Consistency of local perceptions of climate change in the Kangchenjunga Himalaya landscape

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The Himalaya is experiencing rapid climate change that is likely to significantly impact local ecosystems, biodiversity, agriculture and human well-being. However, the scientific community has been slow to examine the extent and consequences of climate change. Local communities have been coping with environmental change since millennia. Thus they often have considerable knowledge about environmental change and means to cope with its consequences. We (a) examined the perceptions of local communities about climate change and its impacts on ecosystems, biodiversity, agriculture and livelihoods in the Kangchenjunga Himalayas region; (b) analysed the consistency of perceptions across geographical regions, and (c) assessed the conformity between local perceptions and scientific evidence. Our study is based on surveys conducted in 576 households, focus group discussions, key informant surveys and direct observations. The results show that people in the Kangchenjunga Himalayas region have considerable knowledge of climate change and its effects on the weather, ecosystems, biodiversity and agriculture. These perceptions are consistent across the region and conform to scientific findings.

Keywords: Climate change, Kangchenjunga, local perceptions.

THE Himalayas like many other places on earth are experiencing signs of rapid climate change. Weather has become unpredictable and erratic, snow is melting rapidly and water sources are drying up[1,2]. Glacier retreat and glacial lake outburst flooding (GLOF) are widespread throughout the region[3–6]. The Himalayas constitute one of the 34 global hotspots of biodiversity, and are the source of the 8 largest rivers in Asia. Being a watershed for the land masses of China, India, Bangladesh, Bhutan, Nepal and Pakistan, the region constitutes the lifeline of billions of people. Thus the consequences of climate change on biodiversity, agriculture as well as on human well-being are likely to be severe[1,7,8].

The impacts of climate change on biodiversity include shifts in geographical ranges of species[9–12], alterations in species composition of communities[13,14], changes in the time of phenology[15–18] and extinction of species[19–21]. Similar effects on biodiversity are also likely in the Himalayas, but there has been little attempt to systematically document such changes. Problems of climate change also vary in nature and intensity across large geographic regions, with higher regions, for instance, experiencing more rapid temperature rise[22,23]. Impacts on endemic and endangered species at high altitudes thus could be catastrophic as such species will simply 'blow off the top of mountains' in the face of global warming.

The effects of climate change on local livelihoods and well-being might be mediated through changes in agriculture and human health. Climate change affects phenology of crops, emergence of new agricultural pests and spread of new weeds in agriculture[7,24,25]. Organisms transmitting diseases can expand their ranges and adapt to higher altitudes[1,26]. Mosquitoes, for example, have been found at higher altitudes than they generally occur[27–30]. Although the pace of climate change in the Himalayas may be rapid and its impacts on nature and people severe, the scientific community has been slow to examine the extent and consequences of climate change. Climate change research in the Himalayas is meagre and has received scarce mention in IPCC reports and other scientific and policy discourses[31].

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Local communities have been coping with environmental change since millennia. Thus they often have considerable knowledge about environmental change and means to cope with its consequences[32,33]. Such knowledge can propel scientific inquiry and at the same time help design mitigation and adaptation measures to deal with climate change. Thus documentation of local knowledge about climate change is gaining popularity[34–37]. Nevertheless, such studies have so far remained largely descriptive or are based on small sample sizes or quick field observations[33]. Furthermore, in the Himalayas, south of China, there is scarce documentation about traditional knowledge concerning the impact of climate change on biodiversity even though the region is extraordinarily rich in biodiversity and traditional knowledge systems held by various ethnic groups.

Here we describe local or indigenous knowledge about changes in climate and potential impact of such changes on ecosystems, biodiversity, agriculture and livelihoods among local communities of Darjeeling hills and Ilam District of Nepal in the Eastern Himalayas. We address the following three questions: (1) What are the perceptions of local communities about climate change and its impact on biodiversity, agriculture and livelihoods? (2) How consistent are these perceptions across geographical regions? (3) What is the level of conformity between local perceptions and information obtained from modern scientific methods? Our work is unique in three respects. First, to the best of our knowledge, the study represents a comprehensive effort to examine local perceptions about climate change and its impact on ecosystems, biodiversity and agriculture in the Indo-Nepal Himalayas. Second, we analyse variation in responses across spatial scales to observe the consistency of responses across much larger geographic locations than any previous studies. Third, we present quantitative results obtained from large samples across geographical areas in India and Nepal. Elsewhere, we report spatial differences in local perceptions about climate change according to altitude and summarize local perceptions about change[2].

