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# Local perceptions of climate change validated by scientific evidence in the Himalayas

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**The Himalayas are assumed to be undergoing rapid climate change, with serious environmental, social and economic consequences for more than two billion people. However, data on the extent of climate change or its impact on the region are meagre. Based on local knowledge, we report perceived changes in climate and consequences of such changes for biodiversity and agriculture. Our analyses are based on 250 household interviews administered in 18 villages, and focused group discussions conducted in 10 additional villages in Darjeeling Hills, West Bengal, India and Ilam district of Nepal. There is a widespread feeling that weather is getting warmer, the water sources are drying up, the onset of summer and monsoon has advanced during last 10 years and there is less snow on mountains than before. Local perceptions of the impact of climate change on biodiversity included early budburst and flowering, new agricultural pests and weeds and appearance of mosquitoes. People at high altitudes appear more sensitive to climate change than those at low altitudes. Most local perceptions conform to scientific data. Local knowledge can be rapidly and efficiently gathered using systematic tools. Such knowledge can allow scientists to test specific hypotheses, and policy makers to design mitigation and adaptation strategies for climate change, especially in an extraordinarily important part of our world that is experiencing considerable change.**

**Keywords:** local perceptions; climate change; Himalayas; local knowledge; biodiversity

## 1. INTRODUCTION

There are a few regions in the world where climate change might be as rapid as in the Himalayas, and even fewer where the consequences of climate change are likely to be as severe for biodiversity, ecosystems services and human well-being. The Himalayas, one of 34 global hotspots of biodiversity [1], and with about 15 000 glaciers—the highest concentration in the world—are a source of Asia's eight largest rivers. More than 750 million people living in the Himalayas, and more than 1.4 billion inhabiting the river basins of

the five major Asian rivers (Indus, Ganges, Brahmaputra, Yangtze and Yellow Rivers), are likely to face consequences of climate change occurring in the region [2]. Despite the immense likely environmental, economic and social costs of climate change, reliable information about the extent and magnitude of climate change and its consequences in the Himalayas are not well known.

Indigenous knowledge held by local communities about climate change can benefit climate science and policy [3–5]. Recent studies on indigenous knowledge have examined perceptions about climate change [6–8] in Tibet, the Eastern Himalaya and the Western Himalayas [9–13], but those studies mostly report qualitative and descriptive results based on a small number of respondents, and do not examine impacts on biodiversity.

Here, we report, for the first time, indigenous knowledge about climate change and its consequences for biodiversity and agriculture in the Himalayas using a large number of households. We address three questions: (i) what are the perceptions of local people about climate change in the Himalayas? (ii) How do the perceptions vary with the altitude? (iii) Are the perceptions consistent with scientific findings reported from diverse regions of the world?

## 2. MATERIAL AND METHODS

The details of methods are provided in the electronic supplementary material, S1. We conducted household surveys in 10 villages located in and around Singalila National Park in Darjeeling Hills, West Bengal, India and eight villages in Ilam district of Nepal that are situated between 1517 and 3121 m.a.s.l. (see the electronic supplementary material, figure S2). Following LRMP [14] and Dobremez [15], the villages were grouped into two categories: low altitude (approx. 1000–2000 m.a.s.l.) and high altitude (approx. 2000–3000 m.a.s.l.). The study sites have been inhabited for generations by indigenous peoples like Rai, Limbu, Lepcha, Sherpa, Newar and Tamang and other ethnic communities that migrated later.

We collected responses from 250 individuals on 18 indicators of climate change using semi-structured questionnaires and recorded responses for each indicator separately. The respondents were asked 'whether they have experienced, observed or witnessed the given climate-change related indicator'. Three options provided to responses included 'Yes, have experienced', 'No, haven't experienced' and 'Don't know about it'. We also conducted focus group discussions (FGDs) in 10 villages that were different from 18 villages sampled for household surveys, but in the same area. The purpose of the FGDs was to test the validity of household responses by assessing the concordance of results obtained from the two approaches. All available people were invited to houses where researchers generally stayed and which often serve as traditional places for people to meet for other purposes as well.

