Changing Climatic Conditions and Shrinking Agricultural Land: A Community Based Study in Betalghat Development Block, Kumaun Lesser Himalaya

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Abstract
Himalayan communities live in a marginal environment. Being dependent on ecosystem services for sustenance, they are regularly exposed to the impacts of climate change. This study summarizes the outcomes of the survey across 300 households purposely and randomly selected from 30 villages; 10 key informant interviews (KII) and six focused group discussions (FGD) in the Kumaun lesser Himalaya.

The study shows that the region has been witnessing changes in temperature and precipitation regimes within the last 30 years and findings show a sharp decline in water availability due to erratic and less predictable precipitation patterns, rising temperature and less snowfall incidents that severely affected farmers harvests (mainly horticultural crops) and shrunk their agrarian land. Consequently, food production and household income decrease mainly by the changing climatic condition.

Keywords: Climate Change, Community perception, Agriculture, Adaptation and Mitigation, Kumaun Lesser Himalaya.

Introduction

The fate of communities in the mountains depends on agriculture and other marginal resources where food security, climate change and natural resources are interlinked challenges that must be addressed holistically.[5] The mountainous resources feed the majority of the world population and support the livelihoods of nearly 200 million people. Globally, agriculture generates between 1% and 60% of national Global Domestic Product (GDP) in many countries, with a world average of about 4% in 2017.[30] The rapid growth of agricultural productivity since the 1960s has impacted environmental resources and contributed to climate change and increased vulnerability. Such impacts are more pronounced in the mountainous landscapes and the communities residing there.

Therefore, it is worthwhile to mention that the mountain regions are particularly vulnerable to climatic change and environmental fragility and thus are impacting communities therein. Global climate change is the most prominent challenge of the 21st century which has affected the socio-ecological systems of the planet through high mean annual temperatures, irregular rainfall patterns and melting of ice and glaciers.[13,14] Any change in these systems will have an enormous effect on the world's rural population particularly in the lesser Himalayan region where a vast population depends upon limited agriculture resources. Besides, climate change intensifies in this region; other environmental changes result in reduced agricultural production. Frequent crop failure negatively affects rural livelihoods and community food purchasing power.

However, mountains are appreciated as a repository of biodiversity, water and other ecosystem services providing13% refuge to the local people and around 40% of the global population to fulfill their requirements for water, energy and ecosystem services.[10,11] Nevertheless, they are the most fragile environments in the world.

Scientific observations and studies on changing climate and its adverse burden on agricultural land in the lesser Himalayan region are extremely limited and most studies mainly focus on climatic variability. However, a very few studies report a sharp decline in agricultural yields in many parts of the Himalayan region.[17,20] Climate change has reportedly affected Himalayan agriculture and increased pressure on farmers because Himalayan farmers have always had to cope with the capriciousness of nature.[1,19,27] Crop-livestock agriculture has long been a source of livelihood in the Himalaya and 40% of the total GDP in entire Hind Kush region comes from this system.[10] Subsistence agriculture constitutes the primary source of livelihood and food for more than 75% of the rural population in the lesser Himalaya. The arable land is severely limited with considerable poor agricultural productivity.[23,24] Poor rural communities are bearing the adverse burden of climate change, mainly whose livelihood is predominantly based on agriculture.

Besides these, water is also needed in large volumes during agricultural production; for instance, to produce 1 ton of maize, about 1200 tons of water is required. Approximately 1000 tons and 111 tons of water are required for wheat and sugarcane. These quantities of water are used only to produce primary commodities. However, water availability is severely affected by drinking, sanitation and food production. The climate change impact complexity or frequency of climate-induced risk in the mountainous region is more frequent and distressing the mountains ecosystem, local communities, their livelihood and their daily needs with growth in population and economy.

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Approaches to deal with the issue of global climate change are mainly divided into mitigation measures, the causative factors and adaptation measures to minimize the damages. So far, the global climate change issues have focused on mitigating greenhouse gases based on international environmental conventions such as the Intergovernmental Panel on Climate Change (IPCC), the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. However, for agriculture, the focus has been shifted to adaptation and adaptability based on assessing the impacts of climate change and its vulnerability. As agriculture is climate-dependent, it is very urgent to prepare adaptation measures against climate change; it takes at least 5 to 10 years to assess the impacts of climate change and its vulnerability and prepare proper countermeasures against it.

Proper countermeasures drawn based on scientific diagnosis and assessment of the impacts of climate change on agriculture communities are essential in establishing vision and administrative policies for the future of agriculture. They will also provide valuable information for local governments in establishing mid to long-term agricultural development plans and for farming households to prepare their production plans. Therefore, focusing on the causes of vulnerability of lesser Himalayan communities to climate change concerning agriculture, food and health security, the objectives of the present study include.