Study sites and research methods

Study sites

The study was conducted at three sites. The first site consisted of 11 villages located in and around Senchal Wildlife Sanctuary (situated between 26°56′N–27°00′N and 88°18′E–88°20′E, at an elevation of 1067–1600 m asl) and the southern belt of Singalila National Park (situated between 26°01′46″N–27°13′15″N and 88°01′51″E–88°7′54″E at an elevation of 2400–3660 m asl) in Darjeeling Hills, West Bengal, India. The second site was chosen from the northern belt of Singalila (situated between 26°31′N–27°13′N and 87°59′E–88°53′E) and consisted of 10 villages. Many of the villages were established by the Forest Department in the last century when the labourers were brought into forested areas for logging and conversion of natural forest into plantations of exotic conifer, *Cryptomeria japonica*. Some villages in the Singalila range have expanded recently, especially along the ridges, from a few households to many to meet the needs of the growing number of hikers. The third site was in Ilam District of Nepal (situated between 26°40′N–27°08′N and 87°40′E–88°10′E) and consisted of eight villages. The villages selected from Ilam site are situated along the country borders.

All villages occupy steep forested slopes that receive heavy rainfall during monsoon months of June–September. The annual rainfall in the regions exceeds 4000 mm. The evergreen forests largely consist of oaks, laurels, maples and *C. japonica*. Hardwood forests above 2800 m are gradually replaced by yew, spruce and fir that give way to rhododendron-dominated communities of small trees or shrubs. The ethnic composition consists of Rai, Limbu, Lepcha and Sherpa communities, with minor representation of Newar, Brahman, Chhetri and scheduled caste groups. In many villages, the land holdings are small, usually less than 0.5 ha. Since the forestry operations such as logging and conversion of forests into plantations have been stopped, the main source of income is agriculture supplemented by livestock or other sources such as wage labour, business, government services, pension and remittances.

Sampling and data collection strategies

At the first site, every single household was interviewed ($N_1 = 326$ households). From the second and the third sites, 30–100% households in a village, depending on the size of the village, were surveyed. The numbers were $N_2 = 121$ at the second site and $N_3 = 129$ at the third site. The selected households were interviewed using semi-structured questionnaire that included 18 indicators of climate change, and the responses were recorded separately for each indicator. The respondents were asked 'whether they have experienced, observed or witnessed the given climate change-related indicator' and allowed to choose one of the following three options: 'Yes, have experienced', 'No, haven't experienced' and 'Don't know about it'. Of the 18 indicators, we selected only 14 for a detailed analysis, following a 66% cut-off rule, meaning the indicators that were experienced by at least 66% respondents at least in one site were selected for further analysis[2].

Additionally, 10 focus group discussions (FGDs) were carried out with local elderly and knowledgeable persons both before and after the household interviews in 10 additional villages. The objectives of FGDs prior to interviews were mainly to refine the questionnaire and steer household-level interviews. The post-interview objective was to validate outcomes drawn from the household surveys and to supplement necessary information mainly on the nature of weather change and name of the species showing early flowering and range shift. In FGDs, local people were invited for a meeting (at the place where we generally stayed) to discuss about climate change and its consequences in the region.

To validate our results, we obtained temperature and precipitation data for Darjeeling hills, the town closest to the villages where we conducted household surveys, from National Climatic Data Center of NOAA Satellite and Information Service[38] and analyse general trends over the past. We also reviewed published reports and articles to supplement and validate our findings.

Data analysis

Data analysis was done by computing frequency and percentage of responses. The number of responses for 'yes', 'no' and 'don't know' was counted and converted into percentage in order to compare the number of individuals perceiving change and those not perceiving change. We considered all the sites (576 households from sites I–III) to calculate frequency of responses for the indicator included in the survey. Consistency of responses across the regions was analysed using chi-square statistics, for which only villages from site I (326 households from 11 villages) were included, because sites II and III represent different geographic, ecological and altitudinal zones; combining those two sites would possibly mislead the results.

We calculated the rate of change in temperature (1901–1996) and precipitation (1961–2000) from the recorded data to compare it with results obtained from surveys of local knowledge. To ease comparison, we grouped the data into year, month and season and then compared standard deviation of rainfall for different periods (1901–1950 versus 1951–2000; 1951–1975 versus 1976–2000; and 1971–1985 versus 1986–2000). In addition, we performed the Levene's test for equality of variances[39], which is used to test whether different samples have equal variances or homogeneity of variance.

