Documenting Climate Change in Uttarakhand

Final report: June 2009-May 2010

Peoples' Science Institute

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Executive summary

Most people in the mountain regions of Uttarakhand are subsistence farmers with no reserve to help them tide over a poor harvest or other crisis. This in combination with a lack of access to information means that they have little or no resilience to environmental changes. Considering that climate change is a leading factor in such changes, it is necessary to help mountain communities develop their resilience to climate change induced effects. The challenge in this is that climate change manifests itself in varying forms across regions. Developing a global or even pan-regional set of solutions for climate change therefore is impossible. Such a set of solutions can be developed for a small region once the impact of climate change on that area is determined.

With this end in view, the Peoples Science institute, Dehradun supported by the Himmothan Trust conducted a baseline study of the impact of climate change in the Bhagirathi and Pindar valleys in Uttarakhand from June 2009 to May 2010. The areas studied ranged from 2000 to 3860 metres above sea level. The methods used included participatory means such as group interviews and direct collection of information through quadrat surveys. The activities included a reconnaissance survey in three valleys, a brainstorming meeting in Dehradun, field surveys, and an analysis of weather data obtained for 4 weather stations in Uttarakhand. The field surveys have provided us with baseline information about species composition in the bugyals, forests and cropping patterns in the fields and orchards. Similarly, information about pastoralism, bee-keeping, and other activities was also obtained. Information about historical weather patterns and recent changes were noted.

Some of the changes observed can be directly attributed to climate change. One of the most important phenomena was the decrease in precipitation. There is a drastic decrease in snowfall which is leading to a decrease in the snow cover on the mountains surrounding the valley. This results in a decrease in water availability in the streams and rivers in summer. At the same time, there is a sharp decrease in winter rainfall. This is leading to a decline in the production of wheat and potatoes and consequently has an impact on food security. Similarly, this lack of rainfall increases aridity which encourages the proliferation of thrips that impact the apple crop. Lack of freezing temperatures has led to a decrease in apple production in the Bhagirathi valley.

Analysis of the 100 year weather data for four stations in Uttarakhand reveals an increasing trend for the maximum temperatures while the minimum temperatures were either constant or decreased slightly. This indicates increasing extremes in weather, with hotter summers and colder spells in winters. While there is no significant trend towards later or earlier occurrence of seasons, there is an increase in the frequency of variation. A study of the number of months with sub-zero temperatures indicates that there is a decrease in length of the winter season. Similarly, monsoons are peaking later in the year.

There are several other changes that are at least partially influenced by climate change. The species composition in the bugyals in both the Bhagirathi and Pindar valleys is changing, with a greater proportion of invasives and grasses. Similarly, there is a lack of regeneration of oak, and an increase in the spread of pine forests. However, these cannot be solely attributed to climate change as anthropogenic factors influence these to a great extent. Similarly, the decrease in pastoralism and increase in cultivation of vegetables can also be attributed to market factors.

A strategy to enable mountain communities to cope with climate change will include sustaining their food security in the face of winter droughts. Improved agriculture techniques to help them cope with water shortage such as the system of wheat intensification in rain fed areas is recommended. Similarly, it is necessary for the farmers to lessen their reliance on a single crop. Establishing a system for managing commons will help prevent over-exploitation of natural resources that are already vulnerable due to climate change.

1. Introduction

Climate change is an undeniable reality today. Instability in weather patterns, increasing occurrence of temperature extremes and increasing frequency of extreme events are evident. The exact causes of climate change, and also the global long-term effects of this shift are still a matter for speculation[1]. Irrespective of whether climate change will benefit humanity a century or two from now, today it is causing havoc with the lives of rural communities across the third world.

The mountain communities of Uttarakhand are largely dependent on natural resources for their livelihoods, with the main activities being agriculture and pastoralism. Non-timber forest products are also heavily depended on for fodder, fuel and food. Water for domestic use, livestock and agriculture is harvested from springs and streams. With this dependence on minimally modified natural resources, mountain communities have developed a way of life that is closely linked with the natural systems, especially the seasons.

Studies indicate that mountain areas are among the most susceptible to climate change[2]. The mountain communities of Uttarakhand and other Himalayan states are therefore, most vulnerable to the impacts of climate change.

At the same time, the people living in the mountain areas of Uttarakhand have little resilience to unprecedented changes. Degraded natural resources, water scarcity, a lack of infrastructure, and poor governance leave people ill-equipped to deal with a constantly evolving phenomenon like climate change.

To facilitate the development of a strategy to minimize the adverse effects of climate change, it is first necessary to determine the effects of climate change that have the most impact on the communities and their livelihoods.

2. Background

PSI has conducted a baseline survey of the impact of climate change in Uttarakhand in 2009-10. The objectives of the survey were:

- To collect data on major parameters such as rainfall, cropping patterns, composition of ecosystems, etc. using different methodologies as required (direct data collection for hydrology, plant population statistics, questionnaire survey, PRA, stakeholder interviews, economic assessments etc.)
- To assess the likely impact of the observed changes on natural resources based livelihoods through detailed discussions with the stakeholders and the economic impact.
- To describe current adaptation practices and possible future adaptations.

The main activities in this project were:

- Literature Review
  With climate change being an increasingly urgent issue, work on it has been done at the global and the regional level. The literature review concentrated on work being done in the Himalayas. In particular, the science behind climate change, baseline information about peoples and ecosystems in the Himalayas and the expected impacts of climate change have been reviewed.

- Weather analysis

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[1] Thomas J. Crowley, Causes of Climate Change Over the Past 1000 Years, July 14, 2000 Science, 289: 270-277

[2] Henry F. Diaz, Martin Grosjean, Lisa Graumlich, Climate variability and change in high elevation regions: Past, present and future. Paper presented at 'Climate Change at High Elevation Sites: Emerging Impacts' 2001 June 25-28, Davos, Switzerland.

Data for 4 weather stations in Uttarakhand have been obtained and analysed. This analysis focused on obtaining evidence for and quantifying changes in the quantity of rainfall, summer and winter temperatures, and shifts in seasons.

- Brainstorming Meet

  The literature review and reconnaissance surveys carried out in three valleys provided an overview of the situation in mid-altitude (~2500 m above msl) villages in the Himalayas and indicated areas where changes are most being experienced. A brainstorming meeting was held at the end of September 2009 to discuss these parameters and their suitability for further study. The methodology best suited to study them and resources that could be used were also discussed. The field study formats used were based on the suggestions made by the experts at the brainstorming meeting.

- Field Survey

  Based on the work done earlier, two valleys were selected for detailed surveys, the Bhagirathi and the Pindar valleys. It was decided to study three villages located in an altitude range of about 2500±200 mts in each valley. People's perceptions were recorded along with other information.

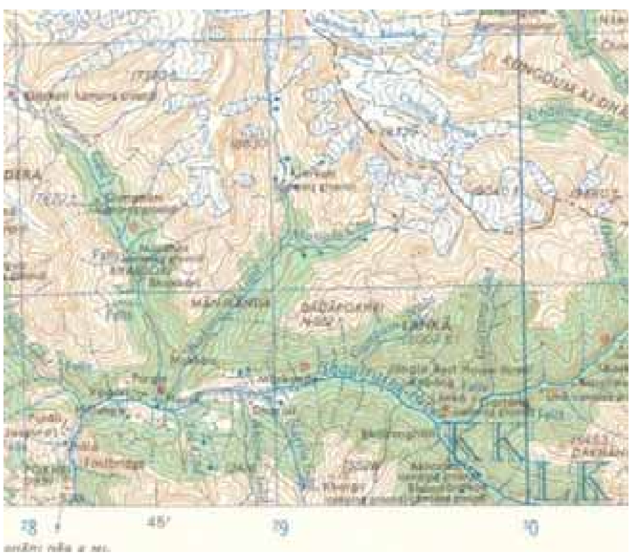

Figure 1[3] Map of the Bhagirathi Valley

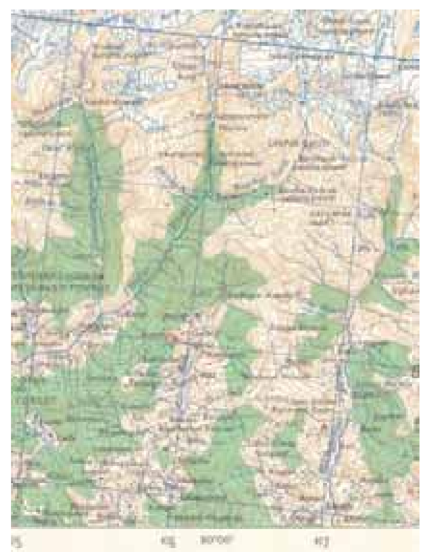

Figure 2 Map of the Pindar valley

The project has developed a working baseline on climate- related changes in two valleys of Uttarakhand.

