Adaptation Policy and Community Discourse of Climate Change in the Mountainous Regions of India

Anshu, Vijendra Kumar Pandey, and Preeti Tewari

Abstract Global climate change is attributed to the increase in greenhouse gas emissions due to industrialisation. Scientists and policy makers are continuously debating on ways to halt global warming. The increasing frequency of disasters as a consequence of this change has had a considerable impact on the livelihoods of people, especially in mountainous regions. Rural communities need to adapt to climate change through adaptation, mainly in their agricultural practices. This paper seeks to examine if there are consistencies in the adaptation programmes of climate change and community response. At the grassroots level, the practical implementation of public policies is thwarted by incoherent and distorted ideologies. Community discourse on climate change is relevant for formulating public policy on adaptation strategies. Diverse ecological and physiographic regions require adaptation policies suited to their unique characteristics. A complete understanding of the adaptation concept requires empirical analysis in different environments. In the present study, quantitative and qualitative methods have been used to understand community response to climate change in the villages of Bhilangana and Bhagirathi basins in Uttarakhand. The study reveals that the involvement of the community is paramount to understanding the adaptation discourse and processes to be undertaken for making policy decisions. There is a need for government involvement in the integration of disaster risk reduction strategies and the climate change adaptation measures in this vulnerable Himalayan Mountain ecosystem. Planning for transformation in agricultural practices can succeed only with due consideration for community needs.

Keywords Community participation · Climate change adaptation · Mountain · Public policy

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1 Introduction

The earth is known as the Goldilocks planet as it has just the right temperature to allow a large amount of water to exist in the liquid form. This is as much because it is neither too close nor too far from the sun as it is because of the composition of its atmosphere. The presence of certain key gases in the right amounts is crucial in maintaining the energy budget of the planet. That the atmosphere induces the greenhouse effect by retaining some of the heat received from the sun was first suggested by the French scientist Joseph Fourier in the 1820s (although he did not use the term greenhouse effect). In 1859, the Irish physicist John Tyndall identified water vapour and carbon dioxide as the two atmospheric gases responsible for trapping radiation. Towards the end of the nineteenth century, Svante Arrhenius first put forth the idea that the combustion of fossil fuels by humans would release carbon dioxide into the atmosphere in quantities large enough to raise average global temperatures. However, he thought that the outcome of warming would be of benefit to humanity. That the earth was indeed becoming warmer was established in 1938 by Guy Stewart Callender through his study of temperatures recorded over five decades. However, little attention was paid to scientists raising alarm over warming earth. By the 1980s, the problem had assumed proportions so large that it was no longer possible to ignore it. The community of nations responded by setting up an Inter-governmental Panel on Climate Change (IPCC) in 1988. The First Assessment Report published by the IPCC in 1990 confirmed the role of the emission of greenhouse gases by humans in raising global temperatures by 0.3–0.6 °C in the preceding hundred years.

Faced with incontrovertible evidence about the reality of climate change, the focus has now shifted from whether it is happening to how fast it is happening, what its effects are likely to be, and whether we can do anything to mitigate its impact. Some effects have already become evident. For instance, the onset of phenological spring happens earlier than before while the onset of phenological autumn is delayed. Melting of polar and mountain glaciers and the subsequent rise in sea levels too have already been observed. On the basis of inputs from scientists and experts around the world, the IPCC has predicted an increase in the frequency of extreme weather events, leading to loss of lives and livelihoods. They will also threaten food security in vulnerable populations and act as conflict multipliers (IPCC 2021). Rising sea levels will lead to the submergence of fertile coastal lands, displacing large numbers of people as coastlines migrate inland. Changing atmospheric and oceanic temperatures will induce changes in the movement of winds and ocean currents. This in turn will lead to alterations in the spatial and temporal distribution of precipitation. However, our current understanding of the likely effects of climate change is far from perfect, and "unanticipated effects from a globally warmed world will undoubtedly occur" (Raven et al. 2013).