Results

Local perceptions about change in weather patterns

We examined local perceptions for two climate parameters: overall warming and onset of spring (early March at low altitudes and late March at high altitudes), summer (early April at low altitudes and late April at high altitudes) and monsoon (early June). The analyses show that 84.4% of the people believe that the weather is getting warmer and nearly 78.6% believe that onset of summer and monsoon has advanced during the last 10 years. More than 40% of local people also claim that droughts are more frequent than before (Figure 1). The key informant surveys revealed that the nature and intensity of rainfall have become more erratic and unpredictable than before and that heavy but short-duration downpours have become more prevalent. Moreover, local people feel that the winter period is shrinking and summer is becoming longer. People also believe that there is less frost and winter is warmer than what it used to be 10 years ago. Several people also stated that 'the weather in *pahad* (hills) is becoming like the weather in *terai* or *madhes* (plain terai region)'. More details of perceptions gathered from the study sites are summarized by Chaudhary and Bawa[2].

The data also show that more than three-fourths of the local people believe that water sources are drying up and 60.2% of them feel that there is less snow in the mountains compared to the past. People in some areas have not

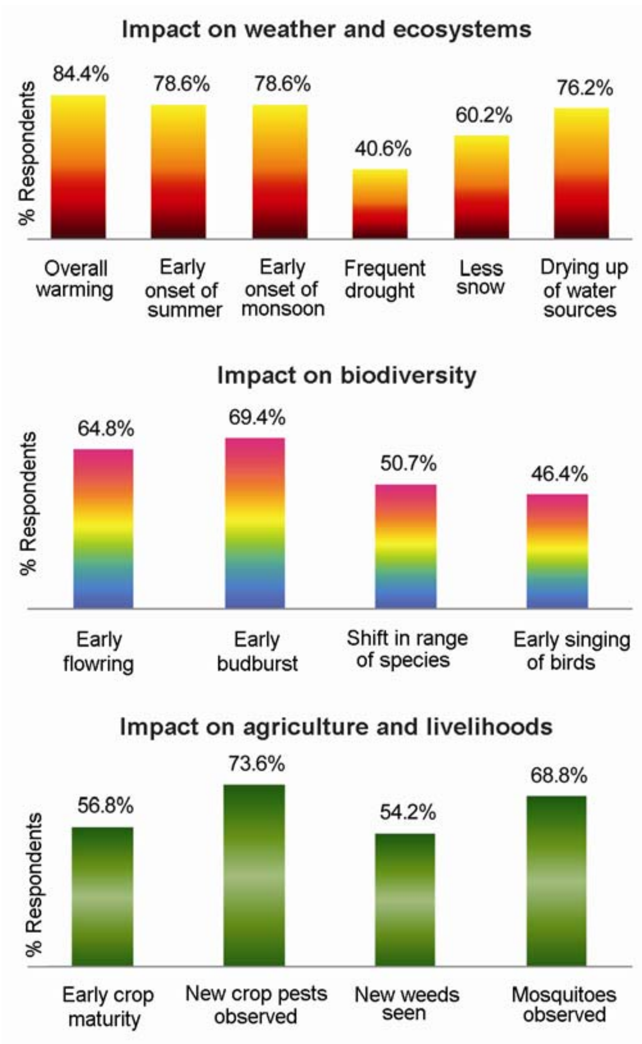

Figure 1. Percentage of people who have experienced or perceived changes in weather, precipitation, ecosystems, biodiversity and agriculture.

