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Climate change perception: an analysis of climate change and risk perceptions among farmer types of Indian Western Himalayas

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Abstract

Climate change and variability have created widespread risks for farmers' food and livelihood security in the Himalayas. However, the extent of impacts experienced and perceived by farmers varies, as there is substantial diversity in the demographic, social, and economic conditions. Therefore, it is essential to understand how farmers with different resource-endowment and household characteristics perceive climatic risks. This study aims to analyze how farmer types perceive climate change processes and its impacts to gain insight into locally differentiated concerns by farming communities. The present study is based in the Uttarakhand state of Indian Western Himalayas. We examine farmer perceptions of climate change and how perceived impacts differ across farmer types. Primary household interviews with farming households ($n = 241$) were done in Chakrata and Bhikiyasian tehsil in Uttarakhand, India. In addition, annual and seasonal patterns of historical data of temperature (1951–2013) and precipitation (1901–2013) were analyzed to estimate trends and validate farmers' perception. Using statistical methods farmer typology was constructed, and five unique farmer types are identified. Majority of respondents across all farmer types noticed a decrease in summer and winter precipitation and an increase in summer temperature. Whereas the perceptions of impacts of climate change diverged across farmer types, as specific farmer types exclusively experienced few impacts. Impact of climatic risks on household food security and income was significantly perceived stronger by low-resource-endowed subsistence farmers, whereas the landless farmer type exclusively felt impacts on the communities social bond. This deeper understanding of the differentiated perception of impacts has strong implications for agricultural and development policymaking, highlighting the need for providing flexible adaptation options rather than specific solutions to avoid inequalities in fulfilling the needs of the heterogeneous farming communities.

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1 Introduction

Climate change, characterized by changes in long-term temperature and precipitation regimes as well as increasing interannual variability, is among the most substantial challenges being faced by the world today (Chakra et al. 2018). In the Himalayan region, the potential impacts on ecology, economy, and society are enormous as the rate of increase in temperature and variability in precipitation is significantly higher (Mathison et al. 2013). Although climate change is a physical process, its cascading negative impacts transcend to the social, cultural, ecological, political, and economic sectors and shape prospects for water, food, and health security (Hirabayashi et al. 2013; IPCC 2014).

Long-term trends for observed as well as projected temperature and precipitation have been studied in this region (Panday et al. 2015; Choudhary and Dimri 2017). Recently, Ren et al. (2017) reported that there is a significant increase in the rates of the mean temperature (0.104 °C per decade), mean maximum temperature (0.077 °C per decade), and mean minimum temperature (0.176 °C per decade) over 1901–2014 in the region. Unlike the temperature data that shows an overwhelming warming trend, trends in precipitation are spatially inconsistent in the region. Due to the changes in the climatic parameters, there have been frequent incidences of droughts, floods, cloudbursts, landslides, pest infestation, and livestock diseases in the region (Das et al. 2006; Norris et al. 2017; Kumar et al. 2017). These conditions are expected to worsen in near future, constituting a widespread threat to welfare, livelihood, and food security of the Himalayan farmers (Macchi et al. 2014).

Farmers, whose livelihoods and welfare is under direct exposure to climate change risks unarguably, have a long-term perspective on climate change and its associated risks (Barnes et al. 2013; Niles and Mueller 2016). Perception is a cognative process through which humans interpret experiences of the environment and in turn generate response stratergies. Schlüter et al. (2017) highlights that in various behavioral models, perception is the initial receptor stage, i.e., "what comes in" and behavior is the final outcome, i.e., "what goes out." Likewise, adaptation behavioral theories emphasize farmer's perception to be an important factor that influences adoption of adaptation stratergies, as individual's climate change risk appraisal is based on risk perception (Li et al. 2017). Although the perceptual elements of climate risk form the foundation of climate adaptation, however the perceptions are modified by several antecedents associated with financial, social, political, and farm characterstics (Li et al. 2107; Singh et al. 2017).

Literature on farmers' perception to climate change processes and their impacts accentuate that perception to climatic risks is mediated through farmers' demographic assets, and farmland characteristics, such as the amount of cropland, irrigation availability, farming experience, age, literacy, off-farm income sources, and access to agriculture out-reach services (Deressa et al. 2009; Singh et al. 2017). Deressa et al. (2009) showed that the perception of the farmer is positively related to the education and farming experience. Simelton et al. (2013) highlighted the role of farming systems and its sensitivity (i.e., being rainfed or not) in determining the perception of farmers. Further, Scherer and Cho (2003) identified that perception can be augmented through social network via information sharing, resulting in differential perception among farmers. These findings assert that there exists a heterogeneity in climate risk perception among different farmers who are endowed with differential resources (Menapace et al. 2015; Niles and Mueller 2016). Thereby, a conscientious assessment of perception of climatic risk by heterogeneous farmer households is warranted to gain insight into locally differentiated concerns by farming communities and to efficiently support the

needs of diverse farmers in adapting their tactical (short-term) and strategic (long-term) planning to the evolving climatic risks.

Empirical research on Himalayan farmers highlights that there is a persistent diversity within farming communities, entrenched in differential biophysical, social, economic, cultural, and institutional factors; therefore, farmers in this region by no means represent a monotypic group rather specific subgroups, i.e., farmer types are present (Jones and Boyd 2011; Singh et al. 2017). Researchers have identified the role of not only social factors like caste, class, income, gender but also other factors like land, labor, and livestock in contributing to farmer heterogeneity in the region (Ojha et al. 2017). The guiding assumption of this research is that diversity in Himalayan farming communities is induced by several intrinsic and extrinsic factors which lead to differences in perception of farmers. The intrinsic diversity factors are linked to individual farmer (beliefs and intentions), and household capital (financial, natural, physical, and social) characteristics (Kuivanen et al. 2016), whereas chief external factors that stimulate diversity are identified to be access to market, presence of agriculture extension services, and agricultural policies (Skjeflo 2013).