Changes in the form and distribution of precipitation is one of the crucial factor determining the effects of climate change. Though predicting changes in precipitation is more difficult than predicting changes in temperature, some outcomes can be predicted with a reasonable degree of certainty. Warmer air has a greater capacity to retain moisture, but the additional moisture will not be distributed equally across the globe. Redistribution of precipitation will lead to an increased frequency of droughts and floods in different parts of the world. Scientists also anticipate a decrease in the number of rainy days even in areas where the annual average rainfall remains unchanged. This means that more precipitation comes in the form of single-day events, with prolonged dry spells potentially causing more damage to crops, more soil erosion and increasing the risk of floods (EPA 2021). By modifying the hydrological cycle, global climate change creates stress in freshwater ecosystems (Oki and Kanae 2006). Huge reductions in the size of water bodies impact the availability of water for drinking and agriculture. Climate change adversities thus become the cause of the large-scale displacement of populations that lack safeguards against them. By affecting access to education, food, healthcare and safety, such displacement will put the future of vulnerable groups, especially children, at stake. While the impact of climate change will be universally felt by all individuals, the existing and future threats are greatest for people engaged in primary activities such as fishing and agriculture. Alterations in the biophysical conditions that affect the growth of crops will require massive adjustments by farmers if the productivity of farmlands has to be maintained. This means that cropping patterns and cropping calendars will have to change in accordance with changing temperature and precipitation patterns in order to build resilience against climate change.

At the COP 21 in Paris in 2015, parties to the UNFCC pledged to contain the rise in global temperatures by the end of the current century to within 2 ºC of the pre-industrial levels, and if possible, even to 1.5 ºC. The 2 °C target can only be met if renewable sources of energy are developed to reduce the dominance of fossil fuels. At present, renewable energy sources contribute about 25% to the world's energy needs but their use is expanding very rapidly. Technological advancements, increased competition, and support from government policies have resulted in significant cost cutting in the renewable energy sector. The deployment of renewable energy has outpaced other sources of energy. There is a further need to sustain and increase the momentum of growth to achieve the dream of a carbon free world. As action to reduce emissions has thus far been short of targets, it is best to understand the nature of changes and devise suitable adaptive strategies.

2 Impact of Climate Change in Mountain Areas

Fragile ecosystems such as mountains are especially vulnerable to the effects of climate change. In fact, the earliest evidence of climate change has come from these areas. "Many scientists believe that the changes occurring in mountain ecosystems may provide an early glimpse of what could come to pass in lowland environments, and that mountains thus act as early warning systems" (Kohler and Maselli 2009). Increasing temperatures cause the snowline to rise. As snow-covered areas become snow free, the albedo changes and the reduced reflectivity of snow and ice free mountain surfaces will cause more insolation to be absorbed by the earth-atmosphere system. This positive feedback mechanism will cause further warming of the system, exacerbating the impact of global warming. The reduction in snow accumulation zones and the retreat of glaciers will bring changes in the flow of water in snow-fed rivers. This will pose a threat to humans as well as to wildlife. As more precipitation begins to fall in the form of rain rather than snow, the timing of runoff will change. More water will flow into streams and rivers immediately after rainfall while the flow will dwindle soon afterwards. This will significantly affect the efficiency of existing water storage and delivery infrastructure (Summers 2019). River systems dependent on melt water from mountain glaciers provide freshwater to nearly half the world's population, making mountains the water towers of the world. Ten large Asian river systems originate from glaciers in the Hindukush and Himalayas, meeting the water requirements of a fifth of the world's population (UNEP 2016). Changes in the flow of water in these river systems will have severe implications on the lives and livelihoods of people who depend upon them. Some changes are already evident. A study shows that the changing dynamics of the melt water have had a considerable impact on the nature of river flow in the Himalayas. (Bookhagen and Burbank 2010). There may be an overall increase in the stream flows in response to these changes but the effects will vary spatially and temporally across the Himalayas. An increase will be observed in wet monsoon months and a decline in the dry months, thereby impacting the water availability for human usage and agricultural activities.