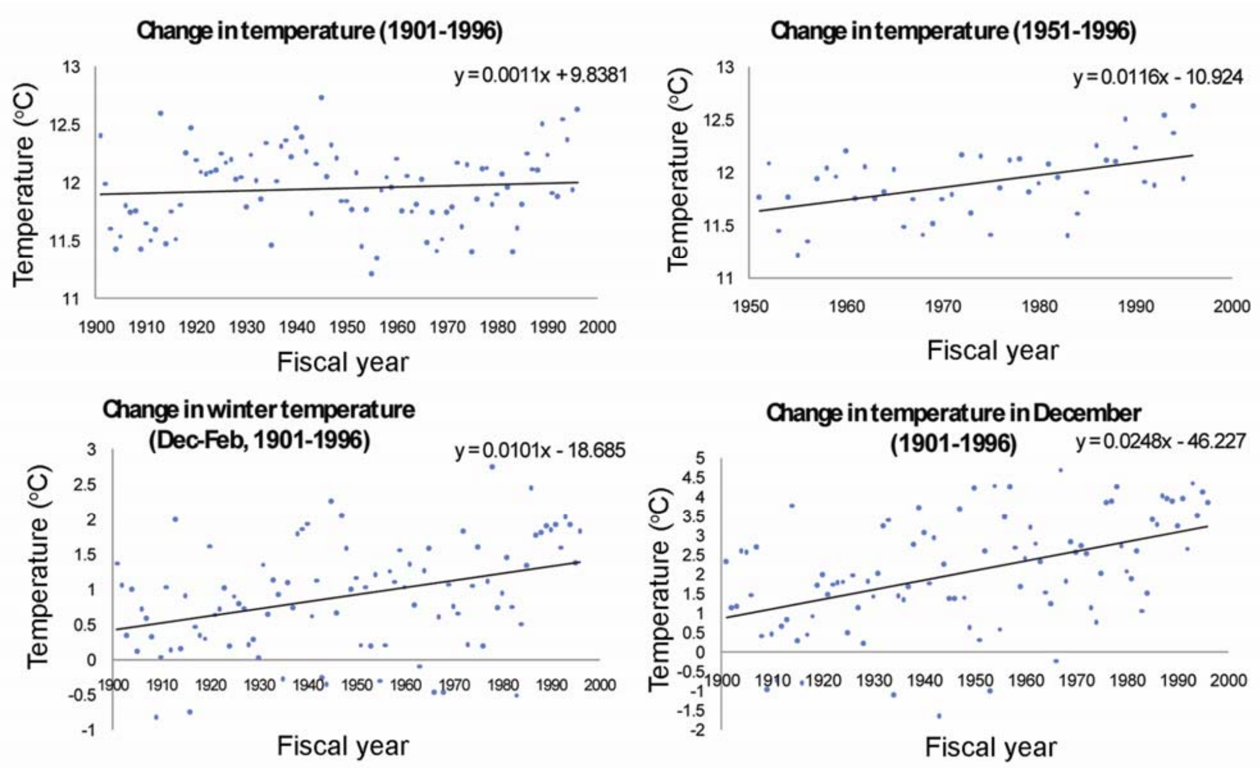

Figure 2. Temporal variation in temperature in the Darjeeling hills region.

observed snow in their villages for the last 5–10 years and several others firmly believe that the lowest points of snowfall have shifted upwards.

Data analysed from a secondary source show that average temperature in Darjeeling region has increased at the rate of 0.001°C per year in the period between 1901 and 1996, and at a faster rate since 1950s (0.01°C annually). Also, temperature during the winter season has increased much more (0.02°C annually) than other seasons (Figure 2).

Perceptions about biological responses to climate change

Phenology shift in some local species is evident from the experience of the respondents. Nearly 69.4% and 65% individuals respectively have perceived early budburst (sprouting of shoots) and early flowering that were advanced by 1–6 weeks. Species showing early flowering included magnolia (*Magnolia* sp.), rhododendrons (*Rhododendron* spp.), chrysanthemum (*Chrysanthemum indicum*), marigold (*Tagetes* spp.), peach (*Prunus persica*), plum (*Prunus cerasoides*) and some orchids (also see Chaudhary and Bawa[2]). Many people (46.4%) have observed birds starting to appear in their localities few weeks earlier compared to 5–10 years ago.

The survey revealed that slightly more than half of the respondents have perceived the range shift of certain species to higher altitude regions. In the subtropical region or lower hills, major wild plant species making their way upwards include aule katush (*Castanopsis hystrix*; 'aule' literally means tropical or humid climate regions), aule chilaune (*Schima wallichii*), jhingane (*Eurya acuminata*), nivara (*Ficus roxburghii*), uttis (*Alnus nepalensis*), gagoon (*Saurauia nepaulensis*) and siris (*Albizzia lebbek*) (also see Chaudhary and Bawa[2]). Several crop, vegetable and fruit species have also been introduced to higher altitudes, with better adaptability than a few years ago. Such cultivated species include chilli, tomatoes, ginger, winter potato, onion, radish, carrot, cauliflower, cabbage, beat, millet, wheat and cardamom.

Perceptions about impact on agriculture and human health

A total of 56.8% of the people experienced early ripening or maturity of their crops and vegetables. Approximately 73.6% and 54.2% of individuals respectively have seen new crop pests and new weeds in their fields. Crops like maize, cardamom and ginger are infected with a new disease like 'bhasme' (a virulent or pandemic disease). Local perceptions indicate that 68.8% of the people have been observing mosquitoes in their villages for the last 4–5 years, mainly in lower hills. Interestingly, some key informants reported that they have started seeing wild boar, deer and new species of wasps and bees in higher