Though several studies have studied farmers' perception to identify local impacts of climate change on agriculture systems and validate regional trends in the region (Manandhar et al. 2011; Gentle et al. 2014; Macchi et al. 2014; Sujakhu et al. 2016; Devkota et al. 2017; Singh et al. 2017; Uprety et al. 2017), yet limited research is available on identification of farmer types and understanding the climate risk perception of different farmer types in the region. The Uttarakhand State Action Plan on Climate Change (SAPCC) identifies that farmers in the region are highly vulnerable to climate change impacts and proposes the imperative need to comprehensively document farmers' perception along with its validation with observed climatic data (GoU, 2014). Therefore, this study aims to fill this gap by examining if impacts of climate change are indeed being perceived differently by different farmer types in conjugation with long-term climate data analysis for the Uttarakhand state of Indian Western Himalayas (IWH). The specific objectives of this study are to (1) delineate and characterize diverse farmer types based on differnetial resource endownment and household characterstics, (2) detect annual and seasonal monotonic trends in observed temperature and precipitation data, (3) document the perception of farmers for major climatic variables, and (4) compare the perceived impacts of climate change by different farmer types. Section 2 describes the study area; Sect. 3 introduces the methods used for data collection and analysis. Section 4 subsequently presents the results of our study and discusses them in the light of previous findings in the region, and Sect. 5 concludes the paper.

2 Study area

The Uttarakhand state, a part of IWH, extends from 28° 42′ N to 31° 28′ N and 77° 35′ E to 81° 05′ E and consists of 13 districts and 78 tehsils[1] (Fig. 1). These districts are clubbed into two administrative zones namely Gharwal and Kumaon region which differ in topographic and physiographic features (Kuniyal 2003). Agriculture and allied sectors form the primary source of livelihood for about 75% of the population (Sati 2012). About 85% of the agriculture land is rainfed where farming is practiced on small terraced slopes, while the rest of the land (15%)

[1] Tehsil is an administrative division which consists of villages and municipalities, often described as a sub-district.

lies in the valleys with irrigation networks (Maikhuri et al. 2001). The state constitutes three distinct altitudinal zones—lower plains (< 1200 m), middle hills (1200–1700 m), and upper hills (> 1700 m) (Fig. 1). Four seasons are experienced in the state, namely, cold winter (December–February (DJF)), summer (March–May (MAM)), summer monsoon (June–September (JJAS)), and the post-monsoon (October and November (ON)) (Basistha et al. 2009). Seventy-five percent of the precipitation in the region is received during the summer monsoon months in the form of rain and 25% during the winter season in the form of snow as well as rain. Majorly there are two cropping seasons namely *Kharif* (summer crops) and *Rabi* (winter crops), but sometimes few crops are grown in between the summer and winter crops known as *Zaid* crops.

The study was conducted across ten villages selected in the two tehsils Chakrata (Dehradun district, Garhwal region) and Bhikiyasian (Almora district, Kumaun region) located in the middle altitudinal zone of Uttarakhand state (Fig. 1). The selection of the two study tehsils was based on the results of state-level inherent vulnerability assessment conducted by Shukla et al. (2016). The selected villages varied in elevation, access to road, and market availability. Further, the villages were inhabited by farmers with a diverse mix of class and caste, with the upper caste *Bhramin* and *Rajputs* notified as general category and lower caste *Harijans* notified as Schedule Caste (SC). Chakrata is a tribal area with notified Schedule Tribe (ST) communities. Practicing agriculture has become progressively challenging in all the surveyed