1. Assessment of community perceptions about climate change and visualization of its impacts on farming, food and health systems,
2. To analyze the community coping and adaptation practices and assess their sustainability,
3. To document local and indigenous knowledge and make efficacious recommendations while incorporating traditional adaptation practices and coping strategies in community-based climate change adaptation plans.

Material and Methods

Study Area: Agricultural activities depend highly on the climate. Agriculture-based countries are the most sensitive and vulnerable areas globally; the Himalayas are also a significant stressor due to their geological instability and fragile environment. Thus, we have selected The Betalghat development block, situated in district Nainital of Uttarakhand, Kumaun Lesser Himalayan region, as the area of study in India.

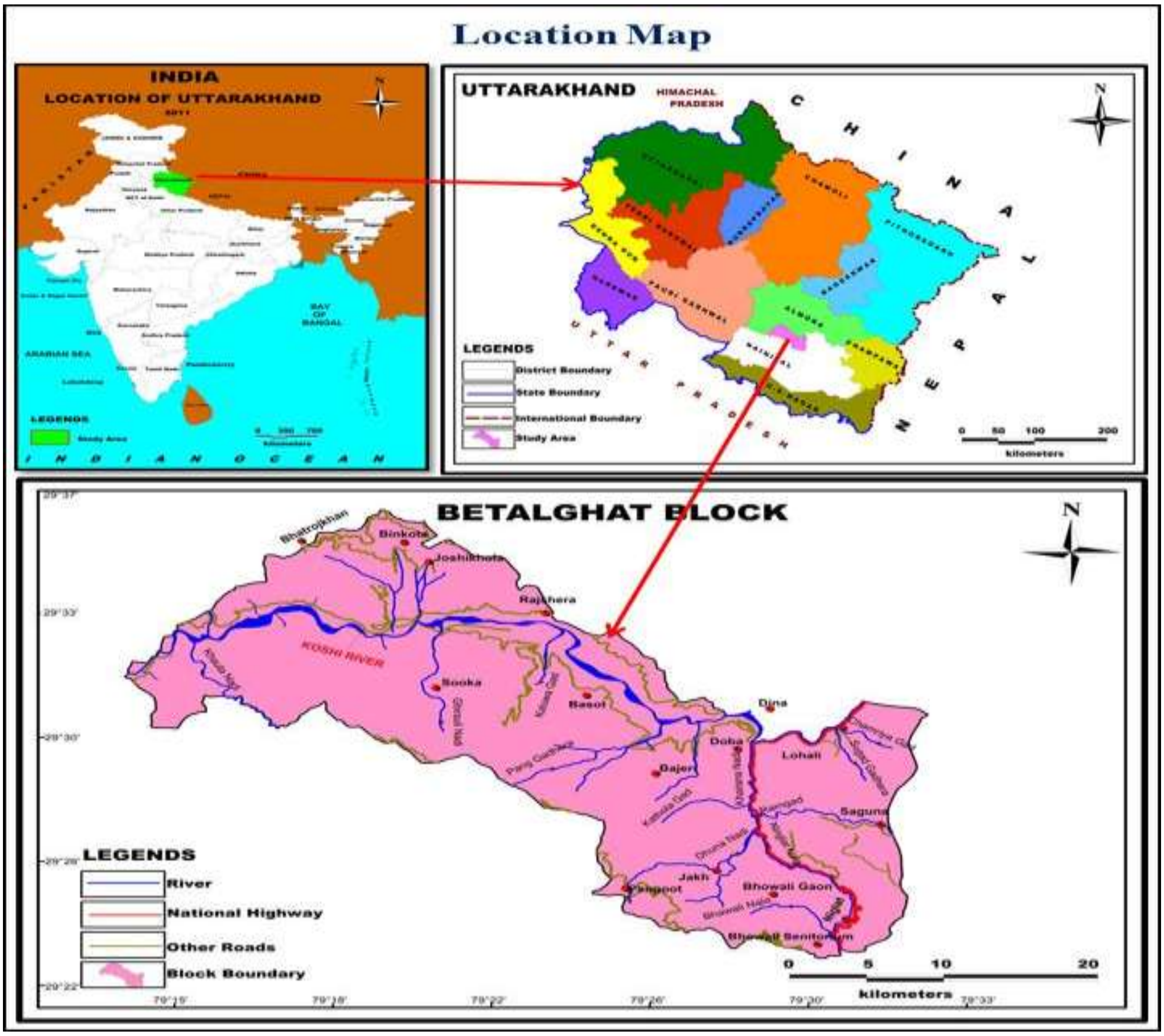

Figure 1: Development Block Betalghat is situated in the lesser Himalayan ranges in the State of Uttarakhand, India

This block is located between 29°26’30” and 29°32’ North Latitudes and 79°14’ and 79°30’30” East longitudes and encompasses a geographical area of nearly 315.7 sq. km. The study area is densely populated and agriculturally colonized region of Kumaun Himalaya. According to the 2011 census, total population of this region is 41535 and the calculated density of population is 131 persons/sq. km. One of the major rainfed rivers of Kumaun drains through Betalghat block is river Kosi which is the tributary of Ramganga.