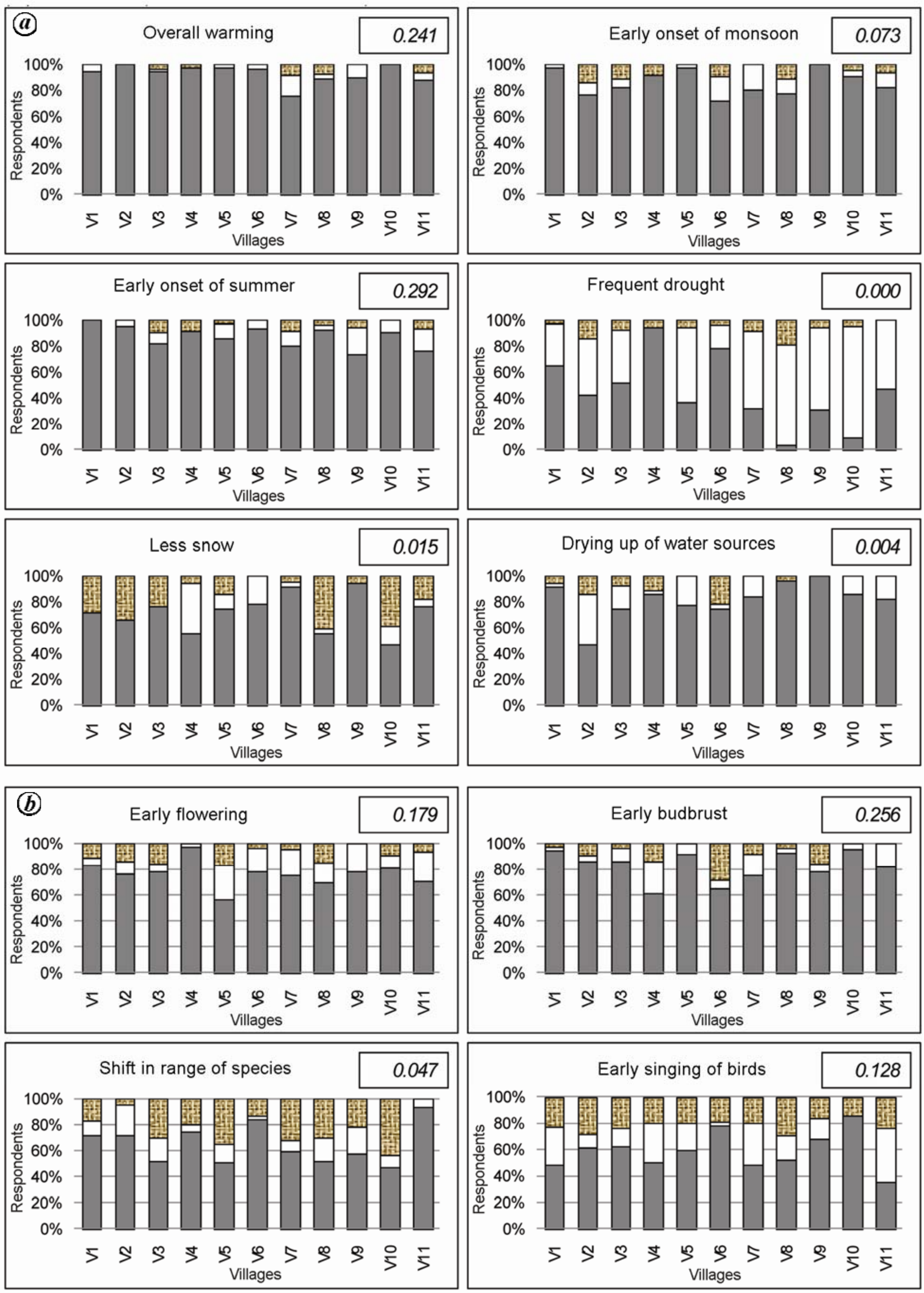

Figure 3. (*Contd*)