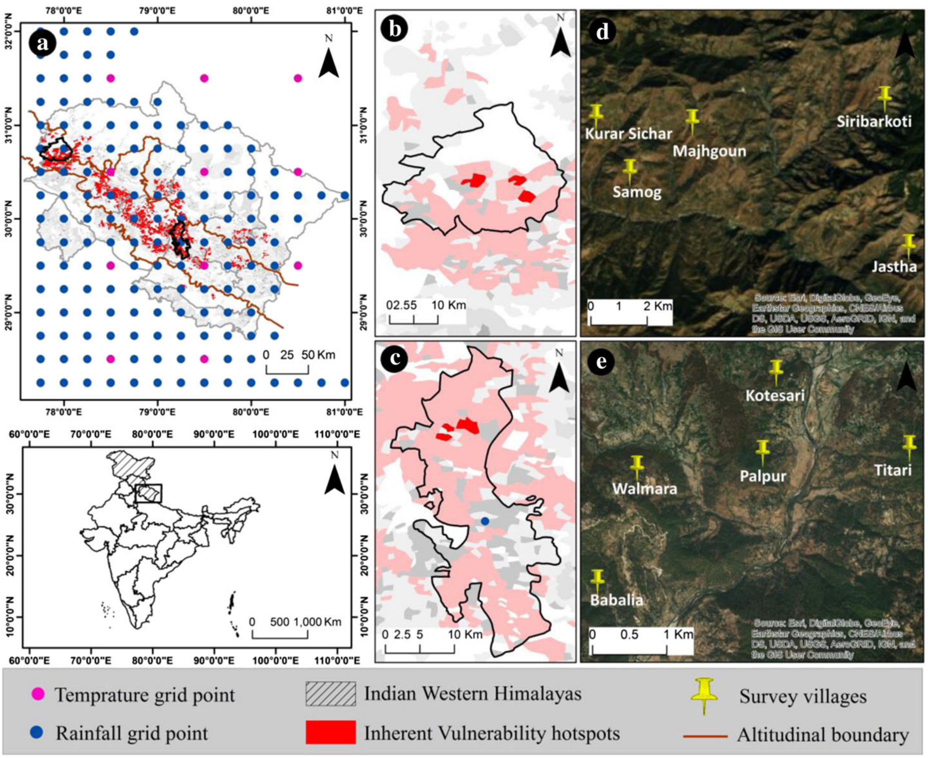

Fig. 1 Maps of the study area showing **a** the inherent vulnerability hotspots for the Uttarakhand state (Shukla et al. 2016) along with the temperature (1° × 1°) and precipitation (0.25° × 0.25°) IMD grid points. The map also shows the selected tehsil boundary of Chakrata and Bhikiyasian in **b** and **c**, respectively. The location of the selected villages in Chakrata are marked in **d** and for Bhikiyasian the villages in subset **e**

villages due to the ongoing unprecedented changes in climatic conditions which have lead to severe ramifications on land productivity, agriculture yield, food self-sufficiency, water resources, and livelihood security (Kelkar et al. 2008; Pandey and Jha 2012).

3 Data and methodology

3.1 Climate data and analysis

We used high-resolution daily gridded precipitation ($0.25^{\circ} \times 0.25^{\circ}$) and daily temperature ($1^{\circ} \times 1^{\circ}$) data for a spatial domain of 66.5° E to 100° E and 6.5° N to 38.5° N covering the mainland region of India (for more details, *c.f.* Shrivastava et al. 2009; *c.f.* Pai et al. 2015) developed by the India Meteorological Department (IMD). For both the study sites, 113 years (January 1901 to December 2013) of monthly precipitation data from nine closely located grid stations (Fig. 1a) were used to analyze the trend in precipitation. Monthly temperature values for the study areas were also extracted by averaging the values of the four enclosing grid points (Fig. 1a) for 63 years (January 1951 to December 2013). For studying the changes in temperature, we analyzed the trend in mean (Tmean), maximum (Tmax), and minimum (Tmin) temperatures. In order to maintain consistency with the survey questions, we not only analyzed the annual trends in Tmean, Tmin, Tmax, and precipitation but also their seasonal (summer and winter) trends. A simple linear regression and bootstrap resampling are used to determine monotonic trends and their significance for each region. Trends in average regional time series were calculated, and the bootstrap resampling 1000× is used to determine confidence intervals and two-sided p values. For precipitation, monsoonal (JJAS) and winter (DJF) season were of interest, whereas for temperature we were mainly interested in summer (MAM) and winter (DJF) seasons. We used non-parametric Mann-Kendall test (Mann 1945) to ascertain the presence of statistically significant trends in temperature and precipitation and the magnitude of the trend was determined using Sen's estimator (Sen 1968).

3.2 Survey method

Perception of farmers to changes in climatic variable and their impacts were collected through household survey, carried out in the selected ten villages, from April to June 2017. The households within each village were purposefully selected with the help of local NGOs and village representatives to adequately reflect on caste, farm size, and wealth diversity. Based on these criteria, 30% of household in each of the villages were surveyed resulting in a total of 241 households with 107 in Chakrata and 134 in Bhikiyasain. We adhered to the Code of Ethics by the International Sociological Association (ISA 2001) and attained an informed consent from the participants before conducting the survey. The questionnaire was tested during pilot field survey conducted in January 2017 in the villages near Bhatrojkhan in Bhikiyasain tehsil, after which modifications were made and questionnaire was finalized.

The questionnaire contained three different sections (i) farmer's personal characteristics, household characteristics, resource endowments, and livelihood orientations; (ii) awarness about climate change and perception of climatic variables (such as summer and winter precipitation and temperature, and snowfall); and (iii) perceived impacts of climate change on crop yield, crop quality, soil fertility, irrigation water availability, food security, income, expenditure, and social bond. These main impacts were identified based on our group

discussion with farmers during our preliminary visits. The authors who executed the survey explained the distinction between weather variability (year to year variations) and climate change (changes over a period of 20–30 years) to the farmers so as to avoid biases in their response. We further complemented our analysis by recording the narratives of the farmers in order to better understand the construction of their perception. The data obtained from (i) was used to construct the farmer typology. Responses to questions from (ii) and (iii) were recorded on a scale. Scale for the perception of the climatic variables was 1 to 3; 1 for the decrease, 2 for no change and 3 for an increase in the magnitude/frequency of the variable. Further, the perceived impacts of climate change were measured across the standard 5-point Likert type scale (Likert 1932) ranging from 1 (strongly un-impacted) to 5 (strongly impacted).