Climate change will also exacerbate dangers from a variety of hazards. Fluctuations in temperature could cause unseasonal frost which would damage crops. Melting glaciers and permafrost will cause rocks and soil to become loose and prone to displacement, causing rock falls, debris and mud flows. The occurrence of rain on settled ice or snow causes it to melt, increasing the risk of flash floods. Flash floods also result from the sudden release of water from lakes formed by meltwater from glaciers (glacial lake outburst floods). Intense precipitation from towering clouds (cloudbursts) is yet another cause of flash floods. Heavy precipitation also triggers landslides, wreaking havoc in affected areas. A precursor to what lies ahead was witnessed in Kedarnath in Uttarakhand in 2013 when flash floods devastated the area, causing loss of human and animal lives and widespread damage to property and infrastructure. It must be remembered that mountains vary greatly in terms of location, shape, extension, altitude and other characteristics, the impact on each of them will be different. Variations in topography within a mountain will further add complexity to the exact nature of change. However, certain broad similarities exist in the pattern of change. The next section of this paper presents an analysis of changes in climate observed in two important river basins in the Himalayas.

3 Research Methodology

Several studies have highlighted the impact of change in climate on human lives and how communities are coping with this altered scenario through modifications in their livelihood and agricultural practices. The purpose of the present study was to understand these changes in a mountainous region in India, using a mixed methodology in which both qualitative and quantitative data were collected. Uttarakhand, a Himalayan state in India, has great altitudinal variations, making it ideally suited for understanding the impact of climate change in varying settings, and for the formulation of a suitable policy. A detailed study was carried out in the basins of the Bhagirathi and Bhilangana rivers. Five villages were selected from each basin. The selection of villages was done with due consideration for variations in altitude. Residents in the selected villages were interviewed to generate primary data. Questions were designed to elicit information pertaining to strategies adopted to cope with changes induced by climate change. The objective was to study variations in the adaptive strategies devised in villages at different heights as climate change has led to variability in rainfall patterns and the flow of meltwaters from glaciers. The base level survey in these villages helped in the mapping of the community perception. Various Government of India Reports, Reports of Uttarakhand State Government, Census of India, 2011, District Census Handbooks, Uttarakhand, Reports of ICIMOD were also consulted to gain a better understanding of the problem and arrive at appropriate conclusions.

4 Study Area

The state of Uttarakhand was carved out of the state of Uttar Pradesh in 2000 and can broadly be divided into the two geographic regions of Garhwal and Kumaon. Of its 13 districts, four districts have a considerable proportion of plain area. These are—Haridwar, Dehradun, Nainital and Udham Singh Nagar. The remaining districts of Pauri, Tehri, Chamoli, Uttarkashi and Rudraprayag in the Garhwal region and Almora, Pithoragarh, Champawat and Bageshwar in the Kumaon region, have a hilly terrain. Due to variations in physiography and relief, these districts show a great deal of variation in livelihood patterns as well as in agricultural practices (Fig. 1, Tables 1 and 2).

5 Results and Discussion

Altitudinal and physiographic variations in the Bhagirathi and Bhilangana Basins have an impact on the climatic characteristics, water resources and consequently in agricultural patterns in different parts. In order to capture these variations, 10 villages were selected, 5 from each of the two basins. The basins were divided into three altitudinal zones, and at least one village was selected from each altitudinal zone (Table 3).

The residents in each village were asked questions about changes observed in temperature, rainfall, water availability (discharge in rivers and springs) and whether these changes had an impact on their traditional agricultural practices. The findings were analysed and are summarised in the following sections.

