Climate Change Impacts on Agriculture in the Garhwal Himalayas: A comprehensive analysis of shifts, changes and adaptation strategies

Abstract

Climate change is adversely affecting many facets of human lives, often varying with the magnitude and scale. The Himalayan environment is showing a perceived change in the climatic parameters and cryosphere response. The aim of the present study is to capture the community perceptions of climate change, and their approaches towards adaptation. A comprehensive field investigation was carried-out in the villages selected within the different elevation range, located in the Garhwal division of Uttarakhand. Nearly, 150 households were surveyed spreading over 25 villages. The analysis shows that most of the respondents (~95%) agreed, about the climate change through their responses, i.e. early and warm summer, short winter months and less snowfall. The variability of precipitation pattern, declining soil fertility and poor yields were the major challenges in agriculture sector, the main source of livelihood of the communities. Traditionally, people are adapting with climatic extremities with adjusting crops Calander, use of improved and high-yielding variety seeds, fertilizer and used of herbicides and pesticides. The findings of the study can be used to prepare policy framework in the climate change adaptations in the Himalayan region.

Keywords: Climate change; agriculture; livelihoods vulnerability; adaptation strategies; Garhwal Himalaya.

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1. Introduction

Climate change is a global problem, and it is already affecting many parts of human life, as well as the natural environment (ICIMOD, 2018). The lives and livelihoods of millions of people across the globe have been affected by the climate change (Giri et al.,2020; Datta and Das, 2019). The local communities and those living in vulnerable ecosystems have felt the maximum impact (Aggarwal et al., 2022; Anshu et al., 2022; Dahal et al., 2023). These communities in the past have sustained through working with nature, surviving through the variabilities of climate particularly the changing precipitation patterns, temperature changes and biodiversity in their local landscape (Datta & Behera, 2022). Himalayan region is the one of the most vulnerable ecosystems in India due to its geophysical setting (Loria, and Bhardwaj, 2016; Pandey et al., 2018). The major impact of climate change in the mountainous region is visible in the reduction in agricultural production and productivity of the crops that have for long provided the farmers with their subsistence food stocks (Kelkar et al., 2008; Pandey et al., 2017; Negi et al., 2017; IPCC, 2022). For farmers, climate change causes the level of vulnerability to livelihood to be higher (Banerjee, R.R.,2015). A high

intensity of rainfall that exceeds the environmental capacity, often is a cause of flood or landslides.

The different studies bear testimony to the fact that frequency of natural and human made disasters has increased in the whole Himalayan area over the last few years, making it one of the most vulnerable and fragile regions in the world (Guntukula, R., 2020; Kumar, V., 2015). The Himalayas are experiencing above-average warming as a result of anthropogenic pressure on natural resources, leading to glacier retreat, reduction in area under permanent snow cover, and negative mass balance due to changes in precipitation patterns and high-altitude precipitation. The bursting of glacial lakes can cause flash floods and landslides in the upper Himalayas can trigger flash floods downstream. Environmental vulnerability and disasters are affecting human societies and their livelihoods, especially in mountainous regions due to scarcity of fuel wood, fodder, water resources, wild food resources, and biodiversity. In addition, there has been an increase in the incidence of forest fires, soil erosion, and changes in land use patterns affecting wildlife and humans alike (Kelkar et al., 2008; Pandey et al., 2017; Negi et al., 2017). Vulnerability is the conditions and processes that decide the exposure and likelihood of being harmed or influenced of an individual, a community, a system, or a unit to disaster as well as their abilities (to hold or do something) to respond effectively to them. The local communities have thrived in fragile and difficult mountainous terrains of the Himalayan region through their indigenous response to variations in climate and the ecosystem modifications (Vardan, and Kumar, 2014; Vinod, K., 2014; Sharma et al., 2023). These communities have developed the ability to adapt to the changes in climate, yet they are at the most impacted at different scales (UNESCO, 2023). Sustainable Development Goal 13 on climate change emphasises the role of local and indigenous knowledge systems by observing changes, adapting to impacts and contributing to global mitigation efforts.

In the paper, an attempt is made to understand how the changes in climate are making the agricultural system vulnerable, making the farmers to adapt to these changes in which they are either using innovating technologies or reverting back to their traditional knowledge systems. The study has been conducted in the Garhwal Himalayas of Uttarakhand where the geographical landscape of Himalayan regions of Shiwaliks, Middle Himalayas and Higher Himalayas lie.