Data collection methods and analysis: To attain the objectives of the present study, we used worth techniques, methods and tools that have been employed for the generation and collection of relevant data, information, analysis and interpretation. In order to gather insight into these issues, the present research study was undertaken to find out the climate change impact on the agriculture sector with its adverse burden on local communities, community adaptation practices, climate-induced disaster and human health. GIS techniques, GPS survey, key informant interview (KII), focused group discussion (FGD) and household (HH) questionnaire survey were also used.

The questionnaire survey collected HH data i.e. farmers' perception and awareness of climate variability and its impacts on the agriculture sector, types, preparedness and adaptation strategies adopted by people. After completing this process, we conducted 6 FGDs by organizing in the central place of Nyaya Panchayat, covering all the settlements. The number of participants in each FGD ranged from 10 to 20 persons. Well knowledgeable men and women have been involved in group discussions and personal interviews to collect information on climate variability and its impact on land use practices, agricultural activities and their management practices and adaptation strategies.

Also, the FGDs were focused on climate change parameters like change in temperature and rainfall and its effects on agriculture in terms of production and quality of grains. Likewise, 10 KIIs were conducted with the senior citizens, agriculture officers and presidents of the village panchayat (*Gram Pradhan*) by asking for their perception of any indicator of climate change effects on the agriculture sector over the last 20 years. For the confirmation, authenticity and validity of the questions, all the FGDs and KIIs have been conducted in the local language because of traditional knowledge systems and understanding of differences in the capacities as well as across the sites of the region in which adaptation strategies developed were based on past experiences and learning under local climatic conditions and environmental stress.

The climate of the study area has been captured by using available data from the Indian Council of Agriculture Research, National Bureau of Plant Genetic Resources, Regional Station (ICAR- NBPGR RS) Bhowali, Niglat, Nainital, Uttarakhand, India and recently published reports. The demographic and other relevant social data at the Nyaya Panchayat level have been collected from the 2011 National Census. The detailed methodological procedure and work plan have been illustrated in figure 2.