3.3 Delineation of farmer types

The first section of the questionnaire dealt with detail questions about household members, demographic profile, income sources (primary, secondary and tertiary), agriculture details (land ownership, location of land, crop choice), months of food sufficiency, and household assets (natural, financial, physical, social, human). From the collected data, 29 (12 numerical and 17 categorical) variables (Table S1) were selected for the construction of farmer typology based on the discussion with experts and literature (Kuivanen et al. 2016; Ojha et al. 2017; Singh et al. 2017) to suit context and locale rationale. We used multivariate statistical methods of factor analysis, followed by sequential agglomerative hierarchical and K-means clustering to delineate different farmer types. We used the *FAMD* (factor analysis of mixed data) function for reducing the 29 variables into uncorrelated factors and then applied hierarchical clustering on principle components (HCPC) function using "FactoMineR" in R package (version 3.4.1) (Lê et al. 2008). We performed clustering on the factors which had eigenvalue greater than 1 (Kaisers' criterion) to identify homogenous farmer type clusters. The final selection of the number of clusters was based on the subjective interpretation of the dendrogram, supported by the inertia gain values and the majority number of cluster suggested by "NbClust" package in R (*c.f.* Charrad et al. 2014).

3.4 Perception data analysis

We performed exploratory data analysis to examine if and to what extent farmer types differ in their response to perception of climatic variables and climate change impacts. ANOVA (analysis of variance) followed by Tukey's HSD (honest significant difference) test for post hoc mean separation were conducted in R for the five identified farmer types with response variables to examine the possible differences and similarity in the perception. All the test values were considered to be statistically significant at $p < 0.05$. Finally, validation and triangulation of the results was done through participatory repeat visits and discussion with locals enabling the cross-checking of the findings.

4 Results and discussion

Table 1 provides the socio-demographic details of the 241 surveyed households. Aggregated descriptive statistics for all the continuous and categorical variables gathered from the survey is provided in the supplementary information (Table S1).

Table 1 Socio-economic profile of the respondents

Variables	Chakrata ($n = 107$)	Bikiyasain ($n = 134$)
Age	40.08	46.39
Male-headed household (%)	62.04	78
Female-headed household (%)	37.96	22
Caste (%)		
General	72	–
ST	23	63
SC	5	37
Education (%)		
Illiterate	50	18.50
Primary	16.66	35.50
High school	12.96	20
Intermediate	10.18	11.85
Bachelors'	6.48	11
Above bachelors'	3.72	3.15
Family size	10.77	4.96
Total land holding (ha)	1.52	0.74
Irrigated land (ha)	0.74	0.31
Abandoned land (ha)	0.11	0.24
Average plot size of land (*nali*)[a]	2.64	3.01
Total livestock unit**	9.71	2.48
Access to credits (%)		
Yes	58	18
No	42	82
Economic status (%)		
Above poverty line	14.80	57.04
Below poverty line	85.20	42.96

[a] One nali = 200 m^2

[b] Conversion factor: buffalo, 1.5; bullock, 1.2; cow, 1.0; mule/horse, 1.0; cow calf, 0.5; buffalo calf, 0.75; goat, 0.2; sheep, 0.2 (Singh and Naik, 1987)

4.1 Farmer typology

Factor analysis generated 13 dimensions, with an eigenvalue greater than one, explaining a total variance of 68%. Dimensions 1 and 2 explained a total of 16.26% and 11.80% variance, respectively. The details of the percentage variance explained by each dimension are shown in the scree plot provided as supplementary material (Fig. S1 (a)). Out of 23 indices, 8 suggested a five-cluster solution for grouping the 241 farming households. Therefore, we group the data into five clusters (supplementary Fig. S1 (b)) based on the farmer's resource and capital endowment along with individual and production orientation. Table 2 summarizes the main characteristics of the identified farmer types.

4.2 Observational evidence of changes in climate

4.2.1 Precipitation changes

In both the sites, there has been a significant decrease in not only the annual precipitation but also the monsoon (JJAS) and winter (DJF) precipitation over the past century (Fig. 2). The magnitude of decrease in the annual precipitation for Chakrata and Bhikiyasain is −

Table 2 Characteristics of farmer types

Farmer types	Main characteristics
Type 1: High resource-endowed: intensified food crop farmers ($n = 29$, 12%)	High landholding, highest proportion of irrigated land, moderate family size, highest number of agriculture implements (power teller), higher education level, mostly belonging to general caste, low agriculture training received, least livestock number, old age household head, greater cultivation of food crops, constrained by family labor availability, permanent off-farm income source (e.g., government salaried jobs),
Type 2: High resource-endowed: market-oriented cash crop farmers ($n = 43$, 18%)	Largest family size, highest availability of family labor, moderate dependence on on-farm income, mostly cash crop cultivation, highest land holding, high proportion of irri gated land, highest number of livestock, middle-aged household head, no agriculture training received by farmers, mostly male-headed households, high accessibility to credits
Type 3: Medium resource-endowed: market-oriented cash crop farmers ($n = 53$, 22%)	High livestock number, large family size, high availability of family labor, constrained by land and irrigation availability, limited off-farm income, high dependence on on-farm income, mostly cash crop cultivation, middle-old aged household head, mostly belonging to schedule tribe and schedule castes
Type 4: Low resource-endowed: subsistence food crops framers ($n = 100$, 41%)	Highest proportion of share croppers (working on others land), low livestock number (mostly one cow), low land size, small household size, low family labor, constrained by land, labor, and capital, mostly belonging to general caste, all women-headed household group under this type, only cul tivate food crops, low market access, low accessibility to credit facilities
Type 5: Low resource-endowed: disengaging farm labors ($n = 16$, 7%)	Landless, young farmers, high dependence income from labor activities, least education, all belonging to schedule caste, low livestock (small ruminants for selling), small family size, constrained by land and capital access, not involved in agriculture training, least annual income

0.70 mm/year and − 0.33 mm/year, respectively. The slope values for Chakrata (Bhikiyasain) for the monsoon season is − 1.95 mm/year (− 0.70 mm/year) and winter season is − 0.25 mm/year (− 0.19 mm/year). The resultant terms of Z-statistic and p values are given in the supplementary table (Table S2). Annual and seasonal series of precipitation between 1901 and 2013 were found to be not autocorrelated at 5% significance level.