3. Method

3.1. <u>Methodology for field surveys:</u>

A baseline format had been developed following the brainstorming meet. The field survey focused on obtaining the information as per the baseline format and open discussions with the local people that gave rise to new information and issues for further study.

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3 Maps extracted from NH44-01 and NH-44-06, obtained from the Perry Castaneda Map Collection, University of Texas, available online at http://www.lib.utexas.edu/maps/asia.html

Forest: Quadrat surveys of 10m X 10m were done at 5 places in the Bhagirathi watershed along a line from the valley to the ridge to get an accurate view of the forest. In the Pindar Valley, the spacing of the trees in the forest did not allow a 10m X 10m quadrat to accurately represent the of the forest diversity. Therefore, the quadrat size was increased to 20 m X 20 m. These quadrats were selected in one of two ways. In the case of the quadrats at Khati and Dwali, they were selected along the transect from the valley to the ridge. At Khatiya and Dhakuri villages however, they were chosen at the four points of a larger quadrat with the rest house in the centre. The latter were located on relatively flat areas. Variations in the forests therefore, did not depend so much on the altitude as on the aspect. In order to capture the diversity in the area, quadrats were chosen around the rest houses which offered a convenient landmark in case of any required follow-up.

Figure 4 Conducting a forest survey in Mukhba

Figure 3 Conducting a meadow survey in Dharali

Meadows: A procedure similar to that for the forest surveys was followed for the alpine meadows. Here the sample size chosen was 1m X 1m. This was retained for both the Bhagirathi and the Pindar valleys. In the Bhagirathi valley, the quadrats were selected at the four corners of the meadows. In the Pindar valley, they were taken along the transect from Khatiya to the Kafni Glacier. This enabled us to form a picture of variation of the species in the meadows with altitude. The survey was conducted at Kafni bugyal, over an altitude range of 600 metres.

Transect walks: The villages visited were located in different watersheds. Transect walks were carried out from the base to as far up to the ridge as was accessible. The plants growing on the way were noted. Similarly, the discharge of springs along the transect was noted wherever possible. Any pests found in the fields as well as other fauna found in the forests were documented.

Focus group discussions: These were carried out in each of the villages surveyed. Separate group discussions were held with male and female cultivators. The topics covered were agriculture, horticulture, precipitation, weather patterns and local biodiversity. These discussions were mainly held in the early morning/ early evening. Late evening meetings at Dharali enabled us to meet cultivators as they gathered in the market square. At Wachum, interviews with groups of people were held after a gram sabha. This enabled us to meet a number of people from various hamlets in the gram panchayat. At Khati, the pradhan of the village organized a

Figure 5 Group interview in Jaspur

meeting for us with approximately 25-30 cultivators. The baseline format was referred during these meetings to address all relevant topics. In addition, informal meeting were also held with the villagers

Indepth interviews: Indepth interviews were conducted at Dharali, Bagori and Harsil. The interview at Dharali was with a forest dweller (a sadhu) who has been living in the sat-tal area in Dharali for a major part of the year over the last decade. At Harsil Mr.Jagdish Bhatt of the horticulture department was interviewed for information about apple production in the area, with particular focus on cultivation methods and pests. At Bagori the woman interviewed gave information about pastoralists in the village, as well as about wool production and the biodiversity in the area. At Wachhum, a goatherd who had been herding for the last decade was interviewed.

3.2. Methodology for weather data analysis:

In order to obtain empirical evidence of the changes in weather, it was decided to analyse weather data. Rainfall and temperature data for four weather stations in Uttarakhand were obtained[4] and analyzed. In order to decrease the influence of the solar cycles on temperature, data for the last 100 years were obtained.

These data included the following information

INDEX = Index number of the station
MN = Month
MMAX = Mean Maximum Temperature (In Deg.C)
NO = No. of observations
HMAX = highest maximum temperature (In Deg. C)
DT = Date
OC = number of occasions
MMIN = Mean Minimum Temperature (In Deg. C)
LMIN = Lowest Minimum Temperature (In Deg. C)
TMRF = Total Rainfall in the month (in mm)
HVYRF = Heaviest Rainfall in 24 hrs (in mm)
RD = Number Of Rainy Days

The data were obtained for the following stations:

Station number	Name	Nominal elevation (metres above sea level)
42111	Dehradun	682
42114	Ranichauri	2100
42147	Chaubatia	1829
42148	Pant Nagar	233

Weather data for two of the four stations (Ranichauri and Pant Nagar) had several gaps, and so the stations for which long-term data was available were used for detailed analysis. Thus

Dehradun data may be considered as representative of valley conditions and the Chaubatia data of elevated altitudes.

[4] National Data Center, ADGM(R) office, IMD Shivaji Nagar, Pune- 411 005, Maharashtra. http://www.imd.gov.in

4. Observations and analysis:

4.1. Literature survey

The Himalayan glaciers are the source of the ten largest rivers of Asia. These rivers have sustained Asian civilizations since time immemorial. In India, these glaciers are fed by both the summer monsoons and the westerlies. The Current Science, Vol. 97, No. 3, 10 August 2009is in turn influenced by the complex glacial environment[5]. In order to have a holistic understanding of climate change in India it is critical to understand the behaviour of these glaciers. Glaciology as a science is relatively new in India. Historical data is available only for a few glaciers which severely limits this science. But recent years have witnessed a sudden spurt in research work due to growing awareness on the importance of the issue.

The Himalayan glaciers are said to be more susceptible to climate change than their Arctic peers because they are closer to the Tropic of Cancer and receive more heat. The WWF-India and BIT report on the Gangotri and Kafni glacier in the Pindar Valley concludes that while larger glaciers like the Gangotri are receding but they aren't under any immediate threat of disappearing due to their large mass balance. But smaller glaciers like Kafni are more vulnerable to local climate variations and are retreating at a faster rate. For the last three decades the Kafni glacier has been retreating at a rate of 16.5m. The rate of retreat fluctuates at different time intervals and the glacier's snout is the best indicator of this retreat and advancement. What has been observed by glaciologists studying the Himalayan glaciers is that both small and large glaciers are retreating at the same rate. But while the larger glaciers are retreating at a rate of approximately 12%, smaller glaciers of less than one sq km have reduced in area by as much as 38%. This has led many scientists to believe that the future for small glaciers is not so encouraging[6].

Over the past few years, climate change has gradually permeated the consciousness of the civil society. Climate change is being seen as one of the most serious challenges facing civilization and increased glacier recession is considered an important indicator of increasing temperatures[7]. Huge investments are being made by governments worldwide in research and technology to understand and overcome this phenomenon. The IPCC[8] is an institution set up by the UN Environmental Programme (UNEP) and the World Metrological Organization (WMO). In 2007 it came out with a report which stated that the world's glaciers were melting so rapidly due to global warming that the Himalayan glaciers could melt by 2035.

However it was later revealed that these estimates were speculative and misleading[9]. This incident cast aspersions not only on the credibility of such research institutions worldwide but also on the entire science of climate change. Many glaciologists believe that the impacts of climate change are hyped and present a skewed picture of the ground reality. Studies like those conducted by Dr. R.K Ganjoo and M.N. Koul, assert that the Himalayan glaciers reflect the micro climate rather than global warming[10].