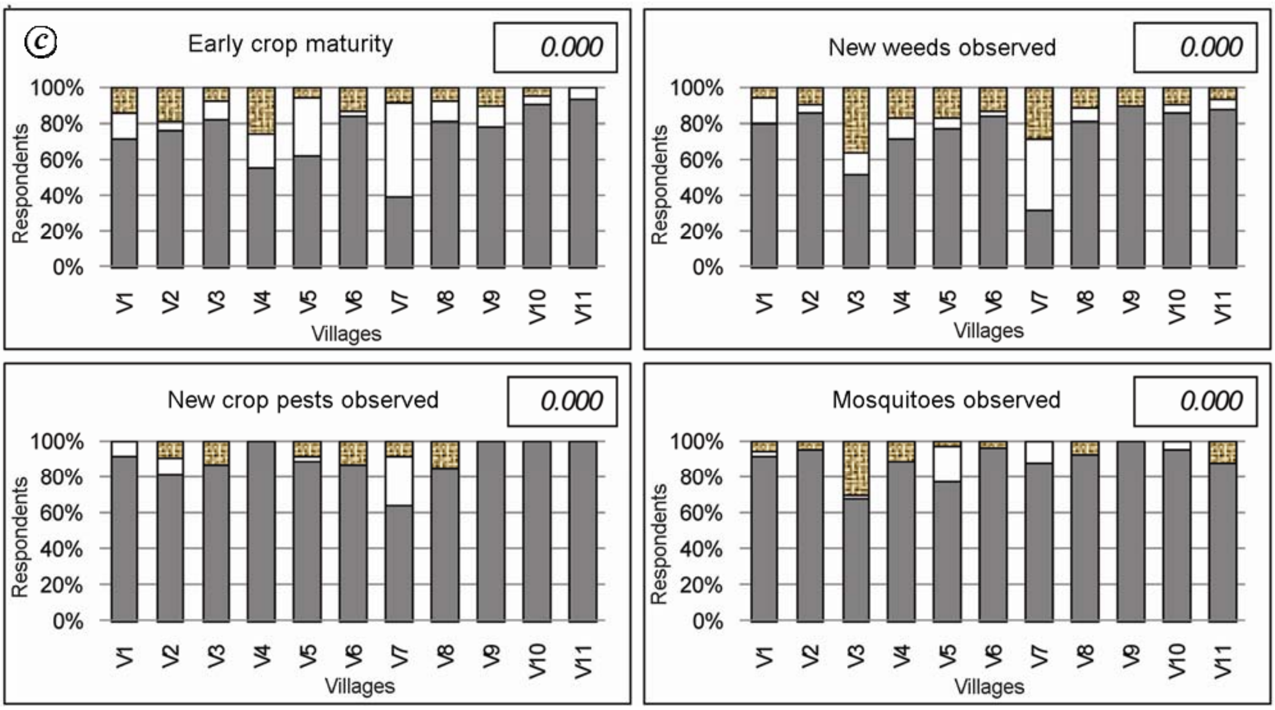

Figure 3. Consistency of local perceptions about the impacts of climate change (measured as percentage of individuals perceiving the given change) in 11 villages. ***a***, Consistency in weather and ecosystem-related indicators; ***b***, Consistency in biodiversity-related indicators; ***c***, Consistency in agriculture and livelihoods-related indicators. V1, Pokhritaar (25); V2, Koiligodam (37); V3, Rambi (33); V4, Upper Chatakpur (17); V5, Rampuria Khasmal (21); V6, Baukhola (35); V7, M1 (35); V8, Ghoom bhanjyang (21); V9, Lalung (56); V10, Chataidhura (19) and V11, Pubung (27). Numbers in parentheses are sample sizes for the respective sites. *P* values are shown in boxes.

altitudes than previously restricted altitudes. Human health has also been impacted. Several people have experienced skin-related diseases like ringworm, measles, prickly heat, etc. likely due to hotter climate, which was non-existent some 5–10 years ago.

Consistency of perceptions at spatial scale

The analysis showed that there is a high level of consistency ($P > 0.01$) across villages in two regions for eight indicators namely overall warming, early onset of summer, early onset of monsoons, less snow, early flowering, early budburst, shift in the range of species and early bird singing. Responses for the indicators such as frequent drought, drying up of water sources, early crop maturity, new crop pests, new weeds and appearance of mosquitoes were not consistent across the villages (Figure 3).

Discussion

Our survey involving 576 households makes it the largest such survey ever conducted in the Himalayas. Moreover, the results we obtained are consistent across space, and are in conformity with scientific findings. Below we first discuss some caveats and then key results.

Potential caveats in perception studies

Caution is necessary in conducting surveys and interpreting the results of participant surveys and responses. Both sampling (selection of sites and sampling of respondents) and non-sampling (phrasing of questions, choosing interview tools, and consistency in delivering questions and recording responses) errors can occur. Such errors can mislead science, policy and society. We minimized the errors in several ways. First, we drew the sample randomly from a larger population, but included every single household in case of small populations. Second, the questions were framed in a manner to reduce the probability of respondents making certain presumptions or showing biases. Third, to minimize interview bias and maintain consistency in interviewing and recording information, orientation was given to interviewers who collected data before they were deployed in the field. Peer reviews and post-edits were also done to reduce inconsistencies. Finally, local perceptions perceived through household surveys were compared with results from focus group discussions and key informant surveys in order to validate the results.