2. Study area

The state of Uttarakhand is located at 28º43′ to 31º27′ Northern Latitudes and 77º34′ to 81º02′ East Longitude. Its entire area is 53,483 Square Kilometers, which is 1.69% of the total area of the country. The state is largely hilly with large areas under snow cover and steep slopes. The state has 13 administrative districts in which Dehradun, Nainital, Udham singh Nagar, Haridwar and Dehradun have the highest population density as they fall majorly in the Siwalik zone. Uttarkashi, Rudraprayag, Chamoli, Pauri and Tehri are in the Garhwal region while Kumaon region have the districts of Pithoragarh, Champawat, Bageshwar and

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Almorah. The physiographic variations control the livelihood pattern of the people and their agricultural practices.

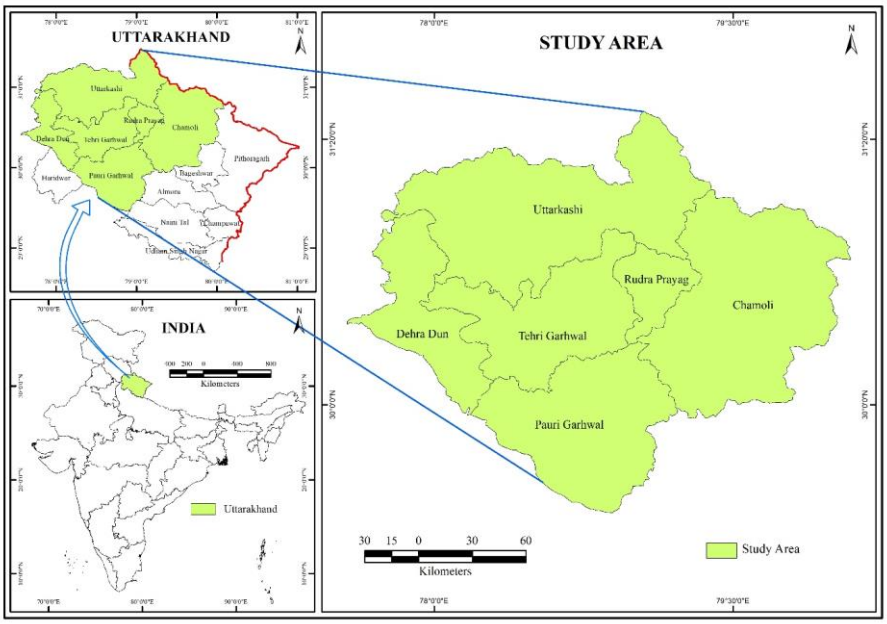

Figure 1. Location map of the study area, Garhwal Himalaya (Uttarakhand).

Garhwal Himalayas lie in the state of Uttarakhand. Geomorphologically, they are situated in the seismic gap along the Main Central Thrust. MCT separates the Greater Himalayas in the north with the Lesser Himalayas in the South (Valdiya, 1988). The altitude varies between less than 1000metres above sea level to as high as 6000 metres. The major rivers of the region are Bhagirathi and Alaknanda. The area experiences monsoonal rainfall with heavy rains in summers. The bedrock of the region is at shallow depth or exposed comprising mainly of gneiss, quartzites and schists with strikes and dips.

3. Methodology

To understand the climate change adaptation and the vulnerability of agricultural practices in the Garhwal Himalayas, mixed methodology was adopted. The present research is based on the field survey conducted in the month of May-June 2023 in the western Himalayan region. Detailed questionnaire was prepared to evaluate the local peoples' perceptions regarding the climate change, the adaptation strategies followed and the modifications in the agricultural

practices. The questionnaire comprised sections on Household details, community perception of climate change, indigenous approached to adapt to change, adaptations and coping mechanisms, indigenous knowledge, role of local institutions, changes in livelihood pattern and community involvement. 150 respondents were chosen at random from different villages of Uttarkashi, Chamoli, Pauri Garhwal and Tehri Garhwal. Focus group discussions were held with the farmers that stimulated deeper discussions regarding their perceptions without constraints.

4. Results and Discussions

4.1 Community Perception of Climate Change

The majority of the respondents agreed that the climate of the region has undergone change as is visible through the early summers and late arrival of cold season, as narrated in Harsil village of Uttarkashi and Reechak of Tehri Garhwal situated in the Higher Himalayan region. It clearly shows the swings in temperature pattern, which led to changes in the crops growing seasons. This observation was made in the middle and higher altitudinal villages of the surveyed region. Due to prolonged summers, there is subsequent change in other seasons. The average rainfall has declined and most of the precipitation occurs in a very short period of time and it is often extremely severe. Though the amount of snowfall has decreased but the incidence of hailstorms has increased substantially particularly during the months of March. This often leads to damage of the flowering plant of the apples as well as the other stone fruits like peaches and plums. So, it is evident that changes in temperature patterns have affected the traditional growing seasons, impacting crop cycles and productivity.