This difference in opinion on climate change is because the science has two major schools of thought. One believes that this is a natural phenomenon while the other believes that anthropogenic activities and accelerated global warming have contributed to the present trend[11]. Whether this is a human induced or natural phenomenon, few deny that there are perceptible

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5 'Witnessing Change: Glaciers in the Indian Himalayas' WWW India and BIT, 2009, Pg. 3

6 Ibid, Pg. 2

7 Nature and Science, 4(4), 2006, Anthwal, et al, Retreat of Himalayan Glaciers – Indicator of Climate Change

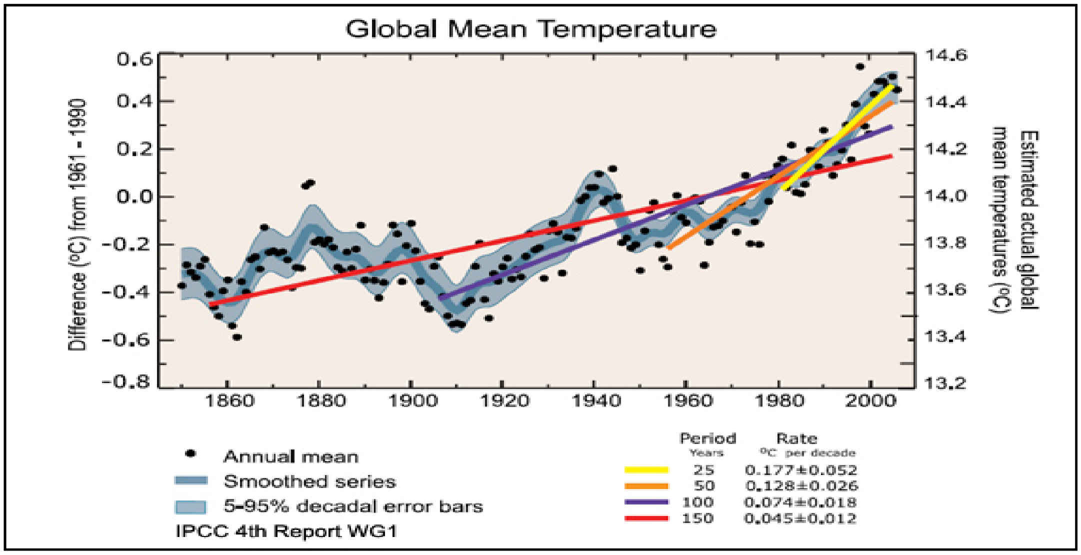
8 Intergovernmental Panel on Climate Change was set up, "to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences."

9 'Pachauri admits mistake in IPCC report' The Hindu, Jan 23rd 2010

10 'Is the Siachen Glacier metling' R. K. Ganjoo and M. N. Koul, Current Science, Vol. 97, No. 3, 10 August 2009

11 'Witnessing Change: Glaciers in the Indian Himalayas' WWW India and BIT, 2009, Pg. 6

changes in the global climate. And there is strong empirical evidence that suggests there has been an increase in the global surface temperatures. The graph below shows the upward trend in the global mean temperature.



There is therefore a need to be wary of not only reductionism which out rightly denies the existence of climate change but also alarmist claims like those of the IPCC's.

Fluctuations in the physical environment of the Himalayan glaciers are being reflected in the livelihood changes of the local communities. The mountain communities of Uttarakhand depend on the varied forest types and alpine meadows to provide for their personal needs and their livestock's sustenance[12].

Research on climate change in the Himalayas displays consensus on some important points. It has been observed that the main trends are increasing aridity and warmer winters. While aridity largely has a negative impact, warmer winters can 'open up' new areas for agriculture. Crops that were originally not grown in the areas are now cultivated, opening up an avenue of income to farmers, or at the least compensating for the loss of older sources of income. On the other hand, communities are adversely affected most by increasing variability in rainfall. Farmers report losing their seed stores because their crop calendars are no longer in sync with the seasons. Untimely precipitation, unexpected frosts and storms play havoc with crops.

As for ecosystems, here too the lower altitude ecosystems thrive. Warmer temperatures facilitate migration to higher altitudes and open up larger areas for colonization. Higher altitude ecosystems, notably the alpine meadows, however are limited by the topography and are squeezed into increasingly narrower belts[13]. Alpine meadows, locally known as *'bugyals'* have numerous species of fodder and herbs. Non-Timber Forest Produce (NTFP) found in these high altitude forests can prove to be an additional source of income. Some of these are highly valued in local and international markets. An example being *'keeda ghas'*(*Cordyceps sinensis*), a parasitic fungus which is used in traditional medicinal practices in India, Nepal and China. A

12 Forest Resource Management in Mountain Regions: A case for the Pindar basin of Uttaranchal Himalaya, Vishambhar Prasad Sati, June 2006 (retrieved from : http://www.lyonia.org/downloadPDF.php?pdfID=2.478.1 on May 26, 2010)

13 Impact of climate change and coping strategies in Nanda Devi Biosphere Reserve (NDBR), Central Himalaya India, R.K Maikhuri et al GBPIHED

kilogram of this wild fungus is said to be sold for an exorbitant sum of Rs. 1 lakh. Such NTFPs can prove to be a highly rewarding income-generation opportunity in the remote Central Himalayan region. Population pressure has led to over-exploitation of these resources and it has been observed that several plant species are now either endangered or extinct. To make matters worse, with climate change there has been a shift in species within each ecosystem, with invasive species colonizing bugyals and forests.

Another integral part of the rural economy of the Himalayan region is animal husbandry. It ensures economic stability and sustainable farming for the local communities. Despite the hardships of high altitude this region exhibits a wide variety of livestock. But increased demand for fodder and extensive summer grazing by pastoral nomads has led to over grazing which has added to this degradation[14]. Therefore the question of how climate change will impact the quality and quantity of livestock forage is a critical one.

But it is not just the local communities that will be affected. In the last few years there has also been a decline in the transhumance in the region. There are numerous factors which have led to this such as loss of available grazing land due to conservation of land cover in the alpine regions. But climate change has also been attributed as one of the factors for this. The transhumant population has an important relationship with the lowland Terai region for their winter grazing[15]. However due to dry spells in the Terai regions during December to May the higher altitude regions are under pressure to provide winter grazing as well. It is also believed that poor winter precipitation is followed by poor fodder quality as well as quantity. The transhumant population usually employ different adaptive strategies based on their three main resources, viz., animal herds, pasture lands and water. All these three resources are directly influenced by changes in the climate[16].

Several studies have attempted to identify the indicators of climate change, and their effects on mountain livelihoods (Vedvan 2001, Naithani 2001, etc). These studies have assessed the response of selected parameters to climate change and its effects. Some of the studies have dealt with the effect of climate change on glaciers (Naithani 2001), on vector movement (Bhattacharya 2006), and on precipitation (Dash 2007). Vedvan and Rhoades' paper assessed people's perception of climate change with a focus on the apple growers of Himachal. This paper proved to be a good source of both the impact of climate change on apple production and also for people's awareness about changes that might be happening.

Several organizations both in the civil society and government sectors are developing policy papers and reports to help develop strategies to combat the effect of climate change on humans. Oxfam international (Briefing paper 130 and Gum, 2009) has listed a number of strategies that need to be implemented in the short term if hunger is to be effectively combated. Increase in irrigation, and shift from traditional crops to vegetables are recommended. Disasters will probably increase and need to be planned for. ICIMOD's perspective paper (Eriksson et al) provides an indepth-analysis of the effect of climate change on the Himalayas. It makes a strong argument for reducing scientific uncertainty and including research while formulating policy. The International labour office warns that climate change impacts will make it more difficult to achieve the Millennium Development goals, especially those of achieving food security.

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14 Forest Resource Management in Mountain Regions: A case for the Pindar basin of Uttaranchal Himalaya, Vishambhar Prasad Sati, June 2006 (retrieved from : http://www.lyonia.org/downloadPDF.php?pdfID=2.478.1 on May 26, 2010)

15 Primal Elements: The Oral Tradition, 'The Nomads: Man, Animal, Nature by R.S. Negi' (retrieved from: http://ignca.nic.in/ps_01008.htm at May 28, 2010)

16 Proceedings of National Seminar on Climate Change: Date Requiring and Availability, 16-17 2009 (retrieved from: http://mospi.gov.in on May 26, 2010)

Livelihoods can be supported by adding non-agricultural components such as community tourism and small businesses. At the same time, the added infrastructure required for adaptation will lead to the creation of more jobs.