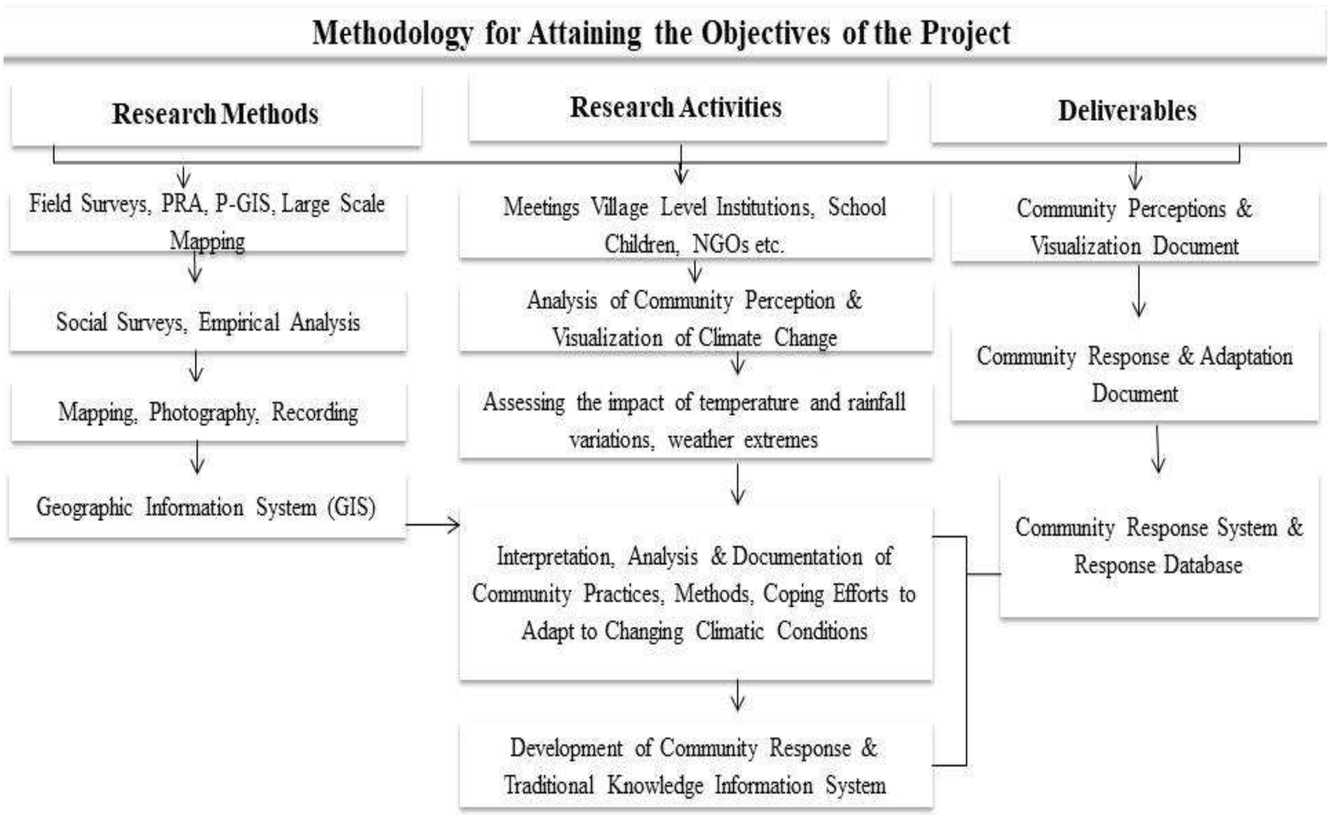

Figure 2: Illustration of detailed methodological framework

Results and Discussion

Observed changes in climatic conditions: The fluctuations in temperature and rainfall at Bhowali Niglat (the only climatic data recording centre in Betalghat block) have been analysed for the 35 years from 1984 to 2018 (Figures 3, 4, 5 and 6). The mean value of average annual maximum temperature (T_{max}) and the average annual minimum temperature (T_{min}) in the region are 22.49°C ± 0.93 and 9.83°C ± 0.88 respectively. However, the T_{max} has recorded a decrease by about 0.02°C/year over the 35 years.

On the other side, the average annual T_{min} has increased by about 0.02°C/year (Figure 3). The seasonal climatologies for T_{max} show an increasing trend in the pre-monsoon (0.007°C/year) and winter season (0.002°C/year) and a slightly decreasing trend is seen for the monsoon (0.047°C/year) and post-monsoon season (0.042°C/year) (Figure 4). Moreover, the T_{min} shows an increasing trend in pre-monsoon (0.027°C/year), monsoon (0.047°C/year) and post-monsoon season (0.008°C/year) and a slightly decreasing trend in the winter season (0.016°C/year).