The villagers also asserted that due to warmer temperatures the types of crops that can be cultivated in the different altitudes have shown a change (Fig. 2). The apple belt has significantly shifted onto the higher altitude as the temperatures in the valley have become too high and number of chilling hours required for flowering has declined tremendously. The yield of the orchards was showing poor results.

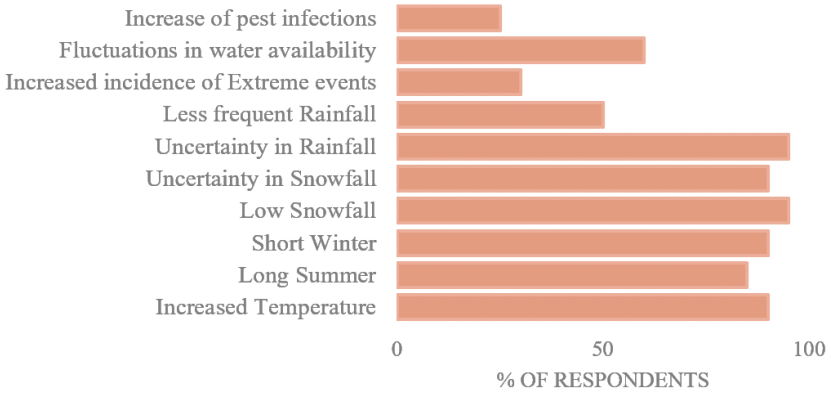

Figure 2. Community perceptions of climate change in the selected villages of Garhwal Himalayan Region of India (May – June, 2023).

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The villagers were asked regarding climate change through direct and indirect questions. Directly, they were unable to give a definitive answer, but several proxy questions indicated the occurrence of climate change. Most villagers accepted that temperature is increasing in summers. More than 90% respondents spoke about short winters and less snowfall. It was also highlighted that uncertainty of rainfall and snowfall is more prominent. The incidences of extreme weather events have considerably increased (Fig. 3).

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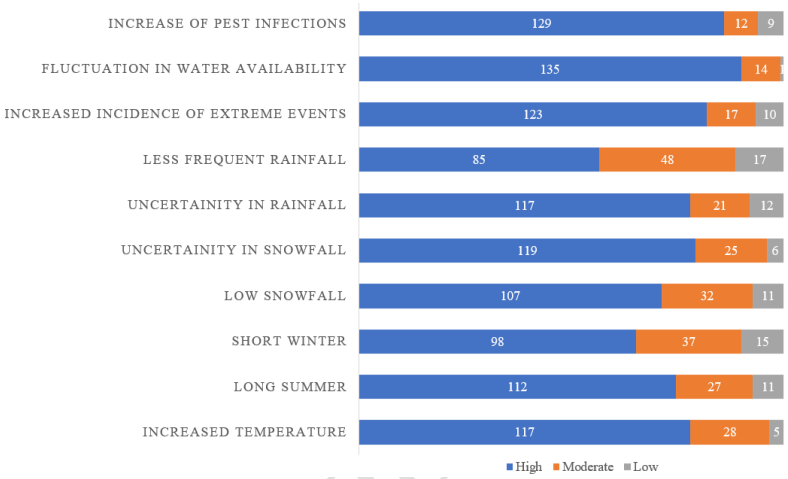

Figure 3. Community perceptions of climate change and its potential impacts.

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4.2 Increased Frequency of Extreme Weather Events:

More frequent and intense weather events, such as floods and landslides have frequently damaged crops and disrupted agricultural activities. In the valleys of Bhagirathi and Bhilangana, the flash floods caused due to cloud bursts in the year 2013 disrupted the life and livelihood of the local people and created large scale damage to the agricultural lands. The entire hill sides of the lower valleys near the banks were eroded and washed away. The people were forced to shift from agriculture to other activities to sustain their livelihoods. The marginal and rural communities are most affected by these extreme weather events and it takes a heavy toll on their socio-psychological wellbeing. The frequency of these events has been increasing as is evident from the cloudbursts of July and August 2023 in Uttarkashi and Pauri Garhwal. These regions lost their agricultural lands – the summer crops were heavily damaged and there seemed to be no future for the winter harvest (Fig. 4).