We analysed household data by calculating frequencies and percentages of responses for each indicator included in the survey. Although we recorded responses for 18 different indicators, nine indicators that were experienced by at least 66 per cent households at least in one site were considered for further analysis (table 1).  $\chi^2$ -tests were used to test the consistency of the responses for high- and low-altitude regions. The responses from FGDs were not analysed because the data were descriptive in nature and in line with the quantitative data collected from household surveys. However, the qualitative responses are presented as summary table (see the electronic supplementary material, figure S4) and discussed below.

The research reported here was done as a part of a larger community-based conservation project, in which Ashoka Trust for Research in Ecology and the Environment (ATREE, [www.atree.org](http://www.atree.org)) has been engaged in research for the last 10 years. All information that is collected is shared with local communities, and the communities understand and agree that some of this information, particularly non-proprietary knowledge, over which no individual or a particular community has intellectual property rights, may be published.

## 3. FINDINGS

Our analysis shows that 73.2 per cent of people believe the weather is getting warmer, 67.2 per cent believe

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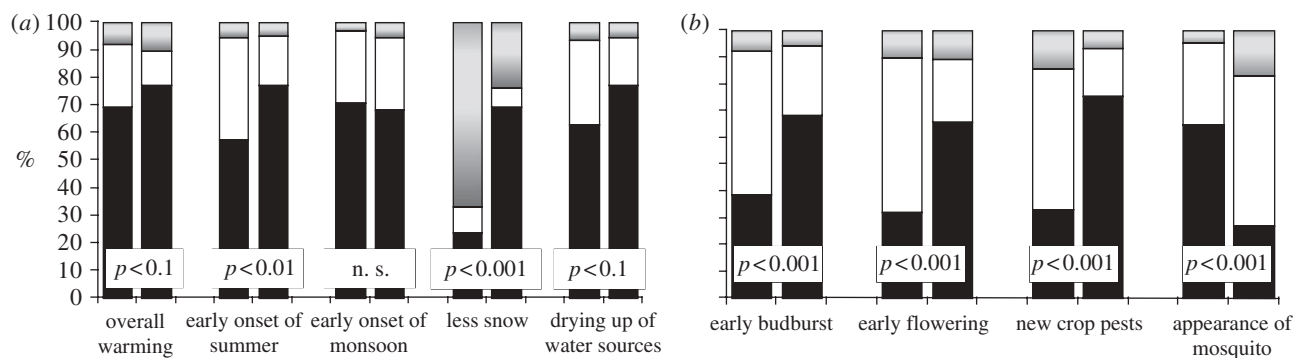


Figure 1. Comparison of responses for (a) low-altitude and (b) high-altitude regions (black, yes; white, no; shaded, do not know) ( $n = 127$  for low-altitude and 123 for high-altitude regions);  $p$ -values are shown in boxes.

Table 1. Indicators included in the survey and selected for reporting and response for each indicator. HA, high-altitude region; LA, low-altitude region; shaded rows, eliminated indicators.

indicators	Mirik (LA)	Samalbung (LA)	Rimbik (HA)	Jaubari (HA)	average for LA	average for HA	average for four sites
overall temperature rise	67.21	72.73	86.67	68.25	69.3	77.2	73.2
early onset of summer	57.38	57.58	71.67	82.54	57.5	77.2	67.2
early onset of monsoon	60.66	80.30	55.00	80.95	70.9	68.3	69.60
less snow	34.43	13.64	43.33	93.65	23.6	69.1	46
drying up of water sources	67.21	59.09	73.33	80.95	63	77.2	70
early budburst	40.98	36.36	66.67	69.84	38.6	68.3	53.2
early flowering	32.79	31.82	65.00	66.67	32.3	65.9	48.8
new crop pests	22.95	42.42	76.67	74.60	33.1	75.6	54
mosquitoes observed	40.98	86.36	50.00	4.76	64.6	26.8	46
increase in frequency of drought	19.67	7.58	36.67	58.73	average figures for these variables are not shown here because those are not included for further analysis.		
shift in range of species	22.95	65.15	21.67	23.81			
new species observed	6.56	22.73	1.67	9.52			
change in species composition	0.00	37.88	1.67	1.59			
early bird singing	26.23	21.21	33.33	39.68			
early bearing of offspring in the year	9.84	4.55	10.00	9.52			
early crop maturity	40.98	33.33	35.00	33.33			
new weeds	6.56	53.03	31.67	30.16			
new human diseases	8.20	1.52	0.00	0.00			

that the onset of summer and monsoon has advanced during the last 10 years; furthermore, 46 per cent believe that there is less snow on mountains than before and 70 per cent think that water sources are drying up. FGDs reveal that there is less frost, winter is less severe and shorter, the nature and intensity of rainfall have become more erratic and unpredictable and short-duration downpours have become more frequent than before. Additional responses collected through FGDs are provided in the electronic supplementary material, figure S4.

