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Impact of Climate Change on Life and Livelihood of Indigenous People of Higher Himalaya in Uttarakhand, India

Piyoosh Rautela[1,*], Bhavna Karki[2,*]

[1]Disaster Mitigation and Management Centre, Uttarakhand Secretariat, Rajpur Road, Dehradun, Uttarakhand, India
[2]Department of Disaster Management, Uttarakhand Secretariat, Rajpur Road, Dehradun, Uttarakhand, India
*Corresponding author: rautelapiyoosh@gmail.com; bhavnakarki@gmail.com

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Abstract Increase in average temperatures and abrupt changes in the precipitation regime are perceived to take place in the region by most people. Duration, amount and form of atmospheric precipitation is reported to have changed significantly. Even during winters the people of the region are increasingly getting overwhelmed with liquid precipitation rather than solid precipitation that was traditionally recived in the form of snow. This is perceived to be responsible for reduced duration of snow in the region. This is held responsible for reduced water availability in the region and people have already started to face scarcity of water. Most people of the region at the same time agree that there are changes in the timing of flowering and fruiting of plants. Productivity of the agricultural fields is also reported to have decreased. Increased incidences of pest infestations and animal attacks are also reported from the region. These have forced the inhabitants to introduce many changes in their traditional life support pursuits. Of these some are identified as being part of the coping strategy of the people of the region that is witnessing climate induced changes at an alarming rate. These are required to be studied, documented, researched and improvised with appropriate inputs from formal science and technology so as to make these viable and acceptable to the masses.

Keywords: *traditional knowledge, climate change, adaptation, coping mechanisms, Himalaya, Bhagirathi, Niti, Byans, Johar*

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1. Introduction

Mountain ecosystems play an important role in ecological sustainability, economic development and livelihood security of people at local as well as global level. Mountains are however amongst the most fragile environments on earth. These are at the same time identified as being repositories of biodiversity and water and providers of ecosystem goods and services on which downstream communities rely on both regional and global level [1,2,3]. The mountain ecosystems help in stabilising atmospheric circulation by creating barriers to free movement of winds. In the Indian subcontinent these have played an important role in stabilising the summer monsoon and shielding the region from the westerlies during winters [4].

Scientific evidence for global warming is now considered irrevocable [5] and climate change impacts are lately being held responsible for instability in the monsoons resulting in spells of intense precipitation and unusually long dry spells. These at the same time are understood as being superimposed on a variety of other environmental and social stresses, of which many are recognized as being severe [6]. Climate change is perceived to threaten livelihoods of the people, particularly where they are dependent upon natural resources that are particularly vulnerable to changes in climatic conditions. Declining natural resource availability and uncertainty introduced by climatic variability are understood as posing threat to the sustainability of agriculture and allied sectors in the face of already declining natural resource base.

Influenced by climate change, people living in the mountain ecosystems are experiencing wide ranging effects on their environment, biodiversity and socioeconomic conditions [7]. Study and documentation of coping mechanisms of the indigenous people thus becomes important and this is a must for developing long term adaptation strategies for reducing vulnerability related to climate change.

Adaptation is widely recognized as a vital component of human response that helps in coping better with changed ground realities; particularly so with regard to ones introduced by climate change. Without adaptation, climate change is generally understood to be detrimental but with adaptation, vulnerability could largely be reduced [8-13].

This study is an attempt to record impact of these changes as perceived by the masses and understand the impact of these on the life and livelihood of local people. In the process attempt is also made to document efforts of masses to overcome the hardships so being introduced.

1.1. Study Area: People and Economy

Bhotiya tribe constitutes majority population of the study area. Though agro – pastoralism is the major economic activity of the area trans - Himalaya trade used to be their traditional pursuit. For this they used to maintain large animal herds; particularly those of sheep and yak that were utilized for transporting various tradable commodities from terai, in the foothills of Himalaya that used to be their abode during harsh winter months, to Tibet traversing high-altitude passes and rugged Himalayan terrain.

Various sugar and oil products together with tobacco, spices, pulses, grain, coffee and various miscellaneous consumable items constituted the package carried across and exchanged by these people in Tibet for borax, salt, wool, gold dust, animals, yak tails, and raw silk. These tradable commodities included products bartered by these people on way with the local inhabitants. Local fairs of the region that coincided with the movement of these migratory traders ensured that the local producers fetch fair price. This ensured variety in the economy of the region and at the same time infused new vigour into the economy of this region.

The people of the area traditionally crossed over to Tibet through a number of identified passes. For the people of Johar valley it was Gonkhal Dhar, a ridge defining the eastern border of Milam village, where the traders were given a hearty send-off and accorded a warm welcome on their return. From there the route to Tibet was through Untadhura pass (5377 meters) that could be crossed between June and October [14].

People of Byans valley carried out trade through Lipulekh pass following the Kali valley and the importance of this route can well be assessed from the fact that Baz Bahadur Chand, the king of Kumaun, personally supervised construction of this route [15]. En route Garbyang was a major trading destination and importance of the same can well be assessed from ornate multistoreyed buildings of the area [16].

In the Garhwal region trans - border trade was carried out through Niti, Mana and Nilang passes. The way to Niti pass (5025 m) was along Dhauli Ganga, Mana pass(5764 m) was through the higher reaches of the Alaknanda beyond Badrinath and Nilang pass(3245 m) was accessed through narrow gorge of Jad Ganga beyond Harsil.

After the Sino-Indian war of 1962 the border was closed and this flourishing traditional commerce was suddenly disrupted. This forced the people to pay attention towards settled agriculture.

Lipulekh pass (4990 m) of the study area is the first Indian border post to be opened for trade with China in 1992. This was followed by the opening of Shipki La in Himachal Pradesh in 1994 and Nathu La in Sikkim in 2006. Presently, Lipulekh pass is open for cross-border trade every year from June through September and people of the area still engage in traditional cross border trade. Their ethnic characteristics and linguistic skills together with traditional acumen to traverse difficult terrain that is still largely traversed on foot help them dominate this trade.

People in all the four valleys taken up under the present study still resort to seasonal migration and live in these high altitude valleys in summer (May - June to October - November) and migrate to lower altitudes around November and stay there till April.

2. Study Area

Habitations located in the northern frontier of the Uttarakhand state that are largely populated by the people of Bhotiya tribe are taken up for the present study, with specific focus on Johar, Byans and Niti valleys together with upper reaches of Bhagirathi valley (Figure 1). These valleys are home to some of the world renownedglaciers, meadows and dense forests. These are inhabited by communities that have been traditionally living in harmony with nature.