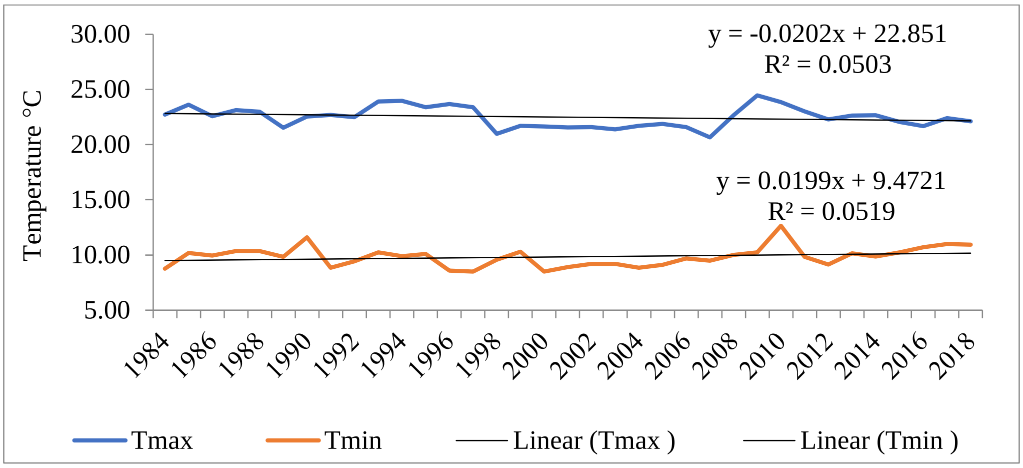

Figure 3: Annual mean temperature trend between 1984 and 2018

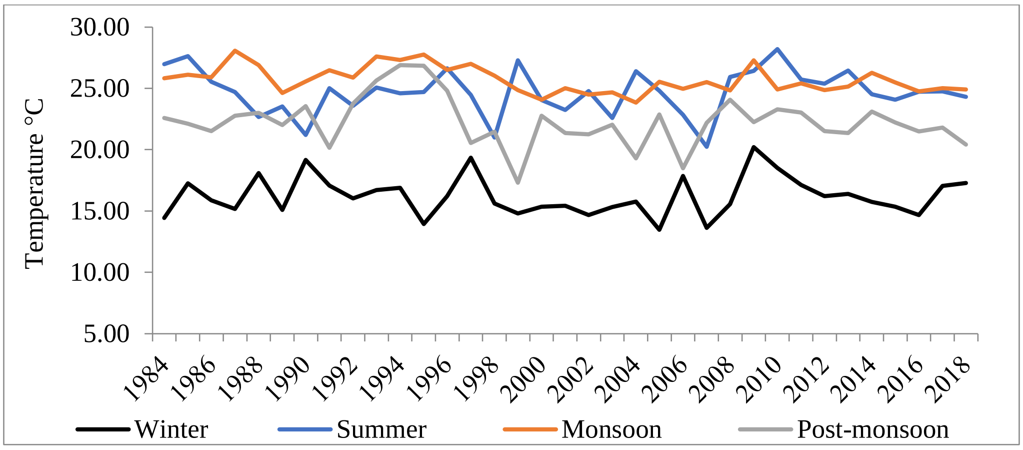

Figure 4: Seasonal climatology (temperature trends) between 1984 and 2018

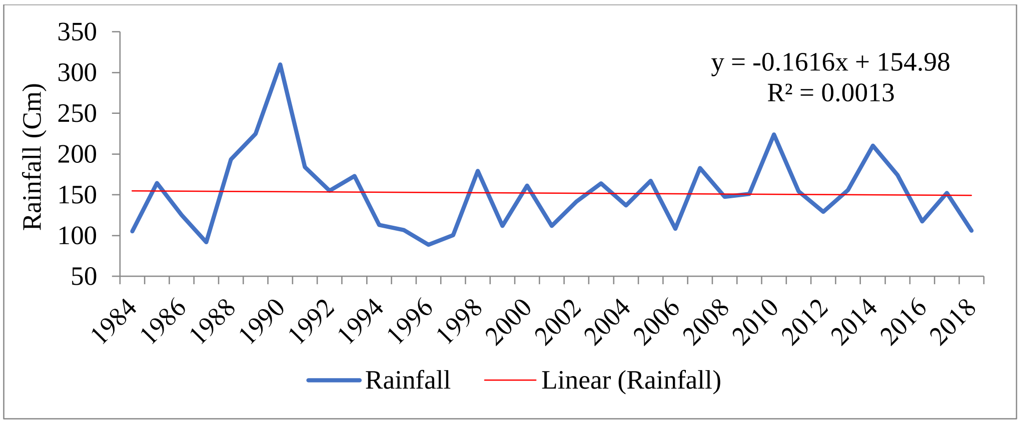

Figure 5: Annual rainfall trends between 1984 and 2018

The mean rainfall over 35 years was recorded at 1465.83 ± 434.61mm (Figure 5). However, the average precipitation per year declined to 0.161 cm/year. The study region obtains its maximum and minimum rainfall during the monsoon period and winter season. The rainfall shows a decreasing trend during the post-monsoon (1.670mm/year) and winter season (3.304mm/year) and a slightly increasing trend during summer (0.433mm/year) and monsoon season (8.260mm/year) (Figure 6).

Impact of climate change on agricultural activities: Climate change has significantly affected the land-use pattern in the study area which can be seen in table 1. Agricultural wasteland has increased by 1493 ha from 4072 ha in 1990-2000 to 5493 ha in 2015-2016. A similar increase was recorded in present fallow land, which increased from 176 ha in 1999-2000 to 534 ha in 2015-2016. However, net-sown area, total irrigated land and total food grain area experienced a massive reduction in their coverage. The total irrigated area decreased the maximum by about 85% from 1895 ha in 1999 to 2000 and 280 ha in 2015-2016.

Apart from the changes in agricultural land in the study area, significant changes are observed in the production area under various food grains (Table 2). The net sown area for rice crop was 1071 ha in 1999-2000 which reduced to just 338 ha in 2015-16. The wheat production area has declined by 890 ha; the maize production area has decreased by 323 ha while the area of oilseeds crops has also decreased by 7 ha. Also, a significant decline of 916 ha in the Ragi (Madua) area is the most important food crop in the study region.

It is clear from tables 1 and 2 that the agricultural sector has been affected due to the changing climate and extreme weather events at a large level in the study area. The major impacts of the changing climate and extreme weather events have been on un-irrigated agricultural land in which *Upraun* (middle and high slope area) is predominant because the agriculture of these parts is utterly dependent on the rain.