Perceptions about climate and weather change

Our study indicates that overall temperature is increasing, with a multitude of impacts on weather and precipitation,

Table 1. Comparison of rainfall patterns in the period between 1961–1980 (before) and 1981–2000 (after)

	SD (1901–1950 versus 1951–2000)			SD (1951–1975 versus 1976–2000)			SD (1971–1985 versus 1986–2000)		
Month	Before	After	Trend	Before	After	Trend	Before	After	Trend
May	652.57	764.98	+	819.42	719.96	–	768.98	774.12	+
June	1519.79	1232.80	–	1194.61	1235.00	+	878.55	1333.15	+
July	1570.51	1480.60	–	1569.61	1381.35	–	662.67	1351.26	+
August	1493.19	1838.04	+	1816.70	1891.35	+	610.88	1936.40	+
September	1337.69	1449.25	+	1296.15	1553.47	+	1300.21	1614.91	+

SD, Standard deviation.

Table 2. Levene's test of homogeneity of variances in different time periods (data were grouped in 5-yr interval)

	Levene statistics (*P* value)				
Month	1901–2000	1926–2000	1951–2000	1971–2000	1981–2000
May	1.634 (0.078)*	1.795 (0.067)*	2.887 (0.019)*	4.425 (0.019)**	18.128 (0.003)**
June	1.446 (0.141)	1.063 (0.409)	2.288 (0.052)*	2.538 (0.093)*	0.255 (0.627)
July	1.111 (0.361)	1.586 (0.117)	1.475 (0.212)	1.125 (0.368)	0.146 (0.712)
August	1.946 (0.027)**	2.303 (0.016)**	3.885 (0.004)***	13.437 (0.000)***	9.455 (0.015)**
September	2.208 (0.011)**	2.807 (0.004)***	4.378 (0.002)***	5.705 (0.007)***	15.875 (0.004)***

*Significant at 10% significance level; **Significant at 5% significance level; ***Significant at 1% significance level; Figures in parentheses are *P* values.

snowfall, glacial retreat, and water availability. Less severe winter and advancement of summer and monsoons perceived by the local people indicate that temperature is rising in winter and the duration of winter is becoming shorter. Decline in snowfall and reduction in severity of frost are also a sign of warmer climate or temperature rise. There is less snow in the mountains and intense but short episodes of rainfall are increasing run-off, causing poor accumulation and recharge of water in soil, thereby resulting in the drying up of water sources.

Studies from different parts of the Himalayas also indicate temperature rise, shift in seasons, reduced severity of cold during winter and changes in the number of cloudy days; changes in timing, magnitude, and intensity of both rainfall and snowfall[1,32,33,40–43], but no study has examined variation in all these parameters in one geographical area.

Ecological knowledge in relation to climate science held by the indigenous people has also been documented from other parts of the world, mainly North America and Europe[37,44,45]. These studies have looked at 'native oral tradition' or indigenous knowledge[46] to assess changes in local climate.

Local perceptions about climate change are supported by scientific data. Our analysis of secondary data shows an increase of average temperature throughout the last century at the rate of 0.001°C annually. This increase was faster in the second half of the century (0.01°C annually) than the first half. Furthermore, the temperature rise was much more in winter than in other seasons. Sharma *et al.*[1] have shown that temperature in the Eastern Himalayas has been increasing annually by 0.01–0.04°C in winter (December–February) since 1970. They have also suggested that the mean annual temperature will increase by 2.9°C by the middle of the century and by 2.9–4.3°C by 2080, with a possibility of greater rate of increase during winter (3.5–5.35°C) than summer (2.8–3.8°C). Shrestha and Devkota[22] have also found an increasing trend in temperature, especially above 4000 m in eastern Nepal and eastern Tibet, that are close to our study site. Shrestha and Bawa[47] have calculated that temperature in the entire Himalayas is increasing at the rate of 0.06°C/yr.

For rainfall, Sharma *et al.*[1] project an annual increase of 18% by the middle of the century and 13–34% by the end of the century. Tse-ring *et al.*[48] have suggested that trend of increase in precipitation is greater during the winter (22–35%) than the summer (17–28%). Similar trends and projections of temperature have also been reported by others for the Eastern Himalayas[47,49] and the Western Himalayas[50]. The available results are, however, subject to verification as 'poor data availability coupled with geographic complexities' create difficulties in interpretation of data[1].

We are unable to confirm the perception of 'erratic' rainfall by the people. Erratic rainfall may mean greater variance or dry spells interspersed by heavy downpour[2]. We analysed rainfall data and found that Levene's test for equality of variances shows a significant change in rainfall pattern over time, mainly in May, August and September (Tables 1 and 2), suggesting that rainfall pattern was not uniform throughout the last century. Nevertheless, available data are not sufficient to firmly confirm whether the trend is linear over time.