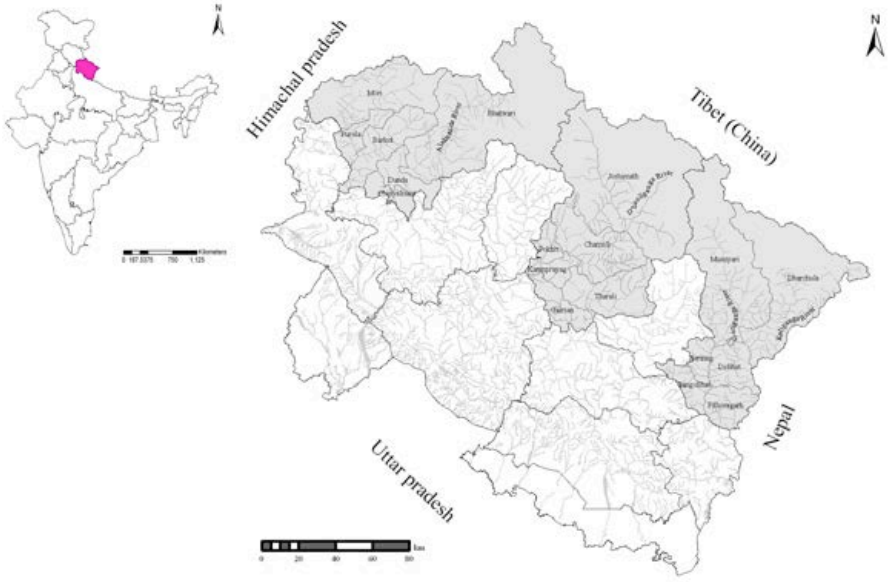

Figure 1. Location of the four valleys taken up under the present study

The study has focused on gathering information on the observations of these communities regarding changes in their environment and having stock of their collective experiences rather than attempting to take stock of sectional comparative analysis of the impact of changimg ground realities.

The valleys taken up under the present study are located in close proximity of glaciers and are highly sensitive to changes in climatic parameters and therefore the effects of climate change, if any, are expected to be most pronounced in these regions. Moreover most people of these valleys still pursue traditional life support strategy that is interwoven around various bounties of nature. Largely unaffected by external interventions these people still face the challenges put forth by nature with their traditional wisdom.

Of the 73 villages covered by this study 26 are located in the upper reaches of Bhagirathi river valley located in Bhatwari subdivision of Uttarkashi district. These include Harsil, Bagori, Mukhba, Dharali, Markunda, Sukhi, Jhala, Jaspur, Chholmi, Purali, Odar, Salang, Jalang, Hurri, Raithal, Natin, Bhatwari, Kyarakh, Barsu, Pala, Tihar, Kujjan, Shiyabba, Dwari, Pahi and Kaamar (Figure 2).

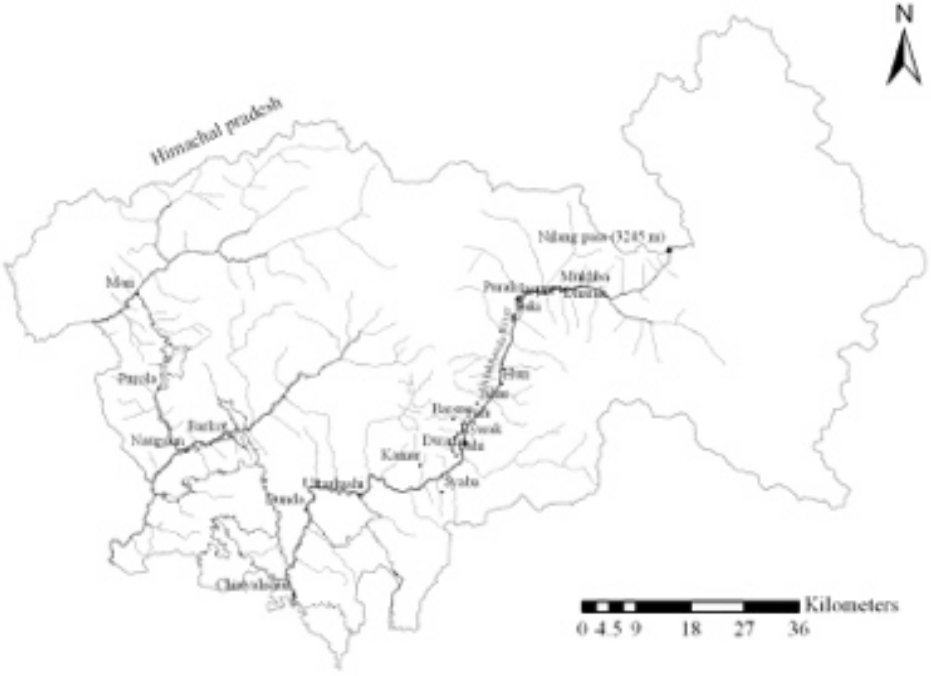

Figure 2. Location of the villages covered under the study in Bhagirathi valley of Uttarkashi district

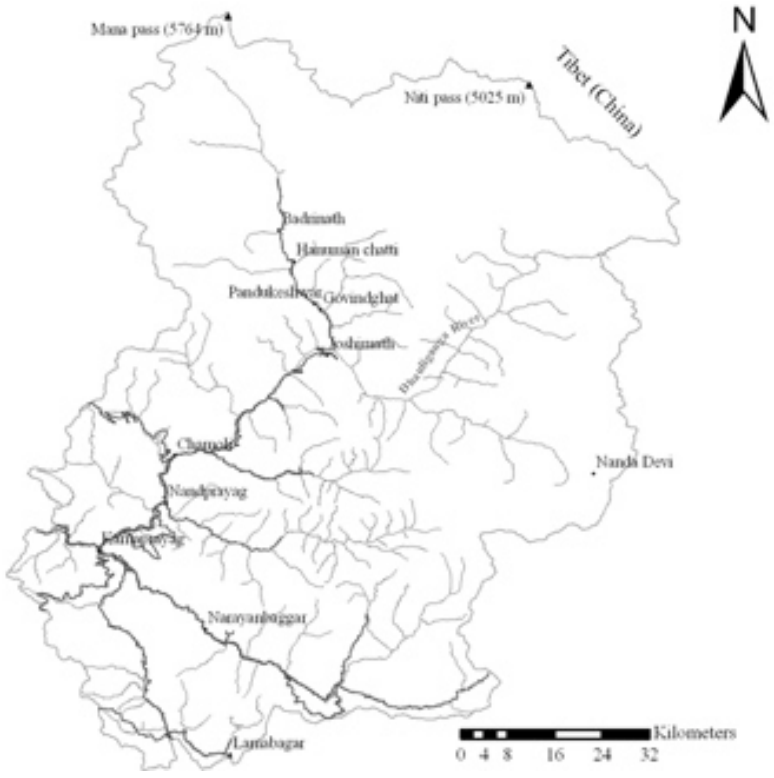

Figure 3. Location of the villages covered under the study in Niti valley of Chamoli district

Altitudinal range of these villages varies between 750 and 2620 meters above mean sea level (msl). Bhagirathi is the main river draining this valley and after its conflence with Alaknanda at Devprayag the same is known as Ganga.

Niti valley covered under this study is located in the Joshimath subdivision of Chamoli district and originating around Niti pass at an altitude of 5070 meters Dhauliganga is the main river draining this valley. This area falls within the buffer zone of the Nanda Devi Biosphere Reserve and 16 habitations of this valley are covered under the present study.