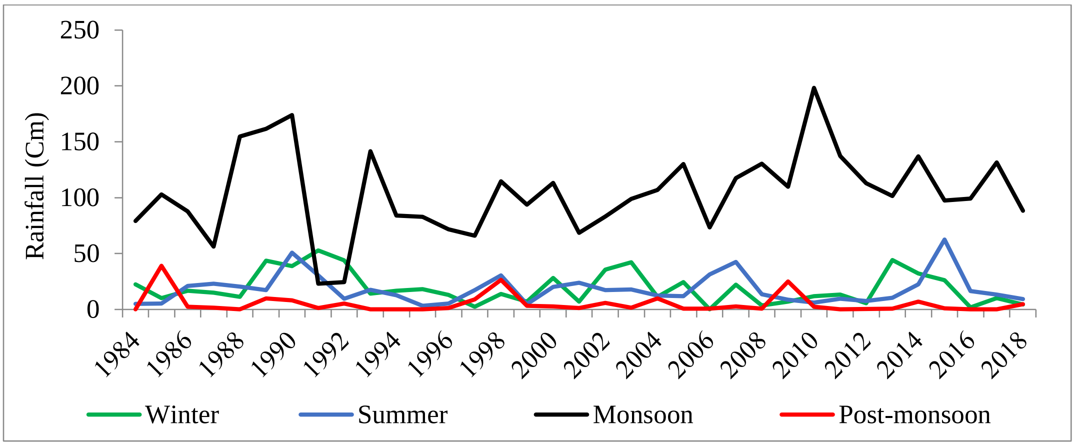

Figure 6: Seasonal climatologist (rainfall trends) between 1984 and 2018

Table 1
Agricultural area (ha) under various land-uses

Area under different uses	**1999-2000**	**2015-2016**
Agricutural wasteland	4072	5493
Present Fallow Land	176	535
Net Sown Area	3717	3065
Total Irrigated Land	1895	280
Total Food Grain Area	5834	3029

Source: Statistical Handbook

Table 2
Impact of climate change on the food-grain area

Area under different Grains	**1999-2000**	**2015-2016**
Rice Cultivation	1071	338
Wheat Cultivation	2792	1902
Maize Cultivation	544	221
Oilseeds Cultivation	168	161
Ragi) Madua(Cultivation	1088	172
Total Food Grain Area	5834	3029

Source: Statistical Handbook

So, any change in the rainfall is directly visible in these areas. In contrast, the contraction in the total irrigated agriculture sector is due to the extreme weather events in the region in the last years; the floods of the year 1999, 2010 and 2013 are prominent. In the past years, the area sown more than once has also decreased by 428 ha, mainly due to the disrupted crop cycle which occurred by climate change and extreme weather events.

Apart from all these negative impacts, some positive impacts have also been observed in some areas of the study region (mainly in total agricultural land). The total agricultural land was 2695 ha in 1999-2000; it increased by 1130 ha in 2015-16. The primary reason behind these changes is people's orientation towards horticulture and cash crops rather than food crops. Closely, it can be said that climate change and extreme weather events have affected agricultural land use and food grain area. The decline in income of local people has accelerated the pace of out-migration to earn more money for survival comfort.

Moreover, agriculture yield and income show a sharp downfall pattern due to uncertainty of climatic conditions such as low rainfall during sowing and high rainfall and hailstorms during crop maturity.[16] Forest resources, mainly green grasses and fodder, have been reduced due to low rainfall in March-May.[15] It has increased the frequency and intensity of forest fire and negatively impacts fodder resources and livestock production system.[4]

Perception of the Local Community on Climate Change (metrological parameters): Most of the agricultural activity of India and our study area are based on monsoonal rainfall. That is why; it has been a constant gamble with the changing climatic conditions.

Figure 7: Impact of hailstorm in study area

Table 3
Community perception (household's people) about climate change in the study region

Community's perception of change	**Respondent's Responses**					
	Yes		**No**		**Neutral**	
	No.	%	No.	%	No.	%
Observed Changes in climate during lifetime	282	94	15	5	3	1
Rise in Temperature	276	92	18	6	6	2
Decreases in rainfall amount and duration	279	93	18	6	3	1
Change in Timing of seasons	282	94	6	2	12	4
Decreases in snowfall incidents	291	97	3	1	6	2
More precipitation in the form of rain instead of snow	225	75	66	22	9	3
Fluctuation in water availability	282	94	9	3	9	3
Increasing frequency of Drought	252	84	36	12	12	4
Increasing flash flood and floods incidents	228	76	42	14	30	10
Increases extreme weather events	231	77	57	19	12	4
Changes in flowering and fruiting time	240	80	48	16	12	4
Decrease land productivity	264	88	24	8	12	4
Loss of agrarian land	288	96	9	3	3	1

Source: Fieldwork

The stakes involved have increased even more because farmers are on the receiving end of this gamble, resulting in a decline in their income levels. The analysis of community perception reveals that maximum people (more than 90%) are well aware of the changes in the climate and adopting various methods to cope with the risk of variations in agricultural operations due to the climate change such as the selection of less irrigated crops and production of cash crops (Table 3). All households (n=300) have experienced climate shocks for the last 30 years by intense storms, extra heat and cold spells.

Due to erratic rainfall/less snowfall, irregular hailstorms and rising temperatures are causing shrinking agricultural land and less production in horticultural crops; fruit wastage due to hailstorms is leading to upper parts of block particularly impressed.

Table 3 shows that 276 (92%) of the households (respondents) perceive an increase in average temperature together with a change in precipitation regime and a large mass (n=288 or 96%) strongly believe that the agrarian land is shrinking due to the climate change. Studies also show that the net increase in temperature ranges from 1.7°C to 2.2°C in the 1970s; likewise, seasonal air temperatures also show a rising trend in all seasons.[12] About 282 (94%) of the households strongly believe that the timing of seasons has been changed, especially during the winter season, due to the late start and early melt of snow which adversely affects the agro-horticultural operations.