The farmers in Chakrata and Bhikiyasain have been facing acute water shortage in the last few years. Erratic and uneven rainfall has resulted in drought spells throughout the villages. The dry and wet years of Chakrata and Bhikiyasain for the years 1901–2013 by standardized anomaly precipitation analysis of the monsoon months (JJAS) (Supplementary Fig. S2) indicate that after 1962, there are prolonged dry spells at both the study sites. However, in Bhikiyasain, dry spells are intermittently scattered throughout the century, and their occurrences have become much more frequent recently. The results of our analysis are in concurrence with the findings of most of the studies which report a statistically significant decline in precipitation in Uttarakhand or western Himalayas of which Uttarakhand forms a part (Guhathakurta and Rajeevan 2008; Dimri and Dash 2011).

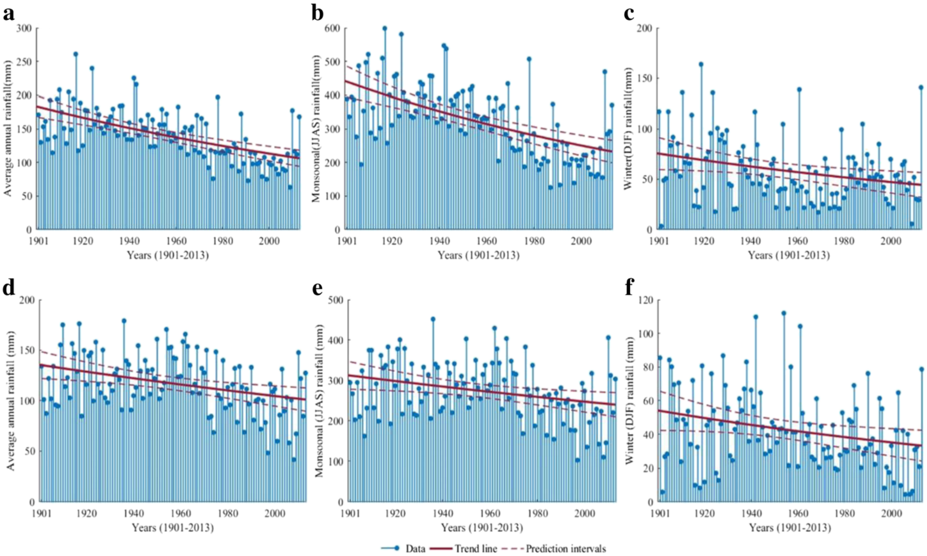

Fig. 2 Trend analysis of annual and seasonal precipitation data (1901–2013). Chakrata tehsil: **a** average annual, **b** monsoonal (JJAS), and **c** winter (DJF). Bhikiyasain tehsil: **d** average annual, **e** monsoonal (JJAS), and **f** winter (DJF)

4.2.2 Temperature changes

The analysis of the temperature data reveal that over the 53 years, annual Tmean has increased by a rate of 0.01 °C/decade ($P > 0.05$) and 0.02 °C/decade ($P > 0.05$) with variations up to 6.02% and 5.56% from the mean at Chakrata and Bhikiyasain, respectively (Fig. 3a, d). However, these increasing trends were not significant at 95% confidence interval. Whereas, a significant increasing trend was observed in annual Tmin with a slope of 0.05 °C/decade ($P < 0.05$) for Chakrata and 0.04 °C/decade ($P < 0.05$) for Bhikiyasain. In contrast, annual Tmax shows a decreasing trend of − 0.03 °C/decade and − 0.05 °C/decade though statistically non-significant.

The slope of Tmean for summer (winter) season is 0.05 °C/decade (0.07 °C/decade) and 0.03 °C/decade (0.01 °C/decade) at Chakrata and Bhikiyasin, respectively. Based on the results, it can be interpreted that on average the magnitude of annual summer warming is higher than that of winter warming in the same period although the trends are statistically non-significant for Mann–Kendall test. Further, no significant trend was observed in the seasonal analysis of Tmin and Tmax for both the sites. Results of Mann–Kendall test for all the annual and seasonal analysis is provided in supplementary information (Table S3). Though non-significant at 95% confidence interval, the average annual temperature shows a warming trend in both the regions. Similar observations on warming in annual temperature have been made by other studies (Bhutiyani et al. 2007; Shekhar et al. 2010). Besides, a greater asymmetry is observed in the trends of Tmin and Tmax which could be due to the huge observational data gaps in northern India as identified by Ren et al. (2017); therefore, there exists great uncertainty and variability in observed trends.