These include Niti, Ghamsali, Bampa, Farkiya, Mehargaon, Kailashpur, Malari, Kosa, Jhelam, Dhungri Jhelam, Singala Jhelam, Jumma, Dronagiri, Ruving, Lata and Reni (Figure 3). Altitudinal range of these villages varies between 2800 and 3600 meters above msl. Johar valley is situated in Munsyari subdivision of Pithoragarh district.

Goriganga is the main river draining this valley and 24 villages of this valley are covered under the present study; namely Lilam, Laspa, Rilkot, Martoli, Burfu, Milam, Pachhu, Ganghar, Mapa, Sai – Polu (Yarti), Kweri – Jimiya, Senar, Jaiti, Dummar, Barniya Gaon, Talla Ghorpatta, Papri, Painkuti, Darkot, Nayi Basti (Munsiyari), Chhori Bagad and Walthi (Figure 4). Large portion of Johar valley, especially to the north of Munsyari can only be approached on foot.

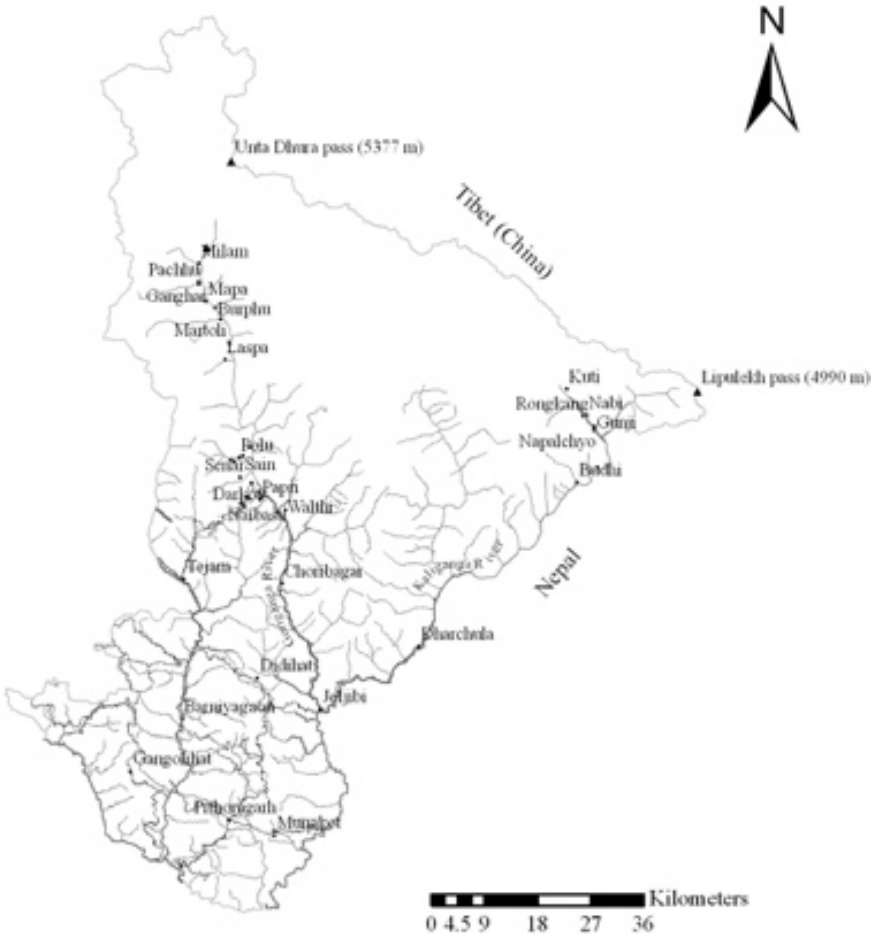

Figure 4. Location of the villages covered under the study in Johar valley of Pithoragarh district

Altitudinal range of these villages varies between 2200 and 3500 meters above msl.

Byans valley of Dharchula subdivision of Pithoragarh district is drained by Kali river that marks the boundary between India and Nepal. Like Johar valley large portion of the valley can be approached only on foot. The valley has seven villages; Budhi, Garbayang, Gunji, Napalchu, Rongkong, Nabhi and Kuti and all are covered under the study (Figure 4). Altitudinal range of these villages varies between 2250 and 3600 meters above msl.

3. Methodology

Purposive sampling was used in the selection of geographical area and villages taken up under the present study. This method has been used in this qualitative research for maximizing relevant representation based on prior knowledge. This is based on both secondary and primary sources of information and an extensive desk review was undertaken beforedesigning the research process and instruments. Secondary information has been used primarily for providing relevant context for understanding the key findings of field research. Qualitative research methodology was applied the collection of primary data.

Responses of 871 persons from 73 villages of the four identified valleys are recorded using a specially designed semi-structured questionnaire (Table 1).

Besides this a total of 12 FGDs, 24 IDIs and 30 KIIs were also conducted. Information contained in the folklores, sayings, folksongs, folktales and various religio-

magical rites and traditional practices of the masses was at the same time analysed for better understanding of their efficacy in effective resource management.

Special care is taken to select elderly people for response as they have memories of longer time span. Gender balance is resorted to in the responses. Proportions of male and female respondents are 46 and 54 percent respectively. The age profile of respondents is given in Figure 5.

The focus of the research was on recording the observations of the community members regarding change in outer environment and on getting into collective experiences rather than on cross sectional comparative analysis of the impact of climate change.

Table 1. Details of respondents covered under the present study in the four river valleys (*n = 871*)

		Number of rspondents		
Valley	**Villages covered**	**Total**	**Males**	**Females**
Bhagirathi	26	312	134	178
Niti	16	205	141	64
Johar	24	201	67	134
Byans	7	153	59	94
Total	73	871	401	470

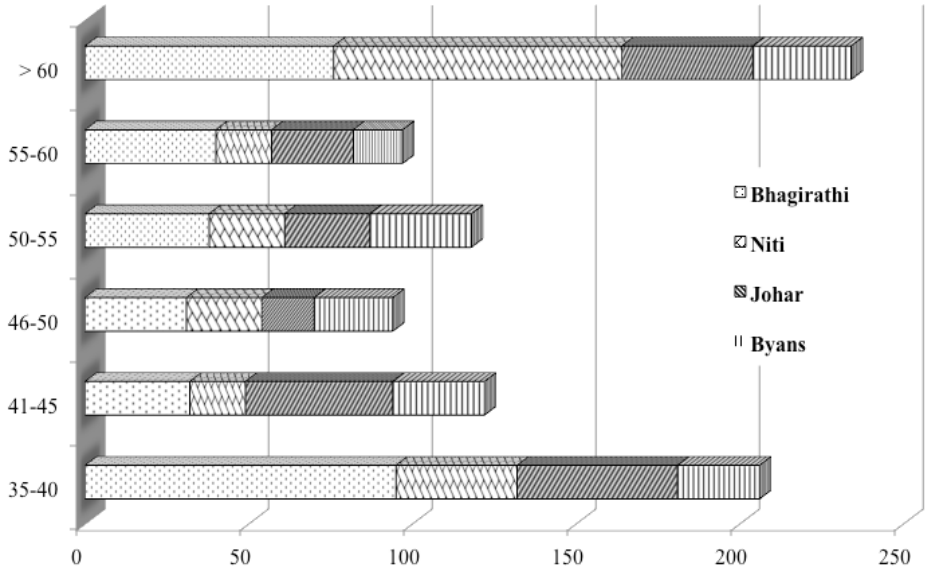

Figure 5. Diagram depicting age profile of the respondents in the four valleys of the study area (n=*871*)

4. Results

4.1. Perception of the People on Climate Change

4.1.1. Meteorological Parameters and Glacial Retreat

The results show that 86 percent of the respondents perceive increase in average temperature together with change in precipitation regime (Figure 6). Studies also show that the net increase in temperature is ranging from 1.7°C to 2.2°C with respect to the 1970's. Seasonal air temperatures also show rise in all seasons [17].