Moreover, duration, amount of rainfall and rain become intense and erratic reported having changed significantly by 279 (93%) respondents. Besides rainwater, the primary sources of water for the people in the study region are rivers, springs and streams and the present study shows a mixed response on the level and availability of water where 282 (94%) of households reported fluctuations in the discharge of the streams and springs.

That has resulted in water scarcity for drinking and irrigation purposes and therefore, community people switched towards cash crops that require less water for production. Table 4 shows that 90% of the key informants perceive an increase in average temperature and a change in precipitation regime. All informants (100%) strongly believe that agrarian land is shrinking due to climate change.

Apart from KII and household level study, we calculated the FGDs data and carefully observed and analyzed it, revealing that the study region has been facing climatic shocks for the last 20 to 30 years by intense storms, extra heat and cold spells. Moreover, the duration of rainfall, amount of rainfall and rain become intense and erratic and are reported to have changed significantly by 90% of the key informants.

Also, 80% of the key informants reported that a significant portion of precipitation is now being received in the rain. Almost 100% of the informants strongly believe that the timing of seasons has been changed, especially during the winter season. Due to erratic rainfall/less snowfall, irregular hailstorms and rising temperatures are causing shrinking agricultural land and less production in food grain, horticultural crops and fruit wastage due to hailstorms leading to upper parts of block particularly impressed. Also, extreme weather events negatively affect agricultural land because they generate flash flood incidents, more storms and squalls that wash the topsoil from the agricultural fields and make it unproductive. They have adversely affected land-based income generating avenues and livelihood commodities, particularly in low land areas.

Table 4
Key Informant perception about climate change in the study region

Key Informants perception of change	**Respondent's Responses**					
	Yes		**No**		**Neutral**	
	No.	%	No.	%	No.	%
Observed Changes in climate during lifetime	8	80	2	20	0	0
Rise in Temperature	9	90	0	0	1	10
Decreases in rainfall amount and duration	10	100	0	0	0	0
Change in Timing of seasons	9	90	0	0	1	10
Decreases in snowfall incidents	10	100	0	0	0	0
More precipitation in the form of rain instead of snow	8	80	0	0	2	20
Fluctuation in water availability	10	100	0	0	0	0
Increasing frequency of Drought	9	90	0	0	1	10
Increasing flash flood and floods incidents	5	50	4	40	1	10
Increases extreme weather events	8	80	1	10	1	10
Changes in flowering and fruiting time	6	60	2	20	2	20
Decrease land productivity	9	90	0	0	1	10
Loss of agrarian land	10	100	0	0	0	0

Source: Field work

Table 5
Community responses towards climate change impacts on different parameters

Parameters	Responses in percentage (%)		
	Increased	Decreased	Same
Agriculture yields and income	10	80	10
Horticultural yields and income	10	40	50
Forest resources availability	0	80	20
Livestock population and income	5	85	10
Water availability	0	100	0
Agricultural land	0	95	5
Frequency of disease and insect/pest	90	0	10

Source: Fieldwork

Community response and adaptation tools: Himalayan mountain agroecosystem is highly dependent on global climate and any changes in it have a significant negative impact on agricultural land. In our study area community, people experienced and admitted that over the last several years, there have been irregular rainfall incidents (delayed or shift in rainfall, low rainfall or no rainfall), drastic changes in the frequency and volume of precipitation pattern (low snowfall, heavy hailstorms) and rising temperatures resulted in low yield of agro-horticultural crops, vegetables and food grains and have adversely affected land-based income generating avenues, particularly in midland and low land areas. Respondents also indicated that low rainfall or shift in rainfall resulted in crop failure, reduced the yield of food grains, fodder resources, horticultural crops and livestock production, which weakened the economic status of the farming communities and due to climatic variability, people started cultivation of cash crops.

Moreover, the local people enforced the gradual increase in temperature and consequent drying up of water bodies in highland areas to reduce the livestock population. Besides this, many households cited that the frequency of disease and insect/pest attacks have increased many folds, particularly in agricultural and horticultural crops and vegetables. The transformation in different aspects of the farming system, a sharp drop in agricultural productivity and a significant decline in agricultural land have also been observed in all studied villages (Table 5).

Adaptation refers to actions that help better cope with the circumstances or ground realities.[22] It is generally referred to as changes in livelihood or survival strategy to reap better returns under changed conditions, consisting of cropland, pasture or grazing land, use of organic manure, thoughtful land-use practices, agroforestry and water management activities.