Effects on biodiversity

In our analyses, early budburst or onset of growing season and early flowering were common perceptions. Migration of birds in spring might have also shifted earlier because many people believe that the time of bird singing has shifted earlier. The effect of climate on physiological growth and breeding behaviour of plants and animals, such as shift in flowering, breeding season, laying date, and bird singing, has been documented in many other parts of the world[15–18,43,51–55]. In contrast to the common observation of early flowering, Yu *et al*.[18] have recently noted a reverse trend of late flowering in high altitudes of the Tibetan Himalayas. Clearly, the impacts of climate change may vary depending upon species and location[16].

Our data also show that certain species that are perhaps highly sensitive to temperature change have started shifting to higher altitudes. Range shifts of species are considered common responses to climate change[9,14]. Trees experiencing 'stronger winter warming' and those with 'diffuse form' are assumed to be more responsive to climate change, and likely to shift their ranges (see ref. 56 for more details). Together with the movement of certain plants, insects, birds and animals might also be shifting their ranges[9,11,57]. Indeed in our study sites wild boar, deer and new species of birds and bees are being sighted at higher altitudes.

Effects on agriculture and livelihood

Our study has shown that some crops in the Himalayas now ripen sooner compared to those in the past. Local people have also observed new crop pests and weeds in their farms. The early ripening combined with new agricultural pests and spread of invasive plant species can decrease crop yields. Early ripening of crops observed by people is consistent with early onset of flowering and growing season observed in wild plants both by the local people and scientists[15–17]. The potential impact of climate change in the decline of crop yield – both short term and long term – is due to proliferation of weeds and pests[43,58,59]. The tropical and subtropical countries are expected to experience more loss in yield compared to the higher latitude regions[60,61].

People in high Himalayas can now grow new crops (cauliflower, cabbage, chilli, tomatoes, ginger, winter potato, onion, radish, carrot, beat, millet, wheat and cardamom) which they could not before. Such a shift of crops can enhance crop diversity, increase overall crop yield (combined for all crops) and diversify local diets in higher altitude and latitude regions[61]. This can mitigate the effects of climate change on livelihoods and help people adapt to change[62,63].

Climate change will not only affect crop health but will also have serious impacts on human health. Skin diseases infecting local people might be the result of their exposure to the scorching heat. It is likely that the presence of mosquitoes at high altitudes can introduce new diseases such as malaria in the hilly regions, as observed elsewhere[1,30,42].

Consistency and variation in perceptions

Consistency of responses for overall warming, early onset of summer, early onset of monsoon, less snow, early flowering, early budburst, shift in range of species, and early bird singing suggests that these changes are widespread throughout the region. The responses were inconsistent for other indicators, which supports the findings of Byg and Salick[33] for Tibet. It is likely that some changes are confined to specific locations. Scientific data for snow and glacier melting in the Himalayas also show considerable spatial variation[64,65]. Local interactions with people indicate that aspects of slopes (northern or southern) may also affect responses. Differences in age, gender, education, occupation and access to information (radio, television and newspaper) of the individuals responding to our questions might also have affected the nature of responses. For instance, perceptions of farmers and non-farmers might be different, because the former interact directly with nature to perform their day-to-day activities and thus might be more aware of the changes than the latter. A detailed analysis, however, is needed to understand variation in responses.

Conclusions

Local communities in the Himalayas seem to have extensive knowledge about climate change and its impacts on agriculture and biodiversity. Moreover, their knowledge conforms to the findings generated by modern science in different parts of the world. Local knowledge about climate change can play a critical role in developing adaptation and mitigation measures, particularly in the regions where data are meagre and climate change is rapid. Such knowledge can also advance research by helping scientists address new questions or formulate scientific hypotheses[66], especially in the Himalayas for which data are scarce and knowledge must be accumulated quickly. For example, on the basis of local perceptions reported here researchers can formulate hypotheses about cropping patterns, phenology and shift in distributional range of species and human diseases. Local knowledge also has an important role in managing and monitoring local ecosystems as well as agro-ecosystems[67]. Emphasis on documentation of local knowledge and its use in policy and decision-making about climate change can have a significant impact on managing the effects of climate change.

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Erratum

Global malaria burden and achieving universal coverage of interventions: a glimpse on progress and impact

Rajni Kant

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On page 290, third line in Box 3 should read:
Before 1953: Estimated malaria cases in India – 75 million and deaths, 0.8 million.