Climate change will definitely change the resource availability in these high altitude regions. Agriculture will be adversely affected by degradation of soil and declining soil moisture due to increased heat stress and early snow melting. Animal husbandry will be influenced by a decline in availability of forage. Alpine meadows which hold several key species of medicinal and aromatic plants will also be severely stressed, since the growth period of the main herbs and fodder species is very short and sensitive to temperature changes. And presently, anthropogenic activities fuelled by the need for firewood and fodder are only aggravating the problem. It is therefore quite challenging to sift through the various observations and categorize which are direct results of climate change and which are human induced. To conclude, climate change has introduced new elements of uncertainty which has adversely impacted mountain communities. High-altitude ecosystems are at risk of extinction. For both humans and fauna, food security and health are impacted negatively. However, hope lies in this fact, that there might be scope for the development of new crop cycles that aim at food security and improved livelihood opportunities.

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15. Ana Belén Sanchez and Peter Poschen, The social and decent work dimensions of a new agreement on climate change, International labour office, policy integration department, June 2009
16. Suffering the Science: climate change, people and poverty, Oxfam briefing paper 130, July 2009
17. Ray E. Ashton, Jr. and Patricia Sawyer Ashton, Plant survey, monitoring and foraging methods.

4.2. Reconnaissance Survey:

Two preliminary surveys of 10- 12 days each were carried out in the Pindar valley (July 2009) and in the Bhagirathi and Yamuna valleys (August 2009). The summary of the surveys is given below:

Valley	Pindar	Bhagirathi	Yamuna
Dates of travel:	9-7-09 to 18-7-09	28-7-09 to 4-8-09	5-8-09 to 7-8-09
Villages visited:	Khati,Bacham,Umla, Bhagdanu, Khalidhar, Sara, Supi	Gangotri, Gomukh, Dharali, Harsil, Jaspur, Dayara	Barkot, Nagawn, Purola
Salient points	Changes in seasons, increase in pests	Increasing aridity, low snowfall	Decreasing snow cover, increasing temperatures

Meetings with the villagers and transect walks were conducted during these surveys. The main points arising from these reconnaissance surveys have been grouped under the study areas detailed earlier:

1. *Weather Patterns*:
    - Villagers claimed a definite **reduction in precipitation** (both rain and snow) in all three valleys. Most villagers in the Pindar valley stated that rain had decreased in the last 5 years. In the Bhagirathi valley, there is a noticeable reduction in snowfall in the last 10 years
    - People in the Pindar valley also speak of the cold being less severe in the last few years. Tons valley communities cited **unpredictability in the winter** for the last 10 years.
    - An increase in hailstorms is observed and this is leading to crop damage, especially in the apple-producing areas of the Bhagirathi valley.
2. *Agricultural Impacts*: There is a shift in production from traditional crops to vegetables. However it is difficult to quantify the relative influence of market demand and climate change.

    There is a **marked increase in the pests** encountered in the farms. Some examples of the pests are *tana bedhak, kala bhrung, safed sundi, balonwali suni, tide, hispa, tela keet, safed titli* etc. These insects were not present a few years ago, though they are common at lower altitudes. The cause of this proliferation needs to be examined. On one hand, the increase in temperature and the lack of freezing temperatures may make higher altitudes amenable to low-altitude pests. This is supported by the increasing occurrence of tropical insects like mosquitoes in high-altitude areas[17]. On the other hand however, the occurrence of insect pests may be linked to the increased cultivation of their food crops due to market demand.

[17] Erickson M. et al, The changing Himalayas: Impact of climate change on water resources and livelihoods on the Greater Himalayas, ICIMOD

The villages in Pindar valley complain about the occurrence of lizards that they claim damage their crops. These lizards were not found in the area before and are now very common. The villagers believe that they eat the crops and destroy them in the night. These might be skinks, which are found in the Himalayas. This sudden increase in these cold-blooded animals might be an important indicator of warmer temperatures and also of a migration of their food species.

Along with studying the skink as an indicator of temperature changes, its food habits also need to be examined. It is possible that blaming the carnivorous skink for damage to crops could lead to eradication of an important predator with disastrous results.

3. *Horticulture*: there has been a significant **decrease in apple production**. These have been attributed to various causes including the lack of water due to less precipitation, unseasonal frost leading to bud-drop, and increase in pests. Lack of freezing temperatures has also been stated as a reason for diminished fruit setting. These factors are all linked to climate change, but the extent to which each influence the crop needs to be investigated. Similar effects have been reported across the Himalayan region.

4. *Forestry*: **Early flowering** of rhododendron (from March to the 1st week in February) has been observed in the Bhagirathi valley. There is an increasing occurrence of **invasive species** that may prove to be damaging to established species. An invasive fern been increasingly found on oak, and the local communities believe that it eventually kills the tree.

5. *Transhumance/ Livestock*: Grasses in the bugyals are now taken over by thorny bushes (*Carronda spp*?). Pastoralists depend heavily on these grazing lands and their loss might threaten a very important livelihood.

   The increase in scrub means that the meadows are moving to higher altitudes and further away from the villages. In addition, increased soil erosion has led to many roads being washed away, increasing the difficulties that the pastoralists face. This has in turn led to a decrease in the number of people following this system.

6. *Cultural practices and lifestyle*:

   There is a shift in livelihoods from pastoralism and cultivation of indigenous varieties towards cultivation of crops for the market. This link to the market economy also leads to a dependence on the market for staples. This is partly linked to increasing rural consumerism, but also to a dearth of the wild foods usually consumed.

   Changes in water availability also are leading to a change in lifestyle. The community managed springs are gradually growing extinct, which leads to a greater dependence on handpumps and unreliable piped water systems. This lead to the formation of a vicious cycle, where this dependence on government supplies leads to further neglect of springs, which cuts down on alternatives available to the villagers.

7. *People's perception of climate change:*

   There is a definite sense of increasing temperatures and unpredictable seasons. This awareness is especially strong among farmers who are faced crop failure due to weather variabilities.

4.3. Field Surveys:

4.3.1. Precipitation.

a. Bhagirathi Valley

Dharali has experienced a reduction in the quantum and the duration of precipitation. Mukhba being on the sunny side of the valley, it experiences less snowfall than Dharali. Despite that, it would still receive about 4' of snow in the village twenty years ago. In 2008 however, they experienced only one snowfall which was not more than a light dusting of snow. While the ground would be frozen throughout the winter a decade ago, there has been no freezing in the past few years.

Jaspur reported the most drastic decline in snowfall, from seven feet a decade ago to only ½” in recent years. The number of days of snowfall have also declined from about 15 to 1.

b. Pindar Valley

Unlike the Bhagirathi valley, there were no reports of any change in the duration or time of occurrence of snowfall in this area. However, the villagers of Wachum reported a drastic decrease in the quantum of snow, from 6’ two decades ago to only 4” in 2009. Ground freezing however, occurs regularly between November and January. They were concerned about the decrease of permanent snow cover, and mentioned that earlier, the snow would not melt all winter. Now however, it melts within a few days.

Twenty years ago in Khati, it would snow approximately twice a month from November to February. The maximum depth of snow was 5-6 feet. Last year, they only received 6 inches of snow. In addition, there is a sharp decrease in winter rainfall. This is a major cause of decline of in the production of wheat. There has been an increase in temperature which has led to increased melting. If it rains in November, then the snow does not melt. Now the lack of winter rain coupled with increased temperatures is causing a decline in the snow cover in the mountains. As one of the respondents said, “*Himalaya khali ho rahe hai.* ”

Figure 6 Exposed mountain face, Khati

4.3.2. Water resources.

The precipitation section makes it clear that snow cover in the upper reaches has almost disappeared. Snowmelt in summer would recharge springs as well as rivers. The disappearance of the snow cover means that underground seepages are bound to be very severely affected.

4.3.3. Forests:

a. Bhagirathi Valley:

At Dharali, which is on a north-facing slope, a distinct variation of forest-type with altitude is seen. The apple orchards and cotoneasters near the village are replaced by deodar. This is followed by pine and then mid-altitude meadows where the slope flattens out. On the steep slopes again, there is a coniferous forest, a mix of fir, pine, and spruce. This is followed by fir with birch, then rhododendron. Above the rhododendron is a meadow and finally the snow clad peaks.