Also, TEK and knowledge-based practices are accepted as being the foundations of resilience and adaptation of rural communities. The inherent dynamism of TEK systems lies at the heart of this ability to adapt and adaptation strategies are constantly renewed through learning by doing, experimenting and knowledge-building processes that allow knowledge holders to adjust and modify their actions in response to changing ground realities.[2] Also, climate change has led to increased pests, diseases and invasive plant species. Eupatorium, Lantana and Parthenium are prominent, which have many negative impacts on crop productivity, food security, human health and animal husbandry.

In recent years, there has been a dramatic increase in the use of inorganic or chemical fertilizers in the study region with easy availability of pesticides and insecticides and less availability of organic manure, which adversely affects soil quality (productivity) in low land (low altitude) region. Farmers of the study region are well aware of the linkage between soil degradation and chemical fertilizers. However, due to the shortage of organic fertilizers, they are dependent on chemical elements to maintain their crop yields. The lower availability of organic manure is a sharp decline in livestock rearing due to the changing climatic conditions which reduce the food, fodder and water availability for animal husbandry and has put extra burdens on the farmers. However, smallholder farmers, who cannot afford to buy pesticides and chemical fertilizers, continue to rely on compost-based fertilizers and biopesticides produced locally using animal dung and weeds.

Hence, some farmers have abandoned crops like pulses, traditional cereal crops, tuber and sweet potato and introduced new crops like chilly, maize, onion, garlic, cucumber, bell vegetable and ginger. Even though farmers have started using chemical fertilizers and pesticides, they are yet to adopt high-yielding seeds because they believe that local seeds are better adapted to their agro-climatic conditions. Also, many farmers have started adjusting the sowing and harvesting time to cope with changing climatic conditions.

Moreover, mitigation and adaptation are required to meet the challenges of climatic variability intervention because mitigation is a long-term process. In many cases, it is found to be expensive. However, adaptation is a superior option to respond to ongoing and immediate threats of climate change. So, community perception and understanding of climatic variability can be essential for adaptation. In addition, this study identified several other promising optimization strategies which are as follows:

- A polyculture activity (more than one crop at a time) is a promising adaptation strategy for small-scale farmers. While more labor-intensive than single-cropping, multi-cropping has advantages because it is more resistant to insect attacks, allows a varied diet and reduces the risk of crop failure.
- Most of the farmers in the study area practice traditional methods, constructing terraces for soil and water conservation and rainwater harvesting. In those areas, it is imperative to convince farmers to adopt terrace cultivation because it helps store water in the fields and hinders topsoil erosion. There is a need to support farmers to restore these practices by the construction of rainwater control and management structures and rainwater storage for supplementary irrigation (in farm ponds, sand/subsurface dams, earth dams, tanks and others) for coping with the high seasonal variation in changing climatic conditions.
- Weather forecast in India is disseminated by Indian Meteorological Department (IMD), the Ministry of Earth sciences, the Government of India and some private sectors. However, weather updates are also ordinarily available on the internet. However, due to the low literacy rate and limited access to the internet, weather information does not reach the farmers on time. The farmers have to suffer a lot and their crop is either wasted while planting or mowing/harvesting. There is a need to establish a weather information system specially designed for the farming community in remote rural areas to make rapid decisions about sowing, irrigation and other farm practices. Also, information could be broadcast through community radio programs or can be disseminated through mobile phones.

Conclusion

The present study shows that the lesser Himalayan region is witnessing changes in temperature and precipitation regimes. All households have experienced climate shocks in the last 35 years with intense storms, extra heat and cold spells. Also, the duration and the amount of rainfall have changed significantly and received a form of precipitation other than snow. Due to erratic and less predictable precipitation patterns, rising temperature and hailstorm incidents, recent years have experienced an overall reduction in water availability, severely affecting harvests (mainly horticultural crops) and a shrink in agricultural land. Besides changes in hydrological regime and agricultural productivity, phenological changes in wild and cultivated crops are everyday observations. Hence, climatic variability decreases livelihood capital, degrades agro-livestock conditions and the emergence of invasive species.

Notwithstanding, the most significant impact is perceived to be on the agricultural sector, accommodating the highest proportion of the workforce in the region. People responded to the changing conditions with various coping and adaptation mechanisms. However, the poor, low-income families, women and other marginalized groups are particularly vulnerable and less able to adapt. For example, the rural community is testing new approaches for adaptation, which are enhancing their adaptive capacity. These local and location-specific adaptation approaches need to be recognized by the Government for their better upbringing. Integration of community perception and their TEK with available scientific knowledge about climate change could be one way of building our capacity for climate change mitigation and adaptation. Also, targeted efforts are required to move from coping to adaptation and reduce the negative impacts of climate change.

The community perception-based study is a rigorous but straightforward approach to dealing with climate disruptions through a shared learning dialogue (SLD) experience involving KIIs, FDGs and local governmental and non-governmental resources. The results of this work have clearly shown that the rural community perception and their TEK are more significant in coping with adverse climatic situations which also can be adopted in urban areas.

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