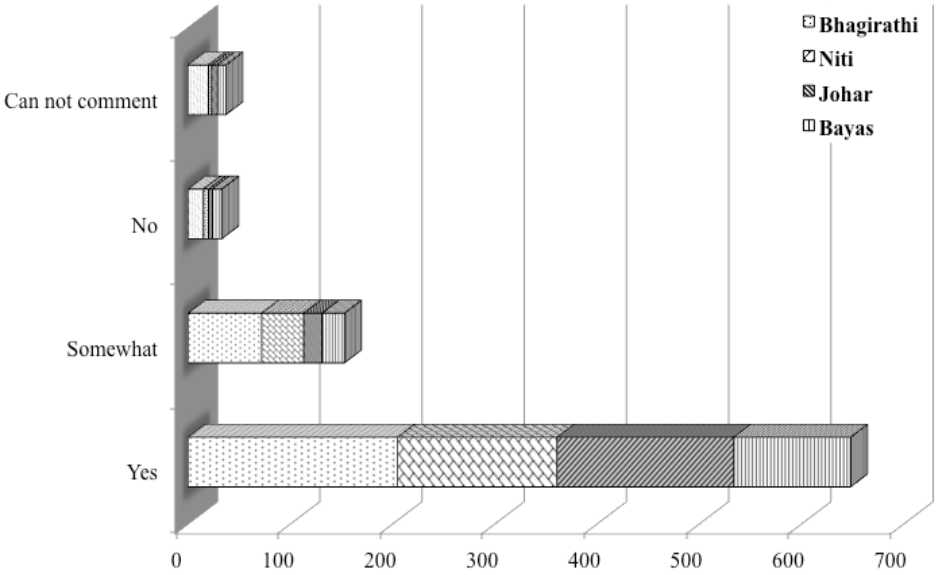

Figure 6. Diagram showing perception of the respondents towards climate change (*n=871*)

Both duration and amount of rainfall is reported to have changed significantly by 92 percent of the respondents. This also includes i) change in the timing of rains, ii) rains having become intense and erratic. There are also invariable reports of occurrences of heavy rainfall that were earlier unknown in high altitudes. This is lately reported to result in flash floods causing loss of infrastructure and property.

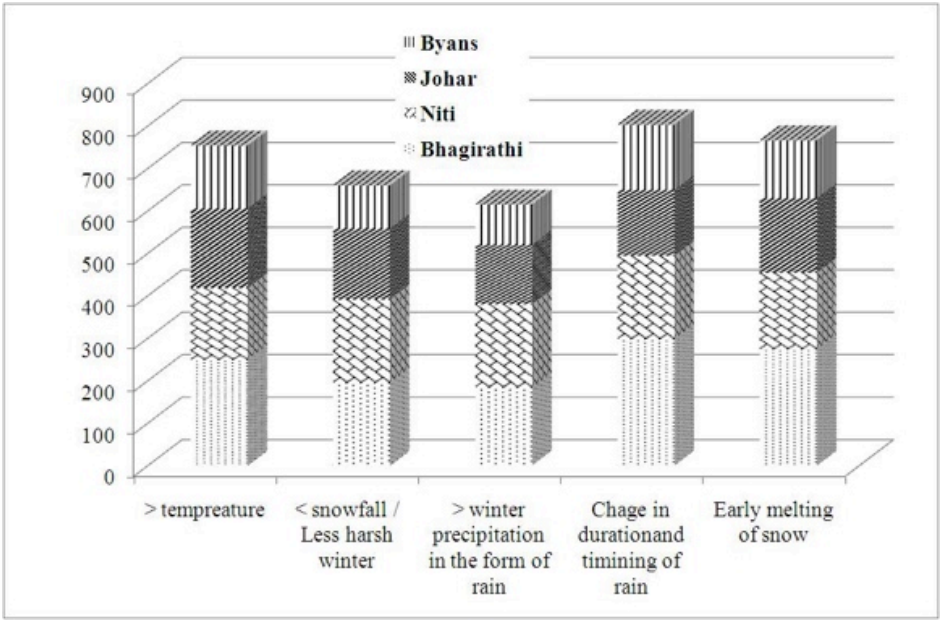

Figure 7. Diagram depicting perception of the respondents to change in precipitation regime

70 percent of the respondents reported that major proportion of precipitation is now being received in the form of rain rather than as snow. As the amount of snowfall is less and it stays for a shorter duration, chances of its getting compacted and converted to ice are reduced (Figure 7).

This is deduced to be responsible for reported negative mass balance of the glaciers and their fast recession. Winter conditions in the study area are reported to traditionally prevail between November and February – March. This period has reportedly shortened drastically over the previous 10 to 15 years. 89 percent of the respondents strongly believe that the winter season has become short and snow has lately started to melt early which is impacting the agro - horticultural operations adversely.

As perceived by the respondents, the major impact of the changes is on the retreat of glaciers in all four valleys. Himalayan glaciers are receding faster today than the world average [18].

Other studies show that the glaciers in the region show fluctuations in retreat rates during the last century, possibly due to the mixed influence of variable topography, temperature and snowfall regime[19].

The Gangotri glacier, which was receding at a rate of around 26m/year between 1935 and 1971, has shown a gradual decrease in the rate of recession. It had come down to around 17m/year between 1971 and 2004, and in the recent years has shown a recession rate of about 12m/year during 2004–2005 [20].

Similarly, the rate of recession of the Milam glacier has been observed as 16.5m/year in the last 150 years[21].Retreat of glaciers can destabilise surrounding slopes and may give rise to catastrophic landslides [22,23] which can dam streams and sometimes lead to outbreak floods. This is also increasing the region's vulnerability to flash floods.

Change in the timing of the seasons is reported by more than 90 perent of the respondents (Figure 8).

4.1.2. Hydrological Regime

Besides rainwater main sources of water for the people in the study area include glacial melt, rivers, lakes, springs and streams. The study shows a mixed response on the level and availability of water. 92 percent of the respondents reported fluctuations in the discharge of the streams and springs and the main reasons cited for this change in water availability include i) increase in temperature or dry spells, ii) glacier recession, iii) earthquake shaking, iv) monsoonal variability, v) irregular rainfall or less or heavy rainfall, vi) landslides, vii) climatic changes, viii) reduced snowfall, ix) construction of dams, x) deforestation, xi) appearance of ground fissures and xii) land subsidence.