Water Scarcity and Changes in Precipitation: In the middle altitudinal zone, the villagers complained regarding the drying up of the natural springs, locally known as *gadera*. The springs have traditionally been the source of fresh water for the people of this region as was told by the people of Sunargaon in the Tehri Garhwal region. Due to decrease in amount of rainfall as well as the high intensity of rains, the springs have been affected.

Figure 4. (a) the yield of wheat crops decreased due to early summer, (b) damaged pees crops due to hailstorms and showers, (c) apple orchards replaced traditional crops near Harsil, and (d) promotion of handicrafts as an alternate source of livelihoods.

The high intensity rains lead to high run off due to which the infiltration of the water does not occur, and the springs are not fully recharged. During summers, the limited water in the springs gets quickly utilised and very little fresh water is available for the local communities for the rest of the time. The small rivulets feeding the larger streams have also low volume of discharge due to loss of precipitation and drying up of springs. Even the changes in snow and glacier melt in the higher altitudinal zones (since the snowfall in most of these regions have shown a declining trend over the years) has had an impact on water availability for

agriculture. Thus, prompting change in livelihood from agriculture to non-agricultural practices. Altered precipitation patterns, leading to water scarcity has also affected irrigation practices. Due to less water availability for irrigation, the locals are disengaging from agricultural pursuits and shifting their livelihoods to either services in cities or tourist activities.

4.3 Pests and Diseases

The temperature changes and change in humidity levels have created a suitable environment where there is seen an increase in pests and diseases that have a direct effect on the health of crop. The weather patterns have become more and more erratic with untimely rains, high humidity, and fluctuating temperatures which encourages the spread of vector-borne diseases. Dehradun, Pauri and Srinagar, have witnessed rise of vector-borne diseases such as dengue and malaria, that were unheard of a decade back. Due to this rise and spread of these microorganisms, the crops are frequently damaged. These are new challenges before the farmers for which they need to adopt innovative methods to safeguard their crops. Since the insects are poikilotherms, the major reason for their increase is the increase in temperature. that influences their behaviour, survival, and reproduction. In Pauri Garhwal region, the villagers reported that different exotic weeds had invaded their agricultural field that were traditionally rainfed. The agricultural production of crops showed a significant decline in above mentioned regions.

4.4 Loss of Biodiversity and Ecosystem Services

The villagers in Bhilangana valley reported that over the years there has been loss of biodiversity. The forest areas have degraded and declined tremendously in the last decade. As a result the ecosystem services that could accrue from these regions have also seen to have dwindled. Caterpillar fungus (Ophiocordyceps sinesis) locally known as *kidda jaddi* was commonly found in the areas of snow. Locals started harvesting this fungus for commercial purposes. The loss of snow cover and over exploitation of this specie has led to its decline as there is little time left for the spores to generate and reproduce. Due to decline in agricultural production, the dependency on minor forest products is seen to be increasing, particularly in the lower and middle altitudes. The local people in the Dharasu region, in Uttarkashi explained that there is great demand for fodder from forests as there is lack of common grasses in the villages due to changing temperatures. The locals have been known to surreptitiously set the forest on fire for growth of new grasses that is used for fodder. The villagers are also exploiting the forests for varieties of mushrooms which they are trying to market.

4.5 Impact on Livelihoods

The impact of climate change has adverse impact on agriculture that has direct consequences on the livelihoods of farmers and rural communities. The majority of the villagers responded that due to climatic changes it is not only affecting the yields of crops but the less snowfall and erratic rainfall is also indirectly affecting soil fertility and there is increase in weeds and pests (Fig. 4). Changes in agricultural practices may be necessary, requiring adaptation strategies and investments.

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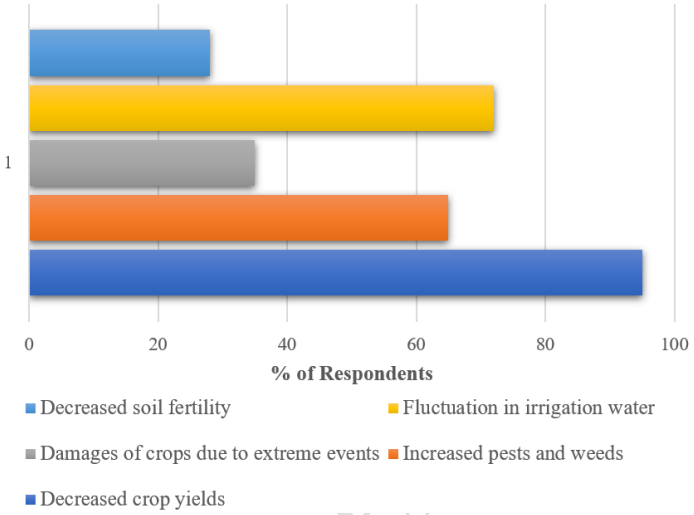

Figure 5. Impact of climatic dynamics on agriculture.

