacts of climate change, while presented as critical in many scholarly accounts, seemed to be of marginal relevance when compared to other pressing issues they were encountering. A phrase we heard often was, "*Why are you so focused on the climate? Nature is not what marginalizes us and exploits us*." Community consensus seemed to echo the work of critical climate change adaptation scholars who question whether the large-scale political, scientific, and financial mobilization around this issue is removing the policy and research focus from the historical structural processes—colonization, state building, globalization—that continue to produce vulnerability in rural communities of the developing world (Ribot 2010; Taylor 2015).

Ultimately, the efficacy of attempting epistemological pluralism remains somewhat moot. This is largely a result of the intramethodological contentions into which we fail to delve. Therefore, convergences and divergences between the different forms of instrumentation used, the inherent dichotomies between "production" differences in precipitation data, varied statistical tests, and relationships between the vast lists of survey variables remain unexplored. Similarly, the varied narratives that emerge from different qualitative data production methods based on the intersectional identities of the subjects involved remain unaddressed. We hope to focus on these in future work.

Breaking the paper up into smaller, more thoroughly analyzed segments corrodes the actual objective: to present an authentic example of the contentious, uncomfortable, and somewhat disjointed process of transdisciplinary research. We believe that the sacrifice of more revelatory analysis at the cusps of the various internal frictions is necessary for a more egalitarian discussion of the various actors across the academy and society. This challenges the HDCC research community to pursue "an openness to explore how we know what we know, as well as a humility that entertains the possibility that others might have something to offer and have an equally valid perspective" (Murphy 2011, p. 505).

Conclusion

We have argued the need for epistemologically plural research designs when engaging with communities in the production of climate change knowledge within HDCC scholarship. The current research attempts overwhelmingly suffer from superficial attempts at interdisciplinarity. Additionally, in most research designs, local community perceptions are confined to monolithic avenues of representation. Our work addresses both these issues by operationalizing a parallel analysis, keeping each different analytical approach true to its own theoretical roots, of a case study in the Indian Himalayan region of Uttarakhand.

According to much HDCC scholarship, the Himalayan region will suffer catastrophic impacts of climate change. However, few scholars have questioned the validity of such claims, given their lack of groundtruthing, both through instrumentation and community perceptions. Our work explored the latter through a hybrid methodological approach. This study investigated the awareness of climate change and climate change impacts, and the worries associated with such impacts of the members of rural communities in the Indian Himalayas.

The results from our 2 different approaches can be summarized as follows. The quantitative approach highlighted extensive awareness of the impacts of climate change in the community; perceptions are similar to some of the conclusions reached through analysis of long-term rainfall and temperature data. The communities expressed that winter snow is declining, overall precipitation is more erratic and extreme, and temperature is increasing. Despite such changes, these are not the most critical worries of most community members. Instead, they are concerned about human–wildlife encounters, lack of healthcare and educational services, telecommunication, road connectivity, and political/institutional mismanagement and corruption. Additionally, disaggregating such worries along different social and economic features finds that older people are significantly more likely to worry about the impacts of climate change.

The results from the qualitative approach revealed a plethora of social, economic, and political processes that are closely intertwined with the changes in climate in producing community awareness. Therefore, ideas about the climate were rooted in changing livelihood aspirations, the politics of regional disaster relief, and changing access to the situation in the plains through the movements of migrants. Similarly, worries about the present and the future were a product of the encounters of communal and individual aspirations with transforming processes of governance, development, and security. Younger, more educated members are often more worried due to their inability to have faith

in the benevolence of religious deities or the welfare state.

Ultimately, when these conclusions from the different analytical approaches were brought together, 2 insights emerged. First, the 2 approaches end up supplementing each other. Therefore, irrespective of whether their conclusions converge or diverge, each approach provides context for the other. Second, the overall research design, by allowing the community more than one platform through which to convey their perceptions and trepidations about climate change, provided a more democratic avenue for involving rural Himalayan farmers in scholarship on HDCC.

Data collection and evaluation problems still plague the overall analytical process. However, we believe attempting such a parallel analysis with other communities in different parts of the world can help to address these problems while also providing new insights into unfolding human engagement with climate change.

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