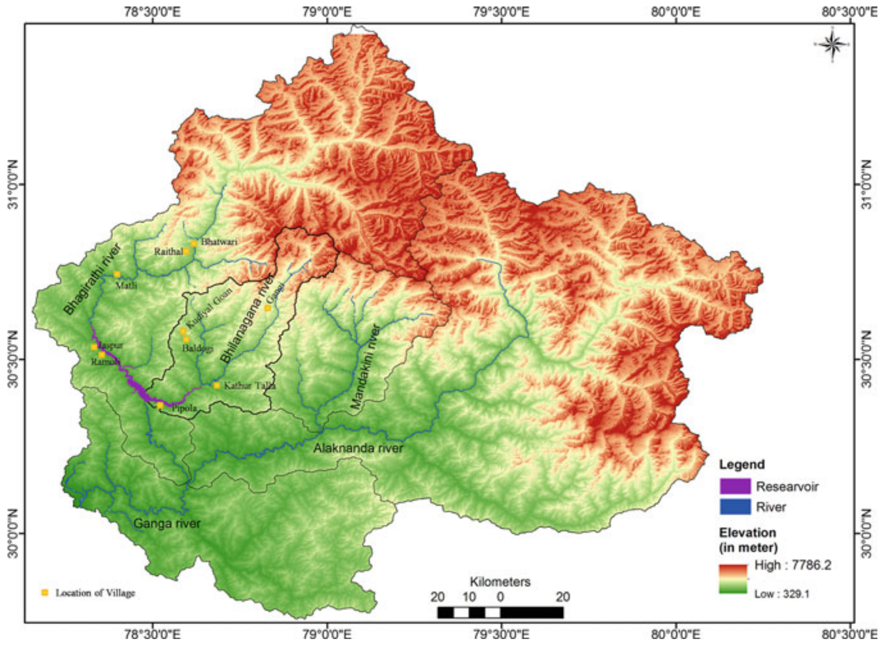

Fig. 1 Study area—location of villages

Table 1 Baseline data of selected villages

District	C.D. block	Village	Area in (ha.)	Population	No. of house holds
Uttarkashi (Bhagirathi Basin)	Chiniyalasaur	Ramoli	67.6	213	51
	Dunda	Jaspur	94.6	453	87
	Dunda	Matali	223.6	3194	651
	Bhatwari	Bhatwari	115.6	1268	279
	Bhatwari	Raithal	375.1	1005	192
Tehri Garhwal (Bhilangana Basin)	Kirtinagar	Pipola	17.6	33	8
	Pratapnagar	Baldogi	60.8	350	75
	Pratapnagar	Kudiyal Goan	41.2	254	46
	Bhilangana	Kathur talla	50.7	446	97
	Bhilangana	Gangi	166.9	386	65

Sources District Census Handbook, Tehri Garhwal, Series 06, Village and Town Directory, Census of India 2011
District Census Handbook, Uttarkashi, Series 06, Village and Town Directory, Census of India 2011

Table 2 Characteristics of Glaciers of Basins

S.No	Basin	No. of Glaciers	Area (km^2)	Volume (km^3)
1	Bhagirathi	374	921.46	13.48
2	Bhilangana	19	112.84	5.98

Source ICIMOD (2001) Inventory of Glaciers, glacial Lakes and Glacial Lake outburst Floods, monitoring and early warning system in the Hindu Kush-Himalayan region, Nepal, (UNEP/RC-AP)/ICIMOD, Kathmandu

Table 3 Physiographic division of the selected villages in the Garhwal Himalaya

Elevation range (in meters)	Bhagirathi Basin	Bhilangana Basin
>2000	Raithal	Gangi
1000–2000	Matali, Bhatwari,	Kudiyal Goan, Kathur talla
<1000	Jaspur, Ramoli	Pipola, Baldogi

5.1 Rise in Temperatures

An increase in temperatures has been felt by the people at all altitudes. The common perception across all altitudinal zones is that winters are getting shorter while the duration of summers is increasing. This has resulted in a shortening of the cropping season. For instance, potato now requires only 3–3.5 months to mature as opposed to 5–6 months earlier. On the positive side, this has provided an opportunity for innovative farmers to diversify crops and introduce cash crops such as cauliflower, peas, turmeric and ginger. The disadvantage of rising temperature is seen in the form of an increase in threats from pests and diseases. Previously, traditional methods of pest control such as using cow urine and ash were adequate for countering these infestations but now the use of chemical pesticides has become necessary. In some villages, people complained that new pests had led to more than 50% crop damage.