In terms of consequences for biodiversity and agriculture, 53.2 and 48.8 per cent of respondents noted that budburst and flowering, respectively, have advanced in several species (*Magnolia* sp., *Michelia champaca*, *Rhododendron* spp., *Chrysanthemum indicum*, *Agetes* spp., *Prunus persica* and *Prunus cerasoides*) by one to six weeks. At one site (Samalbung), the percentage of people observing shifts in distribution of species came very close (65.15%) to our cut-off point. Species that are presumed to have shifted their ranges upwards

include *Castanopsis hystrix*, *Schima wallichii*, *Eurya acuminata*, *Ficus roxburghii*, *Alnus nepalensis*, *Saurauia nepaulensis* and *Albizia lebbek*. A total of 54 per cent respondents observed new crop pests, 38.8 per cent noted new weeds (e.g. abijal and banmara) and 46 per cent have recently observed mosquitoes in their villages. Several people have observed that low-altitude crops can now be grown at high altitudes.

There were significant differences ( $p < 0.1$ ) between low and high altitudes with more people at high altitudes believing in overall warming (77.2% versus 69.3%), early onset of summer (77.2% versus 57.5%), decrease in snow (69.1% versus 23.6%), drying up of water (77.2% versus 63%), early flowering (65.9% versus 32.2%), early budburst (68.3% versus 38.6%) and new crop pests (75.6% versus 33.1%) than people at low altitudes. Conversely, significantly more respondents at low altitudes believed in early onset of monsoon (70.9% versus 68.3%) and observations of mosquito (64.6% versus 26.8%) than people at high altitudes (figure 1). The findings from household

surveys were consistent with results from FGDs (electronic supplementary material, figure S4).

#### 4. DISCUSSION AND CONCLUSIONS

Local knowledge is consistent with scientific observations. Sharma *et al.* [12] have reported a temperature rise in the Eastern Himalaya region mainly in January, February and March (0.01–0.04°C annually). They also project that by the middle of the century, mean temperature will increase by 2.9°C by 2.9–4.3°C annually. Annual precipitation is also likely to increase by 18 per cent by the middle of the century and 13–34% by the end of the century [12]. Our own analyses of climate data from the study region confirm increases in temperature and rainfall [16]. We do not know if the onset of monsoons has advanced. Perceptions about rainfall becoming ‘erratic’ also warrant further investigation. ‘Erratic’ rainfall may mean variable precipitation patterns and heavy downpours.

Similarly, research has revealed early budburst (leafing out) and flowering in many other parts of the world [17–20]. Phenology will continue to be affected in the Himalayas if the climate gets warmer as projected by IPCC [21]. Shifts in the distributional ranges of many species have also been observed by scientists [22–24]. It is also likely that agriculture will be affected by water stress and these problems might be further compounded by new weeds and pests, as observed for apples in the Western Himalaya region [9]. Increase in mosquitoes and their impact on human health have been observed in other regions [25]. The differences in responses between low and high altitudes may be due to differential change. Temperature rise has been observed to be more rapid in high-altitude as compared with low-altitude regions [26], especially above 4000 m [27] with potentially greater impact on vegetation in the former [28].

This is the first systematic study analysing impacts on biodiversity and agriculture based on a very large sample, from the Himalayas, demonstrating widespread climate change and with possibly differential impacts at different altitudes. Local knowledge can be rapidly and efficiently gathered using systematic tools, and it can provide a jump start to scientists for testing specific hypotheses and to decision and policy makers for designing mitigation and adaptation strategies for climate change in a region that is of global significance and undergoing rapid change but for which scientific data are meagre.

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