Hydro-geologic response to earthquakes is well known and there are reports of wells and springs becoming turbid or dry or beginning to flow after earthquakes [24].

The same is reported from the study areathat lies in seismically active zone. Change in the discharge and drying of some sources is reported from Dwari, Siyabba and Raithal villages of Bhagirathi valley after 1991 Uttarkashi Earthquake.

Hardships faced by the people due to reduced water availability include i) difficulty in managing water for household use, livestock and irrigation, ii) long distances to be negotiated for fetching water, and iii) long queues for water collection implying prolonged waiting time for water collection.

Even though some villages including Kaamar in Bhagirathi valley have reported scarcity of water reduced supply has not yet started affecting quality of life or life support strategy of the people. It is however agreed that in times to come the same could become a serious problem.

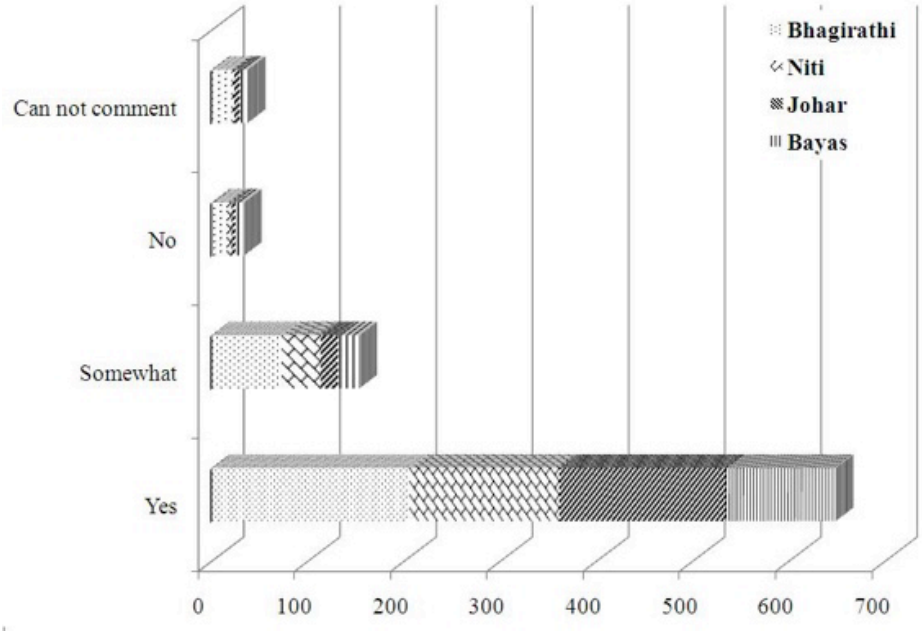

Figure 8. Diagram showing perception of the respondents to change in the timing of seasons

4.1.3. Impacts of Climate Change on Life Support Strategy

a) Impact on agriculture

An overwhelming 93 percent of the respondents believe that the land productivity has decreased and pest infestation has increased due to change in climate.

Agriculture in the study area is of subsistence type and highly dependent on rains. Snow is an important source of soil moisture in the area and essential for agriculture and growth of pastures. Optimal productivity of most horticultural crops of the area is also dependent on persistence of relatively low temperatures for appreciably long duration. In this period plants remain in a dormant stage and come out of it when the conditions are suitable for growth.

Climate change is known to affect two most important agricultural inputs; water and temperature [25]or agricultural productivity is sensitive to two broad classes of climate-induced effects; i) direct effects from changes in temperature, precipitation, and carbon dioxide concentrations and ii) indirect effects through changes in soil moisture and the distribution and frequency of infestation by pests and diseases [26].The impacts of climate change on life support strategy is shown below in (Figure 9).

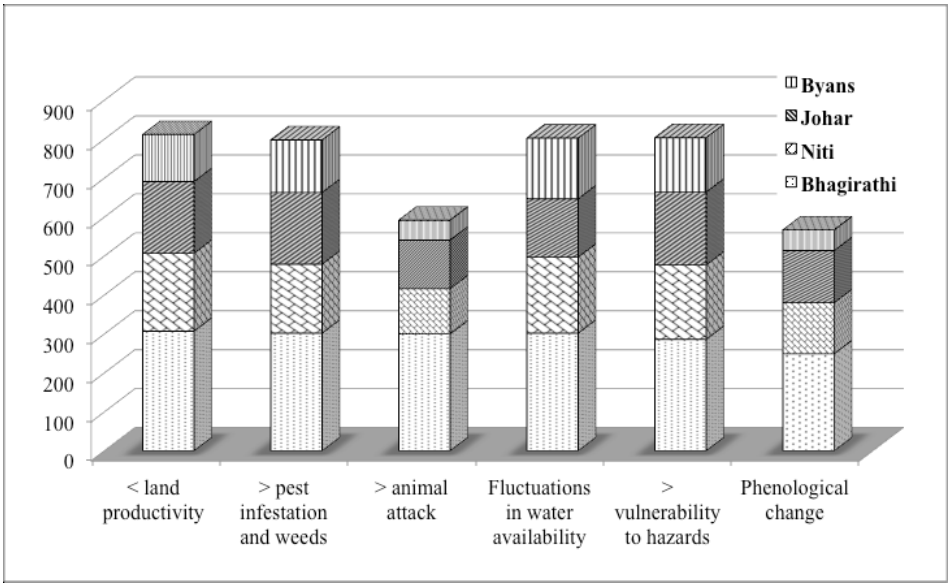

Figure 9. Diagram depicting impact of climate change on life support strategy of the rspondents

Overall seasonal precipitation determines the yield over large areas, but stress and dry spells threaten productivity, even a few hours at critical growth stages (Huntingford et al., 2005).

The phenological responses of plants, particularly the early flowering ones, are considered among the prominent biological indicators of climate change [27]. Due to reduced winter period, dormancy of the plants is broken relatively early and this is reflected in early flowering. The plants thus flower at a time when weather conditions are not favourable for their growth and survival. Hailstorms that are common during this period result in major losses

and moreover, blooming takes place even before local pollinators are active. This reduces fruiting and thus productivity. Warm winter temperatures reduce fruit set of Prunus persica in the field [28]. Apple (*Malus domestica*) production is also reported to be affected by this.

This situation is further exacerbated by the use of pesticides that also wipe out useful insects. Low productivity is also linked to the use of chemical fertilizers and herbicides. It is a general perception that chemicals cause loss of soil fertility and bring forth changes in soil structure. These reportedly result in the formation of hard crust in the soil, which is hard to break and requires a heavy plough for tilling. This is also perceived to reduce porosity and water holding capacity of soil.

Phenological response of plants, particularly the early flowering ones, is considered a prominent biological indicator of climate change [29] and the same is witnessed in the study area.