Here, we see an anomaly in that the pine forests are at a higher altitude than deodar forests. Most likely the local soil structure takes precedence over altitude. Pine grows in the schist layer which is at an altitude lower than the deodar, which grows on shale. In mixed coniferous forests, full-grown deodar trees are more numerous than full-grown pine. However, the seedlings and saplings of pine are more which shows that pine is regenerating more in recent years. Deodar is thus gradually being replaced by pine. The area has not received adequate rain fall for several years and deodar needs adequate moisture to grow but pine can grow in harsh conditions gregariously.

At Mukhba, the aspect of the slope has a greater impact on vegetation than the altitudes. As the slope faces south and is considerably warmer and dryer than Dharali, we see the absence of a noticeable treeline. Pine and deodar extends upto the ridge. There is a certain gradation of species with deciduous trees (mainly cotoneaster) on the lower slopes and a larger proportion of coniferous trees (pine and deodar) on the middle slopes. Rhododendron is present on the rocky cliffs near the top of the ridge. Within the slopes as well, aspect plays a role in the location of the pine and deodar groves. Most of the deodar grows on the easterly slops that are shadowed and cooler. The pine, on the other hand, grows on the sunny and drier western slopes.

Figure 7 Forest at Dharali

Jaspur is also south-facing. Here the dry and sunny slopes have led to pine replacing deodar. This is further exacerbated by denudation of the environment. The forests today are predominantly pine with some berberis.

Figure 8 Forest at Mukhba

The bugyal at Dharali shows increasing growth of weeds, with grasses largely at the higher ends. This might indicate upward movement of invasive weeds. There are also some rhododendron shrubs on the peaks above the bugyals. There are birch trees at the level of the meadows, however no regeneration was observed.

b. Pindar Valley:

Dhakuri has a dense oak forest (Quercus semecarpifolia). In addition to the oak, there are also two species of rhododendron. The forest is even aged and old. There is no regeneration in this patch, though residents report that there are some saplings in the more inaccessible reaches on the way to Khati.

While there are two factors that are responsible for this lack of regeneration, it largely boils down to increased stress on natural resources. The livestock are fed with oak leaves obtained by lopping trees. This is normally a sustainable practice as long as a sufficient rest period is given to the lopped trees. However, in this case, very little rest is given to the trees, with lopping occurring nearly every year. Due to this, acorn formation is not taking place. In addition, small saplings are eaten by the free-grazing ponies and goats. Pack animals and other livestock are essential for the economy of the area, and fodder is essential for their nourishment. For all practical purposes, this is already an extinct forest as no regeneration is taking place. Once this aged generation dies, the forest will cease to exist. Artificial regeneration by the creation of a nursery may be the only option left to save this forest.

Figure 8 Lopping at Dhakuri

Figure 9 Fern growth at Dhakuri

The forest from Dhakuri to Dwali is healthy and shows good regeneration of maple and other species. At Khati, oak saplings and one pole were found in two of the five quadrats. There is therefore some regeneration of oak away from the grazing areas.

The people spoken to were unanimous in their assertion that the rhododendron is flowering early. The forest guard at Loharkhet spoke of looking at a rhododendron tree which flowered as early as the end of February. At the time of the survey in May 2010, the rhododendron blooms upto Dhakuri were past their prime. Near Dwali, they were in full bloom while the rhododendron had not yet flowered at Khatiya.

Figure 10 Wilting Rhododendron at Dhakuri

Figure 11 Rhododendron yet to flower at Khatiya

The Kafni bugyal was just beginning to flower in the beginning of May. This indicates that there is no drastic change in the flowering times. The species in flower were hypoxis and primula. Eulaliopsis is traditionally burnt to encourage re-growth .New shoots were just emerging at the time of the survey. However, this practice is discouraging the growth of heat-vulnerable species. This has led to a loss of biodiversity in large parts of the bugyal which are now colonized entirely by eulaliopsis.

Figure 12 flowering meadow, Khatiya

Figure 13 Burnt Eulaliopsis, Khatiya

4.3.4. Horticulture:

The area visited in the Bhagirathi valley is famous for its apple production. The people of these villages take pride in this reputation and their livelihoods significantly depend on the apple crop.

The crop calendar at Dharali is as follows:

Month	Stage of cultivation
Chaitra	Spraying of apples
Baisakh	Flowering of apples, all people return, ploughing, sowing of potatoes
Jyeshtha	Rajma sowing
Aashad	*godai*
Shravan	Removing potatoes
Bhadrapad (bhado)	Cholai if at all
Ashwin (Asooj)	Rajma, harvesting shrawan apples
Kartik	Harvesting apples, first weeding
Aghain (mangsheer)	Pruning, spraying
Poush	Dormant
Magh	Dormant
Phalgun	dormant

This has been followed for a long time, with little change if any. Apples normally flower in the second week of April. 10 ears ago, the usual time of flowering was between the second and third weeks of April. Last year, flowering occurred 10 days early (i.e end of March).

People mentioned that the crops are affected by a lack of freezing. According to them, the apples trees need below-freezing temperatures for at least 1600 hours, which is equivalent to approximately 2 months. This is no longer available. In 2008, freezing occurred when the trees were already in flower, and the crop was burnt.

Pests have been increasing in the last decade; mites made their first appearance 4 years ago. The increase in pests coincides with the increase of commercial methods of cultivation, mainly the use of chemical pesticides. Other pests like thrips and scale increase with warmer temperatures. In Mukhba, people linked the increase in pests with the cultivation of species other than Wilson's, which is reputed to be a resistant variety. The cultivators of all three villages surveyed (Dharali, Mukhba and Jaspur) reported a shift in the last decade in flowering from mid-April to the last week of March. The Pindar valley is not known for its orchards, and there is next to no cultivation of apples there. The villagers of Wachum They had been provided with 4000 plants of apples but there were attacked by insects and dried up. Currently there is no significant apple crop. They are in the process of setting up of orchards of apples, almonds and walnuts.

Figure 14 Diseased apple trees, Mukhba

4.3.5. Livestock

a. Bhagirathi Valley

In the Bhagirathi valley, first generation yak-cow hybrids were common till a decade ago. 30-35 years ago, chaurgai (the first generation crossbreeds) and pure-breed yaks would also be kept in Mukhba. These would spend 6 months in the higher altitudes, and only come down in the winter. These days, they are fast disappearing and only 3-4 of the old first-generation crossbreeds are left. Most of the cattle now are third or fourth generation crossbreeds, and these too are disappearing. Climate change could be a direct cause of this. Earlier, yak stock for breeding was obtained from the traders who would cross over the glaciers from Tibet. With the disappearance of these frozen passages, fewer traders are crossing over, and there is not enough stock available to maintain the quality of the cattle[18].

Figure 15 young joey, Mukhba

The cross-breeds are now being replaced by cows. Most households have around 2-4 cows, while 10 households have 10-12 cows.

Ten to twelve households in Mukhba rear sheep and goats. A few own around 30 animals. 5-6 have 70, and two families rear 150 and 150 heads. These are taken to a bugyal 10kms away in the summer and to Rishikesh in the winter. Earlier, there was a good market for wool and several buyers would come to the village. Now, no traders come here, possibly because of decline in wool quality. Jaspur has only three shepherds with a total of 450 animals, a sharp decline from 1200 animals the previous decade. With the construction of roads and disappearance of the old salt trade with Tibet, herding is not longer profitable and even these shepherds are adopting new careers.

Figure 16 herd of goats, Dhakuri

18 Personal communication with Dr. Subadhra Sen

b. Pindar Valley

There are 25000 animals in all at Wachum. The sheep and goats are grazed near the Sunderdhunga glacier. Each goatherd has up to 800-900 goats with him. There has been no change in the plant composition in the meadows, while the change in grass depends on the rains. They leave for the bugyals in March and return in August. As mentioned in the section on forestry, the increase in grazing is causing destruction of the forests.