5.2 Erratic Rainfall and Water Availability

Sources of water at higher altitudes include meltwater from glaciers, springs and rainfall. The major concerns expressed were a decrease in winter rainfall, variable monsoonal rain and drying up of springs. Their strategy to cope with the changing rainfall pattern was changing the agricultural calendar. But there was constant uncertainty as there was no stability in the timing and amount of rainfall. Villagers have advanced the sowing of vegetable crops like potato by about 30 days and delayed the sowing of rice by 15–20 days. depending on water availability through irrigation. In case of crop failure due to dry spells, some farmers resowed the seeds while some depended on irrigation facilities. In some villages, they had revived the system of traditional irrigation by joining the water channels through *ghuls*. In some cases, paddy cultivation has been replaced by crops such as soybean, pulses, mustard and fodder grass.

In villages located between 1000 and 2000 m, drying up of springs was turning to be a major cause of water scarcity, especially for domestic purposes. The men have been steadily migrating to the cities for employment, leaving behind women and children. Rain fed agriculture was practiced in the area to raise crops like wheat, potatoes and maize. The villagers spoke about increased risks due to frequent natural disasters including flash floods and cloud bursts. Changes in the rainfall pattern were causing distress due to crop losses. It was also significantly narrated by the villagers that crop productivity substantially decreased over the year. Farmers were keen to shift their agricultural calendar but the adjustment was made difficult by uncertainty in the timing of rainfall. They had observed that winters had now become shorter while summers were not only longer but also warmer. The rising incidences of crop damage by new pests and diseases was another issue of concern. Intermittent rainfall and long dry spells not only threatened agriculture but have also led to an increase in forest fires.

5.3 Socio-economic Considerations and Adaptability

Most areas of this Himalayan zone are experiencing transformation and changes in lifestyle. These have come about as a result of the introduction of new technology in agriculture and the development of tourism. Both have resulted in a heightened demand for water, raising concern in affected communities. In these villages, it was observed that the social and economic characteristics of the population have played a role in the response to climate change and adaptation. Small and marginal farmers did not have access to irrigation and were solely dependent on rain fed agriculture. Farmers with larger land holdings were in a better position to adopt new technology. Large scale male out-migration from the area had led to a feminization of agriculture. Women were shouldering the double burden of household work as well as the care of farms and livestock. It was evident that the impact of disasters and climate change is not gender neutral but is disproportionately greater on women. Special training programmes and schemes need to be designed and implemented to ensure that women are food secure and healthy.

Raithal village, located at an altitude of about 2200 m in the Bhagirathi basin, serves as a base camp for the Dayara Bugyal. The trek to the alpine meadow of Dayara has gained popularity among the tourists in recent times. This quaint village, with a population of 1005 persons, is mainly dependent on agricultural activities. The villagers spoke about the changing climate through their perception of the length of time the snow stayed on the ground. They had observed that the snow cover now lasted for a shorter time. The amount of snowfall has also declined in the last two decades. Moreover, the winters seem to be less severe and the lofty mountains in the vicinity lost their white cover faster than before. According to them, there is a

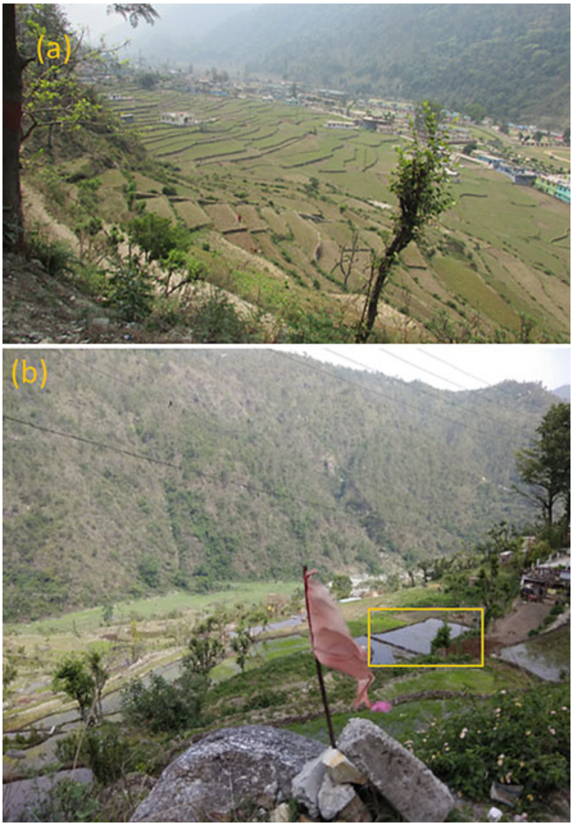

Fig. 2 **a** Terrace farming in broad Balganga Valley, **b** Paddy nursery field raised in 2nd and 3rd week of May