In the present study 65 percent of the respondents agreed that the timing of flowering and fruiting of plants has changed. Early flowering in almost all agricultural, horticultural and wild species is reported to be a common observation, particularly so in *Rubus sp*., apples (*Malus domestica*) and rhododendron (*Rhododendron arboreum*). This change is attributed to increase in temperature, shortened and less harsh winters and early onset of summer. There are reports from Johar valley of *Prunus sp*. fruiting twice in a year.

Agriculture in the area is becoming economically unviable due to reduced productivity and increased input cost because of the use of agrochemicals. This is perceived to be responsible for fast reducing area under kidney bean (*Phaseolus vulgaris*) crop that used to be a major cash crop of the area.

b) Weeds and infestation of crops

91 percent of the respondents reported increased infestation in crops from the study area. Insects beingpoikilotherms, temperature is probably the single most important environmental factor influencing their behaviour, distribution, development, survival, and reproduction [30,31,32]. Major drivers of climate change i.e. elevated CO_2 levels, increased temperature and depleted soil moisture therefore affect population dynamics of insect-pests and thus significantly enhance the extent of crop losses.

The reasons put forth for the same include i) change in frost-thaw cycle, ii) use of fertilizers and pesticides, iii) increase in temperature and iv) less treatment of soil before sowing. There are reports of many exotic weeds invading the traditional rain fed agricultural areas. The changing temperature and precipitation pattern together with decreasing crop rotation and mixed cropping practices have been held responsible for the same.

Growing incidences of crop infestation are also attributed to increased use of chemical fertilizers. In the area around Malari, where herbicides and pesticides were reportedly introduced by organized system of the state government, insects are perceived to have gained resistance against these.

c) Impact on forest

About 61 percent of the respondents agree that the forest around their villages has become depleted and degraded which they attribute to i) road construction activities, ii) increased fuel wood use due to population pressure, iii) loss of vegetation due to glacial action and other disasters, iv) forest fire, v) overgrazing and vi) decreased regeneration rates of trees in the forest area.

Reduced rainfall and increased duration of dry spells are held responsible for low regeneration rates. These are reported to result in withering and drying of buds and flowers thereby adversely affecting growth and regeneration of forest.

People of the area traditionally depend on forest for timber, fuel wood, non – timber forest products, fodder and leaf litter that is used as bedding material for livestock. 73 percent of the respondents believe that there is difficulty in managing these requirements now.

Degradation of forests in the mid-slopes, where concentration of population is high, has reduced the availability of fodder and leaf litter, with implications on the productivity of both livestock and agricultural lands [33]. Fuel wood is the primary source of energy for cooking in the study area, particularly so in the areas not connected by road. Fuel wood collection is becoming increasingly difficult and people now have to devote relatively more time for the same.

Economic and ecological value of oak is generally conceived to be higher. In comparison to other forests such as pine, oak forests are characterized by higher species diversity, stratification, litter production and soil fertility. Oak species are at the same time recognized as being keystone species without which the complex web of the ecosystem would soon unravel. Oak forest is also perceived by people to enhance groundwater recharge. This is attributed to thick undergrowth and litter that retards surface flow of rainwater and promotes groundwater recharge.

The regenerative capability of oak is reported to be poor not only in the Himalayas but also in North America [34] and Europe [35]. The reasons put forth for the same relate to i) erratic seed production, ii) defoliation, iii) acorn herbivory, iv) feeding on buds, shoots and foliage v) forest fire, vi) extensive lopping, vii) accumulation of thick litter with slow decomposition rate, viii) infestation by stem parasites such as mistletoe, and ix) leaf damage by insect pests.

Lack of regeneration is sometimes also attributed to climate change [36] but annual, heavy and indiscriminate lopping often precludes flowering and seed production for regeneration. Some respondents said on record that increased population pressure and adverse weather are together responsible for depleting oak population.

Animal husbandry has been the mainstay of livelihoods for nearly 80 percent of the households of the area. Animals are however not traditionally stall fed and rearing these depends on forest and pastures. Familial livestock holdings of the people in the study area are observed to be small; 5 or 6 animals that consist of a mix of cattle, buffalo and goat. Sheep are however held in larger flocks of 10 - 15 animals along with a few goats in some cases. Herd size of tribal and migratory communities are however much larger and range between 100 to 1000 sheep, goats or both. These people still take their animals to the higher alpine pastures, *bugyal* in local parlance, during summers for grazing. Productivity of grasslands and pastures is perceived to be reducing due to the warmer and drier climate. With depleting forest cover and reduced

productivity of grassland, people now have to invest more time on fodder collection.

d) Resources from the wild

Large population of the study area depends on forest resources for supplementing income, resource base, food and nutrition. Dependence on forest products generally increases when agricultural production is low, as is during droughts or other natural calamities.

Most sought after wild plant varieties sprout after the snow begins to melt in the valleys. People consume these by preparing several recipes and also dry these for later use. Food products such as fruits, roots, leaves and mushrooms or morels (*Morchella esculenta*; guchchi in local parlance) together with medicinal plants are traditionally collected by the people of the area from forest.

Wild mushrooms variety, *Morchella* of the area is highly prized for its taste and high return fetching ready market. These grow best during the rainy season (mid-June to mid- September) in wet and shady forests. These are collected by males, females and children and dried by hanging these in the form of garlands in well ventilated part of the house and sometimes in the proximity of hearth. Collection and drying these in marketable quantities is tedious and time consuming but economic retuns are always high. Change in oak forest cover and climate is reported to have adverse impact on the availability of *Morchella* spp.

In the previous some years collection of high value *Ophiocordyceps sinensis*, colloquially known as caterpillar fungus (kida jari or yarsagumba in local parlance) has become a major attraction inducing people of the area to come back during its harvest season. This fungus enters the larva of the caterpillar moth, mummifies its prey and eventually grows out of the head of the caterpillar. It appears in the high altitude meadows of the area in the month of May or June with the melting of the snow. The rights over the pasture land being delegated traditionally particularly for grazing purposes, the same are adhered to for the collection of this highly prized produce. Income from this activity is reported to be enough for many families of the area to sustain all through the year.

On social level the caterpillar fungus is becoming a cause of discord too; both within the community and between the communities. The villagers are reported to fight amongst themselves and conflict becomes inevitable when one person or family collects appreciable volume and another is empty-handed. Claim of rights over areas with good potential of the fungus is reported to be the cause of inter-community discord.

According to the villagers the collection of caterpillar fungus is decreasing every year as there is a decrease in the growth of the fungus and it is also feared that in years to come there would be none left at all. Venturing of people in large numbers in the sensitive alpine region is probably deteriorating the habitat. Moreover rampant and unscientific collection is perhaps leaving less or no time for the fungi to produce spores for reproduction.

Some commonly growing wild green vegetables are perceived to supplement physiological needs of the people in the harsh climatic conditions of the area. These reportedly help in maintaining body temperature and are collected from the forest along with medicinal plants. These include *Rumex nepalensis* (jungli palak or payoom), *Chenopodium foliolosum* (bethu saag / bhethua), *Amaranthus sp*. (jangli chaulai), *Megacarpa polyandrea* (barmau), *Diplazium esculentum* (lingra), *Gerardiana diversifolia* (dhol kanali), *Allium siminoi* (sedum). Changes in forest cover and climatic conditions are reported to have adverse impact on the harvest of these.