4.3.6. Agriculture

a. Bhagirathi Valley

The crop cycle followed earlier is being followed today. The villagers of Dharali, Mukhba, and Jaspur till their fields for 9 months, with all activity suspended during winter. Most residents move down to warmer areas in the valley. The crop calendar for Dharali is representative of the other two villages as well, and is listed below:

Month	Activity
Chaitra	Return on the 15th day of Chaitra
Baisakh	Repairs to house and farm, ploughing for potatoes
Jyeshtha	Sowing of Cholai, Rajma
Aashad	Sowing of Cheena, Phapar
Shravan	Sarson, cutting of grass, weeding
Bhadrapad	Grass cutting
Ashwin	Harvesting of cheena, phapar, rajma, potatoes, sarson, apples
Kartik	Spraying, packing
Aghain	Travel
Poush	Away from farm
Magh	Away from farm
Phalgun	Away from farm

The main crops harvested in the Bhagirathi valley (other than horticultural crops) are potatoes and kidney beans. Other than these, mustard, amaranthus, and brassicas are also grown. There is a decrease in the variety of crops grown with Amaranth on the decline. However, tomatoes have been introduced 8 years ago in the valley. If these are now growing in an area previously considered unsuitable, then these could be an indication of climate change. However, it needs to be noted that market demand could also be triggering this adoption of non-traditional crops.

b. Pindar Valley

Wheat, barley, and potatoes are the primary crops in the Pindar Valley. As we have seen earlier, there is no horticulture practiced in the area, though orchards have been planted this year in Khati. There is one greenhouse in Khati where the owner grows spinach and coriander. Mustard grows well in the area. However in Khati, the villagers would take it to Bageshwar to be milled, which was not economical. The planting of mustard has therefore decreased. Wachum still cultivates mustard on 10,000 nalis. The production of finger millet has decreased, largely because it has been replaced by wheat as a staple grain. Instead, millet is largely grown as a fodder crop. The production of barley and kidney beans has increased due to the use of new seeds from Bageshwar. Wheat output however, has decreased due to winter droughts.

The respondents in Wachum also observed early ripening of wheat, with ripening occurring in Baisakh rather than Jaith. This was attributed to the lack of rainfall in winter. The potato crop is also declining. Earlier, planting 160 kg of potatoes (4 maunds) would yield a harvest of 10 tons. These days, it only yields a harvest of 2 tons. This is attributed to low rainfall, which inhibits the growth of the potato plants, and so of the potatoes. In addition, the potatoes are attacked by a white grub that eats the potatoes.

4.3.7. Pollinators

In the Bhagirathi valley, the apple crops are mainly pollinated by thrips and wild bees. It is only when the number of thrips exceed a sustainable threshold that they are considered pests. In the Pindar valley, however people keep honeybees. According to the people of Wachum, the production of honey has decreased from one kg of honey per hive to only half a kg in recent years. Similarly, while half the number of households would earlier keep hives, only about 10% do so now. To help the bees survive the winter, they are not reared in the conventional box hives, but in hollowed out logs with an extremely small opening, maybe an inch square.

Figure 17 Log beehive, Wachum

4.3.8. Non-Timber forest produce

a. Bhagirathi Valley

The people of Dharali regularly visit the bugyals and forests for herbs. The most frequently used herbs are Chaura, Atees, Salan Panja, Lado, and Archan. In addition, the sap of the deodar tree is also valued as an ointment for joint pain. A rough estimate indicates that 50-60 families each collect 100-200 grams of the herbs for their personal use. The deodar sap is collected infrequently, as it is only used by the elderly. However, everyone collects brahmakamal for the shravan puja. They mentioned that the flower is becoming difficult to find in recent years. However it is not clear whether this scarcity is a result of climate change or of overharvesting.

b. Pindar Valley

Unlike in the Bhagirathi valley, here forest products are collected for sale. The main product is 'jhola' which are sold to contractors. At present the villagers are able to harvest 60 mule loads worth of jhola. The villagers have been engaged in this for the last seven years. These contractors process these to make dyes. The villagers were unaware of what these dyes are used for.

Figure 18 collection of Jhola, Mallya Daur

For personal use, the people of khati collect anees, katki, gokul and chiji from the meadows. 20 -30 people go to the villages from Wachum to harvest herbs. Seasonal grasses are also collected. Some villagers admitted to collecting the caterpillar fungus *(Cordyceps sinensis)*, however the endangered status of the fungus made them wary of answering questions about quantity and frequency of collection. A plant called *'Brahman'* flowers in June. However for the last two years the flowering has reduced. Also the harvesting is no longer done very often. The villagers are scared of the associated gods since the flower can only be touched by a pure person who knows all the 4 Vedas. The *'brahmakamal'* is harvested by all during the Nandadevi puja.

4.4. Weather data analysis

In addition to information received from the communities about changes in weather, analysis of raw weather data has also been done. This has helped quantify the changes and also validate the observations made by the communities living in the valleys.

The data obtained has been formatted and initial analyses done. For further calculations and analysis, Chaubatia and Dehradun data has been used. The data from Pant Nagar and Ranichauri has several gaps. It can be used to provide examples, and reinforce conclusions derived from the complete data sets. For initial analysis, however, it will be more accurate to use the data of Chaubatia and Dehradun. In addition, as Chaubatia is located in the mountains and Dehradun in the plains, the use of these two data sets will enable the study of weather trends in both the plains and the mountains.

The monthly averages of the maximum and minimum daily temperatures have been tabulated and plotted (figure 20: Average maximum temperature and figure 21: Average minimum temperature).