4.6 Soil Erosion and Degradation

Increased intensity of rainfall or changes in precipitation patterns may lead to soil erosion, affecting the fertility of agricultural land. The frequency of extreme events has increased in the regions, and its affects the soil cohesive strength and increases soil erosion. The other reason that villagers have pointed out is the infrastructural development in the area. Many respondents have blamed the development project in the fragile environment causing the soil erosion and degradation. The soil degradation can impact the long-term sustainability of farming in the region.

4.7 Adaptation Challenges

In the wake of uncertainty to the climatic parameters, the farming community has suffered due to losses with crop failure and damages due to climatic extremities. Farmers may face challenges in adapting to new climatic conditions, including financial constraints, lack of information, and limited access to technology.

The respondent's perception regarding impact of climate change has been depicted in Fig.5. As it can be seen the climate change is adversely affecting the people's lives and livelihood. People responded that the yield of most of crops decreased substantially. Apart from that the decline in soil fertility and deterioration in soil condition has led to increase in the ratio of pests and weeds. There is fluctuation in water available for irrigation and crop damage due to extreme events (Fig. 6). So, it is clear from the interviews with the respondents how the climate dynamics are having an impact on the lives and livelihoods of the people of these villages. The adverse impact on agriculture is obviously visible through this perception study.

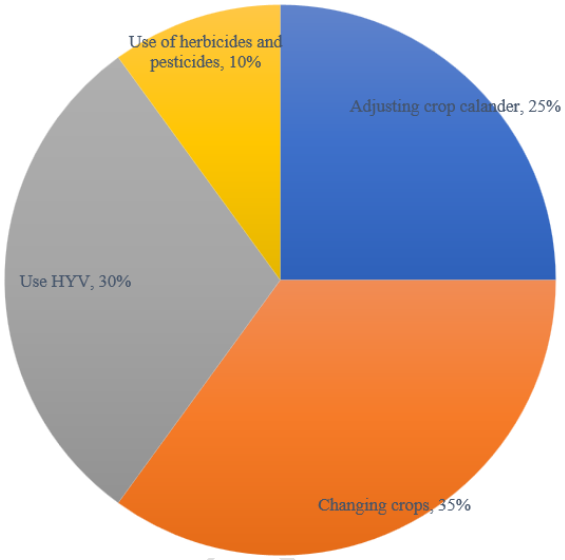

Figure 6. Approaches of adaptations in agriculture

Mechanism for adaptations

From the field study it is evident that there is unanimity of the respondents regarding the change in climatic conditions. The methods the villagers have adopted to combat these changes have varied. Definitely, the adaptation mechanism may be different but their objective remains the same – to improve agricultural production and productivity. 55% respondents resorted to changing the type of crops they were traditionally growing. From madua and barley, ragi, rajmah- coarse cereal to horticultural crops like potato, cabbage, broccoli, peas and high yielding variety of wheat. The traditional wheat grown is showing very low yields and the farmers are showing preference for HYV wheat (Fig. 6). Some farmers opted for changing the crop calendar (25%). Since the summers have become long and it becomes warmer earlier, they have resorted to early sowing particularly in case of

kharif crops such as paddy. Nearly 10% farmers interviewed in the area adapted through use of herbicides and pesticides to improve the crop productivity. This is used through spraying mainly on the vegetable crops. The cultivation of off-season vegetables for the plains is showing a considerable increase. The traditional crops in some villages have been totally replaced by potato and peas. Due to improvement in accessibility the market linkages have been strengthened. The livelihood options have diversified due to these improvements in connectivity.

5. Conclusions

Climate change is a harsh reality that is affecting our lives and livelihoods in numerous ways, particularly in mountainous regions. The community's response to the changes still shows a lack of awareness. However, they can describe it indirectly, such as experiencing warmer and earlier summers, shorter winter months, less snowfall, and often erratic precipitation patterns. The community's perception and understanding of the phenomenon are crucial for the development of mitigation and adaptation strategies to address climatic dynamics.

Climatic dynamics strongly affect the livelihoods of people, particularly in agriculture. Locally, people are using traditional methods and adjusting crop calendars to minimize the impact of changes on agriculture. Hence, integrating traditional knowledge with scientific advancements and government policies would be appropriate to address climatic risks. The findings of the study would be very helpful in developing effective mitigation and adaptation strategies for mountainous regions.

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