4.1.4. Faunal Changes

68 percent of the respondents reported to have observed changes in the population and behavior of wild animals and others in the forest around their villages. It is also reported that the wild animals have lately shed their natural fear of humans and started to come very close to the habitations and agricultural fields.

Climate induced changes have both direct and indirect impact on habitat, distribution limits and food availability for wild animals. Search of food is perceived to drive wild animals towards habitations.

Climate change is put forth as one of the reasons for random movement of Himalayan black bear towards habitations. Acorns and nuts of the previous year are the main food of this species and when availability of these decreases due to unusual weather events they are reported to wander around for other food items. Many other animals might also be victim of such phenomenon.

It is also reported that wild animals have lately shed fear of human presence. This is qualified by increased instances of wild animals being sighted close to habitations and agriculture fields. Incidences of bear and leopard killing animals even in cattle sheds are reportedly rising. The aggression is also observed in apes and monkeys.

Responders acknowledge that the wild animals attack humans due to sudden encounter and some time due to hunger. Human encounter with animals is on the rise due to increasing population of wild animals. People perceive that some animals including ape, monkey, bear, boar and leopard have lately started to reproduce more or survival rates of their progenies have increased significantly. This is held responsible for rapid increase in their population.

An old women from Siyabba village in Bhagirathi valley shared that earlier it used to snow a lot and when the village women used to go for fuel wood collection in the forest, they often used to find bodies of dead wild boars. She continued that with reduced snowfall population of boars has increased due to higher survival rates of progeny.

People also reported increase in the incidences of crop damage by wild animals that include monkey, boar, deer, bear and rodents due to increase in their population. The variation in the distance between farm and forest boundaries and number of neighboring farms is put forth as a reason for increasing vulnerability to crop-raiding by wildlife [37]. Other reasons of this include increase in wildlife population and forest degradation and depletion resulting in less food availability in forest.

The situation is observed to be the worst in the Bhagirathi valley. People of Siyabba and Kaamar villages that were well known for potato production have stopped growing potatoes due to increased menace of wild animals. There are similar stories of increased animal attack from Hurri, Kyarakh, Banadarani, Raithal villages. Farmers universally complained of attack on crops by monkeys

during the daytime and the losses by wild boars during the night. Intentional release of the monkeys captured from other areas by the Department of Forest is also reported to be responsible for this problem.

Impact on bird population due to climate change is reported in the form of shortened breeding period or failure to make nests and reproduce due changes in plant phenology, food availability and habitat alteration. Long dry spells fail to induce flowering and fruiting of plants [38] together with emergence of insects [39] that results in low food availability for the birds.

Bees and butterflies are considered to be indicators of ecosystem change and are used for predicting various environmental alterations [40,41]. Their specific survival related ecological requirements that include temperature, humidity, food plants and egg laying habitats make these most vulnerable to climate change [42,43] Reduced nectar availability due to dry spells and drought together with phenological changes are perceived to be responsible for their reduced population.

Similarly the habitat of the bees is also perceived to have changed due to rising temperatures and growth of modern infrastructure that have little scope of accommodating these. The use of insecticides is also perceived to have taken serious toll of honeybees. Mono-cropping that has become prevalent in the area reportedly requires pesticide use to control various pests and diseases. Besides reducing diversity of food sources of the pollinators it also kills many pollinators. Both diversity and abundance of pollinating insects has thus been greatly reduced in the study area. The perception of people is summarised in Table 2.

4.2. Adaptation Measures

Adaptation generally refers to actions that help in better coping with the circumstances or ground realities. This generally refers to changes in livelihood or survival strategy so as to reap better returns under changed conditions. Adaptation related actions include cropland, pasture or grazing land and water management, use of organic manure, thoughtful land use and agro forestry.

Traditional knowledge and knowledge-based practice are accepted as being the foundations of resilience and adaptation of indigenous people. The inherent dynamism of traditional knowledge systems lies at the heart of this ability to adapt [44].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(Figure 10).

Table 2. Local responses on community's perception of climate change related changes in the study area

Community's perception of change	Responses (*n=871*) (in percent)		
	Yes	No	Don't know
Decreased land productivity	93	6	1
Rise in temperature	86	10	4
Change in timing of the seasons	90	8	2
Fluctuations in water availability	92	7	1
Less snowfall	76	14	10
More precipitation in the form of rain instead of snow	70	23	7
Shorter winters	89	4	7
Changes in the population and behaviour of wild animals	68	22	10
Depletion and degradation of forest biodiversity and cover	61	22	17
Changes in flowering ad fruiting time	65	26	9
Increased crop infestations	91	7	2
Agricultural land being left barren	79	18	3
Increased vulnerability to hazards	90	8	2
Decrease in fuel, fodder and other forest resources	73	7	20

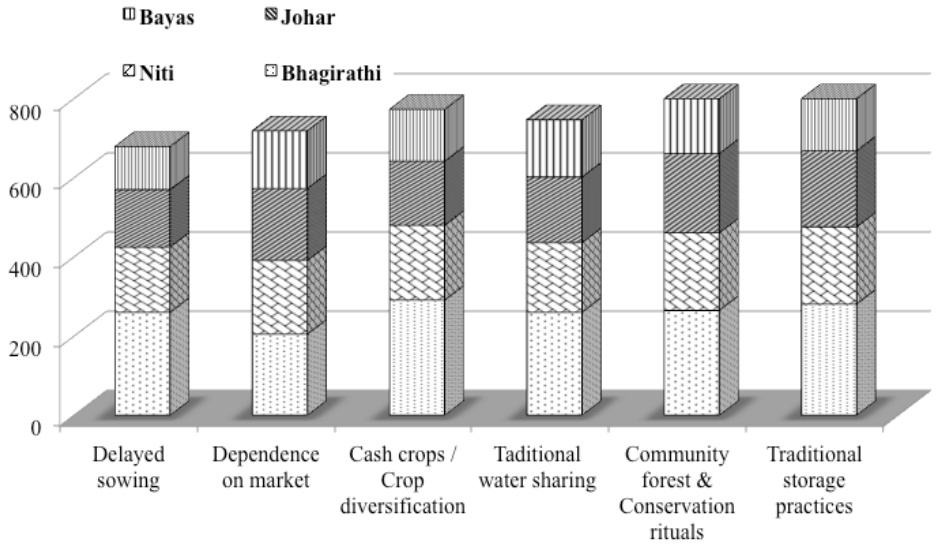

Figure 10. Diagram depicting coping mechanisms adopted by the respondents

4.2.1. Traditional Systems of Governance and Social Networks

These contribute to the ability of the community to collectively respond to environmental change and increase resilience. These include decisions on diversified land use, natural resource management, sacred groves, community water sharing, customary laws and rituals. The collective decision making is traditionally resorted to by the community in the study area and is responsible for greater ability of the community to adapt to change. These norms are still followed by all the people.