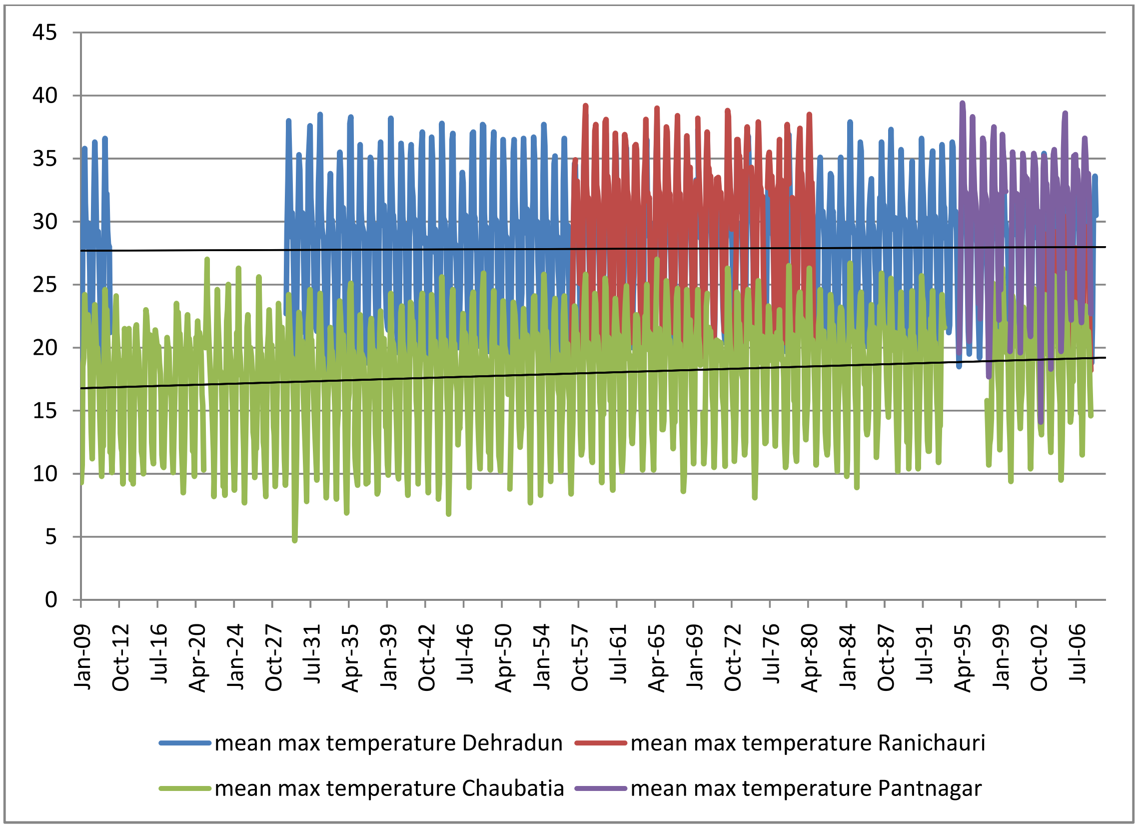


Figure 19 Variation of average maximum temperature with time

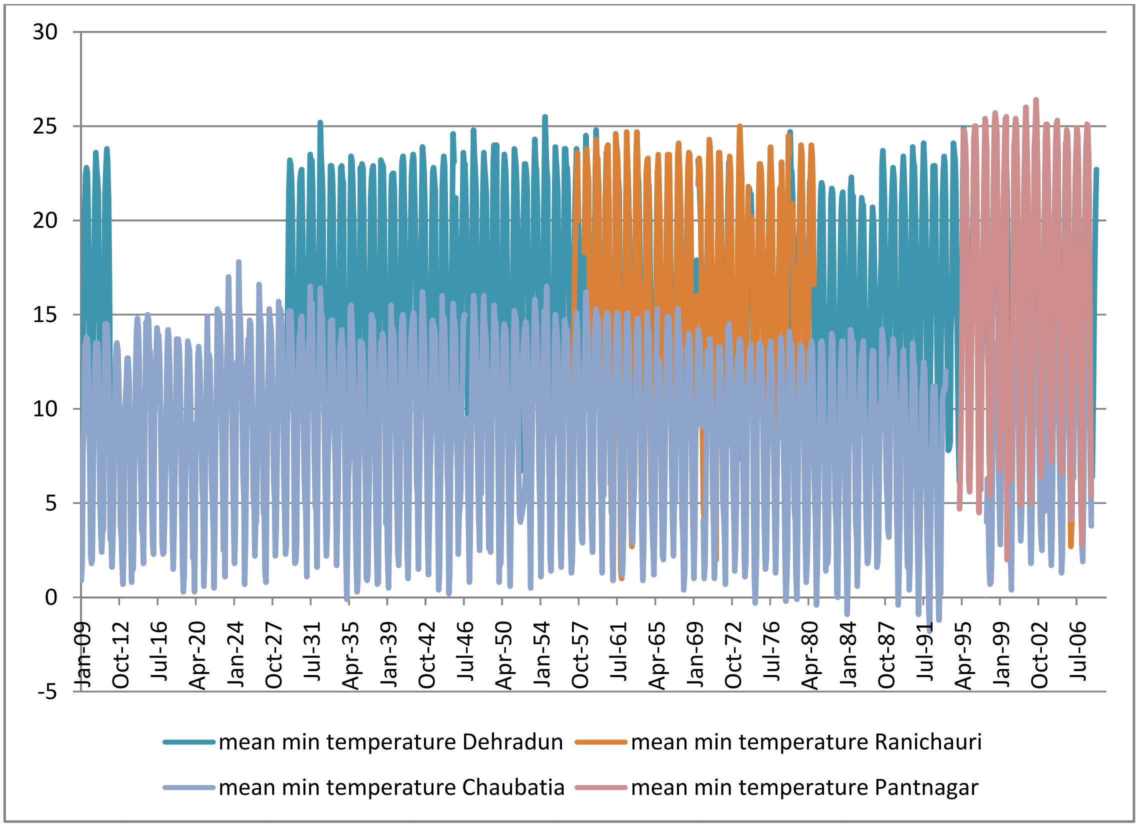


Figure 20 Variation of average minimum temperature with time

An increasing trend is observed for the maximum temperatures while the minimum temperatures either are constant or decrease slightly. In order to clearly understand the trend in temperature change in winters and summers over the last century, the average minimum and maximum temperatures for the months of June and January have been plotted (Figures 22 to 25).