4.3 Perceived changes in climatic variables

About 83% of the farmers were not aware of the term “climate change,” yet the majority of the farmers (97%) believed that climate has certainly changed from what they recall of 20–25 years

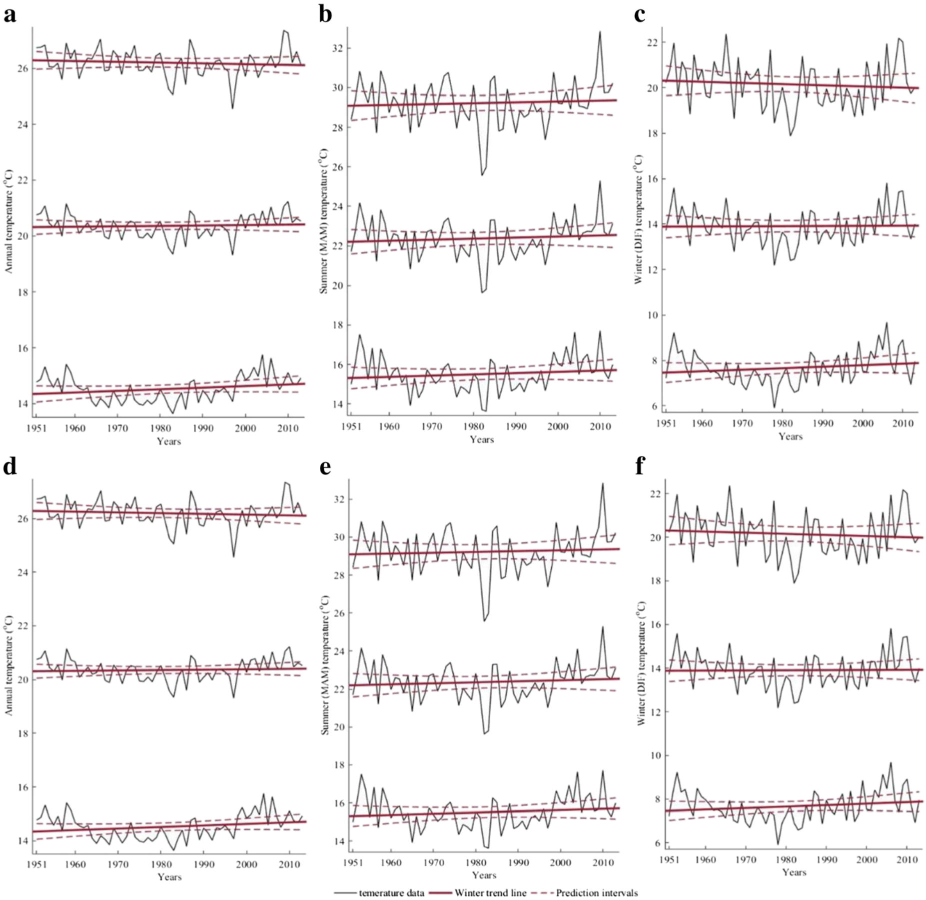

Fig. 3 Temperature trends from 1951 to 2013 showing Tmin, Tmean, and Tmax. Chakrata tehsil: **a** annual, **b** summer (MAM), and **c** winter (DJF). Bhikiyasian tehsil: **d** annual, **e** summer (MAM), and **f** winter (DJF) season

ago. Of the farmers that were aware of the term, climate change have acquired knowledge through camps mostly arranged by local NGOs. Figure 4a shows the overall perception of all the interviewed farmers regarding critical climatic variables, i.e., temperature and precipitation for both summer and winter season. With regard to perceived changes in precipitation (Fig. 4a), it is evident that an overwhelming majority of farmers perceive a decrease in summer (99%) and winter (95%) precipitation. Since farming in study regions is predominantly rain-fed, farmers had vivid observations regarding the changes in timing and intensity of the rainfall. Simelton et al. (2013) highlight that farmers which are reliant on narrow range of resources their greater perception is observed to be confounded by sensitivity of farming systems to rainfall changes. Farmers extensively spoke about the erratic and uncertain rainfall patterns in both seasons. Monsoon rainfall is critical for *Kharif* crops like rice, finger millets, and pulses and winter precipitation is essential for *rabi* crops such as wheat. The majority of the farmers asserted that they are unable to determine when to start their sowing season due to the unpredictable nature of rainfall. This has altered the famers' traditional cropping calendar. Further, due to the subnormal intensity of precipitation, the incidences of drought have become frequent. The amount of snowfall was also reported to have decreased appreciably.

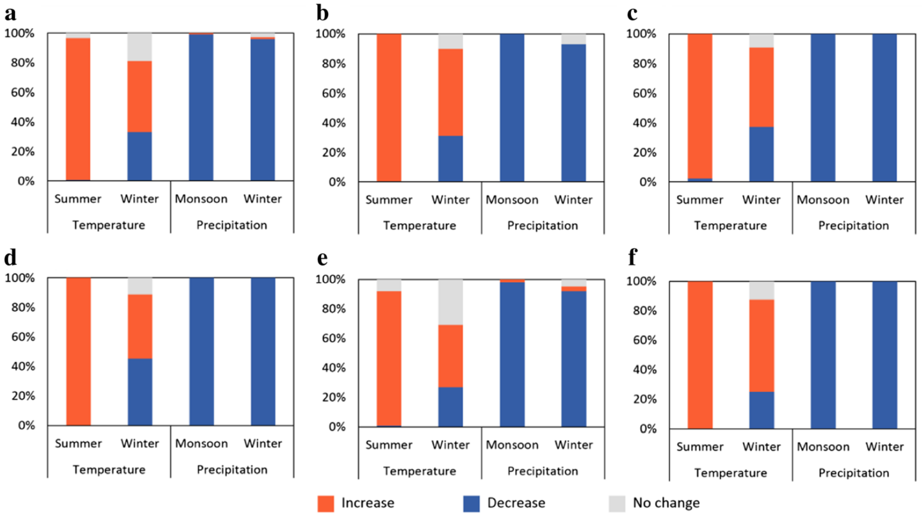

Fig. 4 Perception of climatic variables. **a** Overall response of all farmers ($n = 241$). **b** Farmer type 1 ($n = 29$). **c** Farmer type 2 ($n = 43$). **d** Farmer type 3 ($n = 53$). **e** Farmer type 4 ($n = 100$). **f** Farmer type 5 ($n = 16$). No significant difference was found in the responses across farmer types for all four climatic variables ($P > 0.05$)