4.2.2. Adaptation Measures in Agriculture

Traditional farming practices show fine assimilation of the above practices and these are all the more relevant today in the changing climatic scenario. To combat the negative impacts of the changing climate on agriculture people in the region are observed to resort to various measures, some of which are described below.

a) Fodder and fuel wood requirements

People are trying to address the issue related to decrease in fodder and fuel wood availability by planting fodder trees along the edges of the terraced fields (75 percent of the respondents) and maximizing fodder yields through systemic lopping. Armed with their traditional knowledge the women of the area are able to undertake lopping operations without damaging the main tree and adversely affecting its productivity. This knowledge is particularly applied for managing the oak forest. Women in fact enhance productivity of the oak forest through correct lopping under stable conditions [45].

b) Early sowing and crop selection

With increasing temperature, shortened and less harsh winters farmers of the area have started to sow early (78 percent of the respondents). People have at the same time started to cultivate crops that have become favoured due to changing climatic conditions. Production of off-season vegetables around Harsil together with production of cash crops throughout the Bhagirathi valley is part of the strategy of the people to sustain their livelihood.

c) Crop diversification

The study area enjoys niche advantages in the form of temperate climate that is favourable for growing plants of medicinal value that fetch high price and have a large and ready market. People of the area have lately started to cultivate jambu faran *(Allium stracheyi Baker*), kala jeera (*Carum persicum*), seabuck thorn (*Hippophae rhamnoides*) at many places in the study area. The crop diversification is being adopted by about 89 percent of the respondents.

People of the study area are observed to change their farming practices according to the changed climatic conditions. In the Byans valley people have reportedly started to get good production of garlic in the previous 6-7 years, that could previously not be grown in the area due to harsh climatic conditions. Increase in the production of potato is also reported from the alpine meadows of all the valleys.

Apart from the other fruits changing climate has enabled apple (*Malus domestica*) production in new areas. As it generates more money and has ready buyers, in places like Harsil more and more people are observed to plant apple orchards replacing traditional crops.

d) Organic farming

There is a vast potential of organic farming in the hills and people have lately started to adopt this farming practice with crop varieties that can flourish in the area and fetch good returns. On site availability of the buyers ensures high return and this has encouraged farmers to maintain fertility of the land through organic manure.

e) Mixed cropping and promotion of Millets, pseudo cereals

Genetic and species diversity in fields has been maintained in the study area traditionally through mixed cropping system of Barahanaja, meaning twelve grains. In this system twelve different crops are grown together which ensure favourable conditions for each other and thus improve productivity. This provides protection against total crop failure and is an effective instrument of food security.

Though twelve crops are not grown everywhere lately people of the area have started to grow some of the traditional crops that better suit the climate. This is largely attributed to growing global demand of some of these crops that include buck wheat.

These crops are of short duration and fit the climatic conditions of high altitude temperate zone. These are at the same time particularly adapted to very poor, badly-tilled land which can scarcely produce anything else. The traditional varieties of millet when grown alongside modern crops provide for contingency when conditions are not favourable.

Buck wheat for example is one of the quickest growing crop that takes only 4–5 weeks from seeding to flowering and thus suppresses weeds and prevents soil erosion due to intensive runoff. The crop at the same time has multiple usages; the young leaves are eaten as vegetable and the stalk is an important source of cattle feed. Since it matures quickly, it escapes early autumn frost injury. It is also a good green manure crop and improves soil texture, and also increases nutrient status of the soil, particularly phosphorus and micronutrients in the root zone, which is beneficial for the succeeding potato crop and other cash crops that include(*Malus domestica*) and razma (*Phaseolus vulgaris*).

4.2.3. Pastoralism

The nomadic pastoralists traditionally coped with extreme climate in the region through a variety of practices. The practice of pastoralism has reduced but those still practicing it follow the following for coping up with the changing climate, i) rotational use of bugyals / pastures allowing pasture to recover after intense grazing, ii) division of livestock for grazing on different parts of pasture or land and iii) raising different types of livestock, which ensure different grazing habits and reduce herders' risk of losing all animals to one disease.

5. Conclusion

The study shows that the area is witnessing changes in temperature and precipitation regime. Both duration and amount of rainfall having changed significantly, most precipitation is received as rain rather than as snow. Besides changes in hydrological regime and agricultural productivity, phenological changes in wild and cultivated crops are common obervation. Changes in floral and faunal population and type together with changed animal behavior are also observed. (Perceived changes, impacts on livelihoods, coping mechanisms and future risks have also been summarised in Table 3).

Changing climatic conditions are resulting in loss of livelihood capital, changing agro-livestock conditions and emergence of invasive species. The biggest impact is perceived to be on the agricultural sector that accomodates highest proportion of the workforce of the state. Though fast pace of migration from the region is held responsible for this, climate change is sure to have adverse impact on the livelihoods based on forestry, agriculture, livestock husbandry, Non-Timber Forest Products and medicinal

plants. Communities are observed to react positively to changed situation and taking advantage of the niche of their area and improvising on their traditional knowledge they have started to grow commodities that are better suited to the changed scenario and has ready market. They are also taking advantage of reduced duration and harshness of winters for growing new crops. Organic farming that is observed to gain ground in the area is perceived to stabilise the population of the pollinators and also control infestation of weeds.

Table 3. Perceived changes, impacts on livelihoods, coping mechanisms and future risks

Community's perception of change	Impacts on livelihood systems	Coping and adaptation	Potential future risks
Decrease in rainfall and change in timing of rainfall	Decline in agricultural productivity, reduced agro-biodiversity	Improvising with cash crops; delayed sowing More dependence on market	Increasing food and livelihood insecurity
Longer dry spells	Drying up of springs; less flow in springs and streams	Traditional water sharing system, delayed sowing	Scarcity of water for drinking and agriculture; increased workload for women and children; crop failure
Rise in temperature and decreased water availability	Lack of fodder; less productive land	Shift to smaller livestock, less land area under cultivation; dependence on market for food	Food insecurity, increased drudgery, dependence on cash income
Warmer winters and significantly less snowfall, more precipitation in the form of rain instead of snow	Increased incidence of crop infestations, weeds, health problems;	Increased use of insecticides and pesticides	Increased food and livelihood insecurity
Temperature and rainfall timing	Phenological changes, change in bee populations	No coping mechanism	Degradation of orchards , impact on horticulture
Better survival of animals due to decrease in snowfall and less harsh winter	Increased incidences of animal attack on agriculture	Replacing crops; No coping mechanism	Crop loss , less agricultural productivity
Reduced forest biodiversity and cover	Reduced snowfall, increase in temperature	Afforestation; No coping mechanism	Impact on livelihood dependent on non wood forest products (NWFP)

The efforts of the people are certainly short of what is really required for coping up successfully. The impacts have therefore to be studied in detail so as to devise adaptation strategy that improvises upon traditional practices of the people by dovetailing elements of modern science and technology in the same.

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Statement of Competing Interests

The authors have no competing interests.

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