decline in the productivity of potatoes and fodder due to a loss in soil humidity. They attributed this to the shrinking of the rainy season. Their perception too confirmed that winters have shortened and there is an increase in the duration of summers (Fig. 2, Table 4).

6 Conclusions

The changes in precipitation patterns during monsoon have increased the frequency of flash floods and landslides in the study area. Simultaneously, intermittent periods of intense rainfall separated by prolonged dry periods have caused drought in the villages located above 1000 m. The erratic rainfall and frequent hailstorms have severely affected the agricultural productivity and livelihoods of the people living in these areas. The harsh climatic and physical conditions of the mountains present a plethora of environmental challenges for communities inhabiting the mountains. Food security, income security and energy security remain some of the major

Table 4 Nature of risks and variability and adaptations

S.No	Climate change parameter	Nature of risk	Response to risk	Level of adaptation
1	Low rainfall	Water scarcity, low crop productivity	Irrigation: joining of guhl	Community
2	High temperature	Increasing diseases in crops	Greater use of pesticides	Individual
3	High rainfall	Rapid growth of weeds	Increased use of weedicides	Individual
4	Increase in climatic fluctuation	Decreasing productivity, unstable prices	Irrigation—use of sprinklers. Share and use of water resources	Community-individual connect
5	Extreme events-landslides/slope failures/debris flow	Low productivity, soil damage and soil loss	Exchange labour and increased coordination between stakeholders	Community

livelihood issues. Migration is a common phenomenon for mountain communities. However, in recent decades, climate change has added a new dimension to these problems by amplifying existing risks and adding newer ones. Water scarcity has been another major issue in these mountain villages. In many villages, villagers complained that their natural springs have dried up in the last few years. As men migrate towards cities looking for better opportunities in the form of jobs and education, only women, children and the elderly remain in the villages to cope with the new challenges. As a result, women now spend more time looking after their households and also the farmland. There is increased risk due to frequent natural disasters. However, not all the problems in the area are due to climate change. Some may be the result of anthropogenic changes induced in the form of dam construction and road development projects. In the last two decades, an initiative to build rural roads has been ushered in under the Pradhan Mantri Grameen Sadak Yojna (PMGSY). This has resulted in environmental and ecological issues which were not given due consideration at the planning and execution stages. Keeping in view the vast ramifications of environmental changes on all aspects of human life, there is a need to maintain a delicate balance among various players in the developmental process. The incorporation of effective adaptation strategies into local development and policy frameworks is the need of the hour. A multipronged strategy for the agricultural sector is needed in view of the changing climate scenario. The strategy should incorporate various key areas based on which specific goals can be set. It is necessary to carry out scientific research in agricultural techniques suitable for mountain areas. At the same time, traditional practices of sustainable agriculture need to be revived and strengthened in order to increase the resilience of mountain communities to climate related stress. The promotion of organic farming and crop diversification can minimise the adverse impacts of climate change. Early identification of likely trends and dissemination of this knowledge among all stakeholders will give them time to evolve coping strategies. Farmers, for instance, can devise crop practices keeping in view the emerging future thermal trends. Increasing credit to the agriculture sector in areas and practices which are in consonance with the changing physical milieu should be a focus area of the policy. Central and state governments can help by promoting weather and climate resistant crop varieties, increasing crop insurance cover, capacity development, and information dissemination among farmers through Village Knowledge Centres (VKCs). Involvement and close coordination of the community has to be ensured for long term sustainability of any policy.

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