A farmer quoted, "earlier, we could not see stars in the sky for the whole of the July and August. Continuous rains for days during the monsoon season in old times was good for the soil and the crops. But now, sudden and untimely torrential rains are spoiling the soil as well as the crops. Rains have completely disappointed us." Another farmer form Chakrata narrated, "earlier the snow was about a foot high and it used to stay for weeks but now if ever there is snowfall it is less than 5 inches and melts within a day." With reference to temperature a farmer stated, "summers are more intense and dry now because of which the crops ripen at an early stage without proper grain development." An old-age farmer remarked, "it is dry winter now. Such conditions are different from what we had experienced as young in the village. Because of the dryness there is more pest infestation and health impacts for livestock and humans."

Majority of farmers (96%) perceive an increase in temperature in the summer season. Excessive scorching and wilting of crops was reported by the farmers due to the higher heat accumulation. Enhanced warming during the summer season was linked to a decrease in rainfall by many farmers. Besides, in earlier times, there was no need of electric fans, but now farmers feel it has become impossible to manage without them. In contrast to the perception of summer temperature, a greater variation was observed in the perception for winter temperature with 48% of the farmers reporting a decrease, 33% an increase, and the rest 19% perceived no change in the winter temperature (Fig. 4a). Farmers who reported an increase in winter temperature connected their perception to the reduced intensity of snowfall, whereas for some farmers, the winter seasons have become drier, thereby chillier with frequent incidences of fog, frost, and hailstorm. Our analysis of perception of climate variables confirm the findings of previous studies in Uttarakhand (Vedwan and Rhoades 2001; Kumar et al. 2008; Kelkar et al. 2008; Macchi et al. 2014). The comparison of overall farmer perception with observed climatic trends reveals a close and an appropriate match. Such a correlation provides evidence to the abilities of farmers who are (often absolutely) dependent on natural resources for their livelihoods to accurate recall climatic variations.

Figure 4b–f depicts the responses of each farmer type. As can be interpreted from the graph, there is not much variation in the perception of climatic variables across farmer types.

The results of chi-square test to test the differences in the proportions were non-significant (refer to Supplementary Table S4). These results indicate that though the farmer types differ functionally in terms of resources and demographic attributes but the changes in climatic variables are perceived equally across all the farmer types. A recent study by Singh et al. (2017) analyzing the climate variable perception of Himalayan communities, though not in Uttarakhand, also reported no differences in the perception of precipitation and temperature across gender and wealth classes. Our findings, in conformity, highlight that since farming in the region is highly determined by climatic parameters and practiced through traditional methods; therefore, all farmers perceive changes in local climate.

4.4 Perceived impacts of climate change

Table 3 presents the overall mean as well as mean values of perception for each farmer type in order of the impacts most felt by the farmers. Crop yield was most impacted due to changes in precipitation. Notably, a sizable percentage of farmers reported declining yields of winter crops especially wheat which is grown on non-irrigated fields. Due to declining yield and productivity, household self-food sufficiency has also reduced significantly. Food self-sufficiency is a measure to describe the degree to which a household satisfies its food needs from its crop production (Clapp 2017). Impact on irrigation water sources and crop quality was reported due to declining precipitation and increasing winter temperature. Soil fertility was also identified to be severely impacted by increasing temperature, declining precipitation and snowfall as farmers reported that they feel the soil has dried and hardened, making plowing of fields much difficult in present times. Interestingly, annual expenditure was observed to be more impacted than farmer's household income, since a lot of expenditure was being incurred on maintaining livestock health, agriculture inputs (insecticides) and for buying food. Further, least impact was reported on social bond among farmers.

Regarding crop productivity, a farmers narrated that "I feel ashamed when I compare our previous year production with today's production. 90% difference has occurred in the yield". Another farmer asserted, "about a decade ago when it used to timely rain then the production

Table 3 Perceived impacts of climatic risks by five farmer types. Mean values are shown along with the *F* value and *P* values of chi-square test. Perception was recorded on a five-point Likert scale 1 (strongly unimpacted) to 5 (strongly impacted). Tukey-HSD interpretatin is based on Supplementary Fig. S3

	FT 1	FT 2	FT 3	FT 4	FT 5	Overall mean	*F* value	*P* value	Tukey-HSD
Crop yield	4.79	4.81	4.77	4.70	4.75	4.75	0.41	0.80	–
Food self--sufficiency	4.38	4.37	4.43	4.92	4.25	4.61	10.83	0.00	FT4 > FT1, FT2, FT3, FT5
Water resources	4.79	4.16	4.02	4.75	4.50	4.47	8.14	0.00	FT1 > FT2, FT3 FT4 > FT2, FT3
Crop quality	3.48	3.28	3.21	3.19	2.56	4.37	7.75	0.00	FT5 < FT1, FT2, FT3, FT4
Annual expenditure	4.10	4.33	4.43	4.46	4.00	4.36	1.96	0.10	–
Annual income	3.21	4.28	4.68	3.85	4.75	4.09	11.70	0.00	FT1 < FT2, FT3, FT, 4, FT5 FT4 < FT3, FT5
Soil fertility	4.34	4.33	4.26	4.61	3.38	3.20	1.67	0.16	–
Social bond	1.31	1.42	1.34	1.59	2.38	1.61	9.59	0.00	FT4 > FT1, FT2, FT3 FT5 > FT1, FT2, FT3

of wheat was about 300 kg, but now in present time the production is about 30 kg. We no more have enough grains for seeds as well." Additionally, farmers identified that their household's dependency on market has increased enormously, several farmers stated, "we were dependent on the market only for salt and occasionally for oil, but for past 7-8 years we get all the food items from market including rice and wheat."

Table 3 provides statistical evidence for differences among farmer types' perception relating to impacts on food self-sufficiency, water resources, crop quality, annual income, and social bond ($p < 0.05$). Non-significant differences in perception were noted for impacts on crop yield, annual expenditure, and soil fertility ($p > 0.05$) emphasizing the ubiquitousness of these impacts across all the farmer types. Farmer type 1 (high-resource-endowed: intensified food crop farmers) perceive significantly more impact on water resources and crop quality and least impact on annual income as compared to other farmer types (Table 3 and Supplementary Information Fig. S3). Farmers belonging to this type are mostly cultivating staple food crops such as wheat and rice using traditional seeds without any seed replacement. Since these crops are water demanding (Bajpai et al. 2007) and their yields are predicted to be adversely affected in changing climate scenario (Chhetri and Easterling 2010; Sati 2012), it is reasonable for these farmers to sense more impact. Similar observation was made by Simelton et al. (2013) who highlighted that farmers who are dependent on climate sensitive farming systems perceive more impact compared to other farmers. Further, as type 1 farmers mostly have permanent salaried income sources (e.g., government school teacher, retired army officers), income losses due to climatic risks may perceive to be innocuous. In contrast, the market-oriented cash crop farmers (type 2 and type 3) intuitively report their annual income to be adversely impacted by changes in climatic parameters.

Our typology effectively dissects the low-resource farmer category into marginal subsistence farmers (type 4) and landless farmers who work as laborer (type 5). Pronounced impacts were felt by type 4 farmers on household food self-sufficiency as type 4 farmers tend to meet their immediate basic food requirements by cultivating on marginal rainfed lands, whereas the landless type 5 farmer acquire a greater proportion of food from government-controlled Public Distribution System (PDS). This is an intriguing observation, as previous researchers have shown that landless farmers are most chronically food insecure due to impacts of climate change (Gentle and Maraseni 2012; Tiwari and Joshi 2012). All the type 5 farmers reported to work under National Rural Employment Guarantee Act (NREGA) and use the money to buy low-cost wheat and rice through PDS which helps them fulfill their dietary needs. With regard to social bond, the type 5 farmers exclusively felt stronger impacts. Literature highlights the role of social bond in enhancing the adaptive capacity through creation of strong social network, through which emerge new institutions of cooperation which help the farmers to withstand the impacts of adverse climatic events (Smit and Wandel 2006; Sapkota et al. 2016). However, our findings reveal that there exists inequality with regard to the access to social networks where the poorest, low-resource-endowed farmers are structurally excluded due to skewed power relations and traditional socio-cultural norms thus perceiving more impacts.

In light of these findings, our study shows that farmer diversity in the region is complex and multi-layered leading to differencs in perception of certain impacts of climate change across farmer groups. Several interrelated factors such as choice of crop, orientation towards farming (market or subsistence) contribution of off-farm income, and availability of "social safety net" schemes play a crucial role in how climate impacts are being percieved and what adapataion mechanisms would be adopted in response to the percieved impacts. Therefore, climate change adaptation policies needs to be nuanced to differntail perception and needs of the farming communities for the intended outcomes to be equitable and effective in long term and not reinforce the inequalities.

5 Conclusion

This study examines the differences in farmer types' perception of the climate change and its impacts in the Indian western Himalayas. Based on the historical climate data, changes in climate are evident with gradual trends of decreasing precipitation and enhanced summer warming. The comparison of overall farmer perception with observed climate trends revealed a close, consistent, and an appropriate match. Such high correlation provides evidence to the abilities of farmers to accurately recall climate variations. The perception of climate change impacts differs for farmers with differential resource endowment and household characteristics. Significant differences were noted for perceived impacts on annual income, food self-sufficiency, crop quality, water resources, and social bond highlighting differentiated concerns of farmers. Based on these noticeably different perceptions, our findings have three main policy implications for adaptation planning in the Himalayan mountains:

1. Blanket approaches of climate change adaptation and agricultural policies which do not take into account the heterogeneity within the farmers are unlikely to be successful.
2. Recognition of differentiated perception of impacts offers an opportunity for climate change researchers and policymakers to contribute to the ensured viability of the mountain communities by avoiding rigid trap in climate adaption policy.
3. Understanding relationships between farm resource endowments, household characteristics, and perception of farmers could provide valuable knowledge to policymakers and practitioners to identify farmer groups that require urgent external support for adaptation and the ones who can spread good adaptation practices.

These recommendations ensure that adaptation policies in the mountains do not reinforce the preexisting structural inequalities among farmers' groups rooted in the existing power dynamics and socio-cultural dimensions. Finally, the methods and variables used in this study can be extended to other Himalayas regions as well to characterize farmer diversity and capture the differentiated needs in order to avoid the fixed "one-size-fits-all" solution for diverse climate change problems.

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