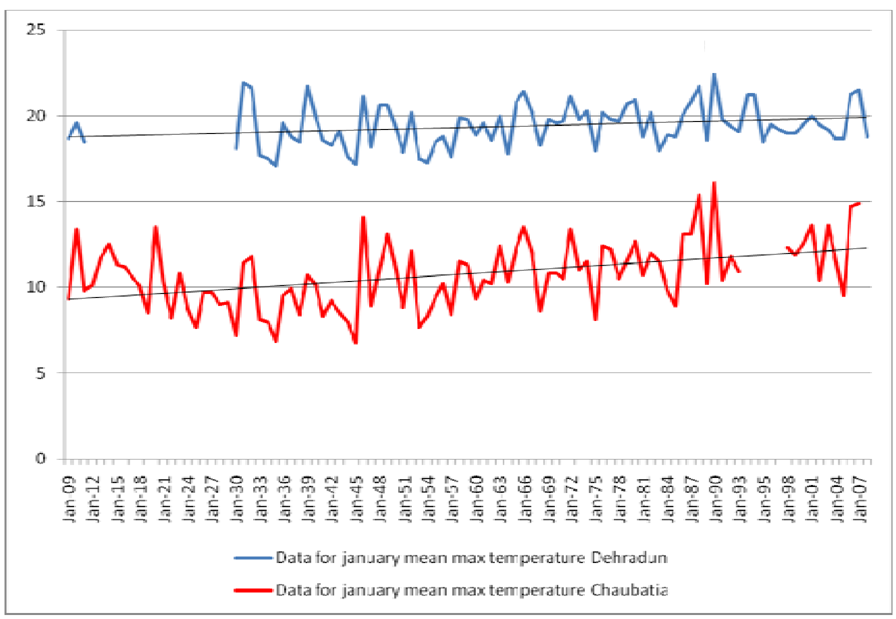


Figure 21 Variation of average maximum temperatures for January

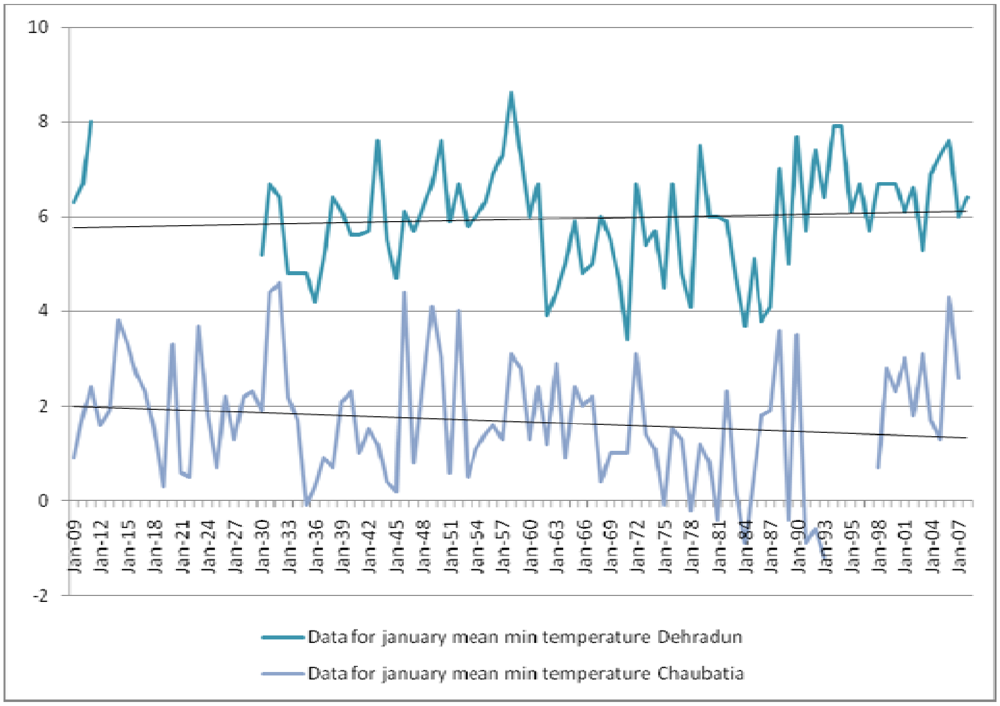


Figure 22 Variation of average minimum temperatures for January

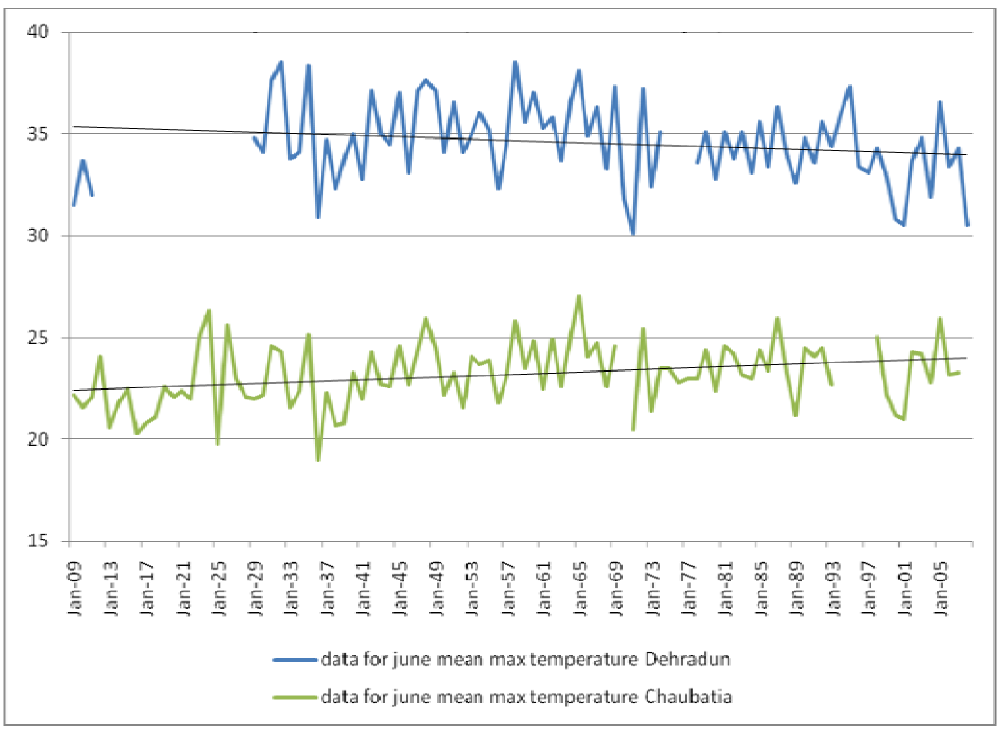


Figure 23 Variation of average maximum temperatures in June

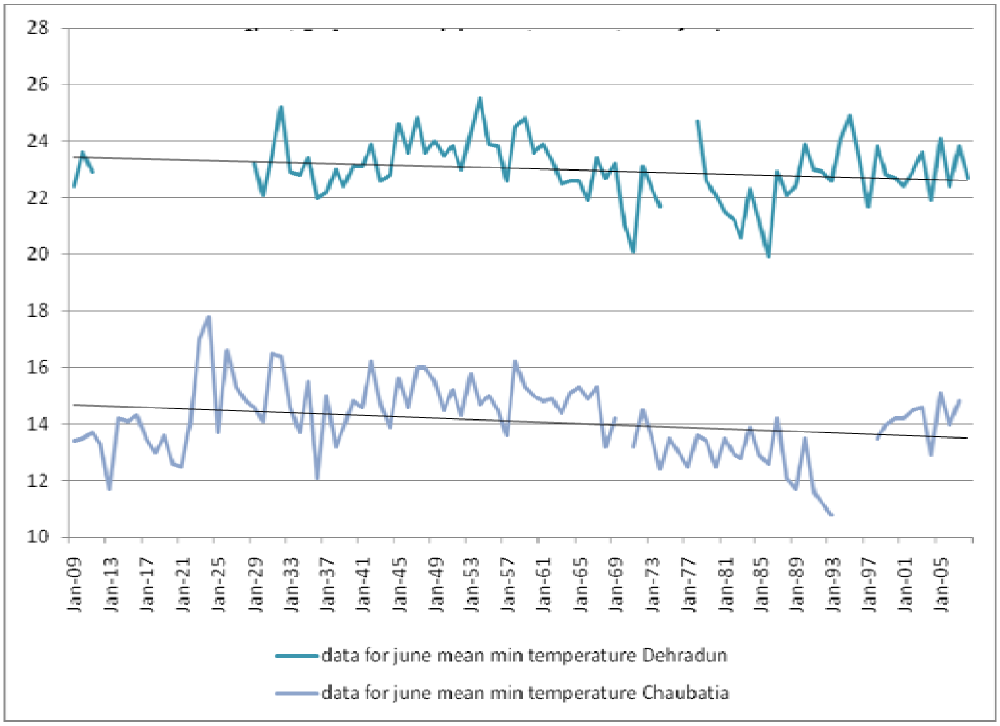


Figure 24 Variation of average minimum temperatures for June

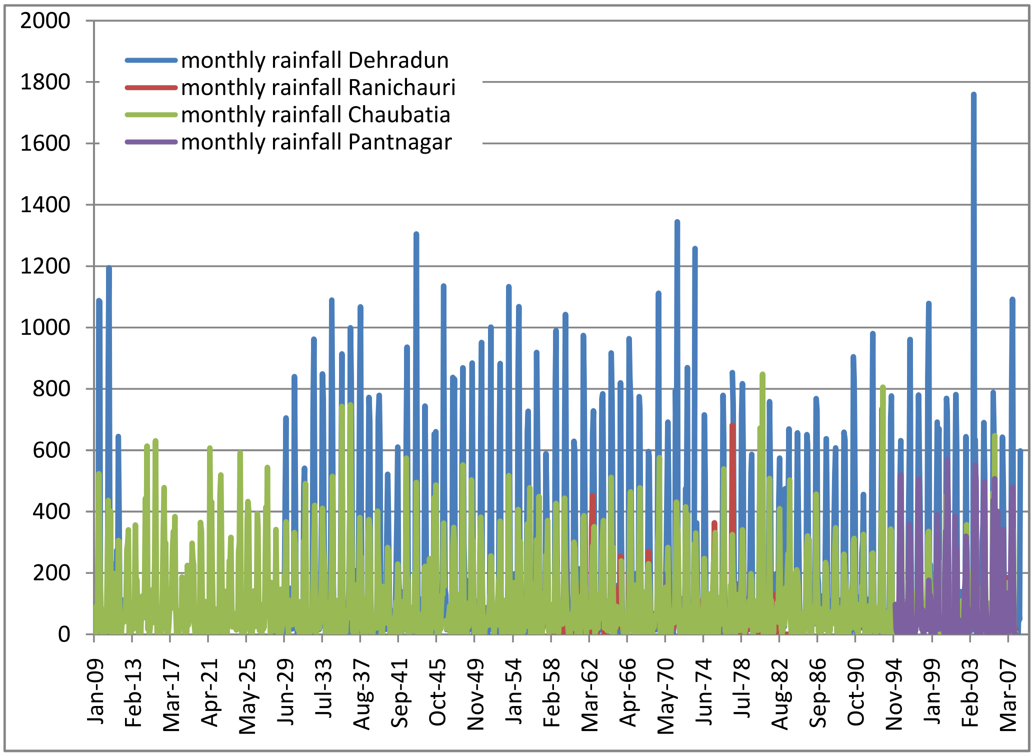
The overall trend of these graphs is as summarized below.

Increasing: Jan-max-Chaubatia, Jan-max-Dehradun, Jan-min-Dehradun, June-max-Chaubatia

Decreasing: Jan-min-Chaubatia, June-min-Chaubatia, June-min-Dehradun, June max-Dehradun,

Here we see an increase in the maximum temperatures in summer and winter, and a decrease in the minimum temperatures in summer and winter. This indicates increasing extremes in weather, with hotter summers and colder spells in winters. However, the maximum temperature in June in Dehradun, and the minimum temperature in January in Chaubatia run against this trend with a decreasing and increasing trend respectively. It needs to be studied further if this is an indication of a shift in seasons with the hottest and coldest months appearing in months other than January and June.

The rainfall data for the four stations has also been plotted (figure 26: Total rainfall in mm).



Again, Ranichauri and Pantnagar have significant gaps in the data sets, rendering inaccurate any general deduction from this set. The annual rainfall for Dehradun and Chaubatia has been calculated and the results plotted (figure 27: Total Annual rainfall in mm).

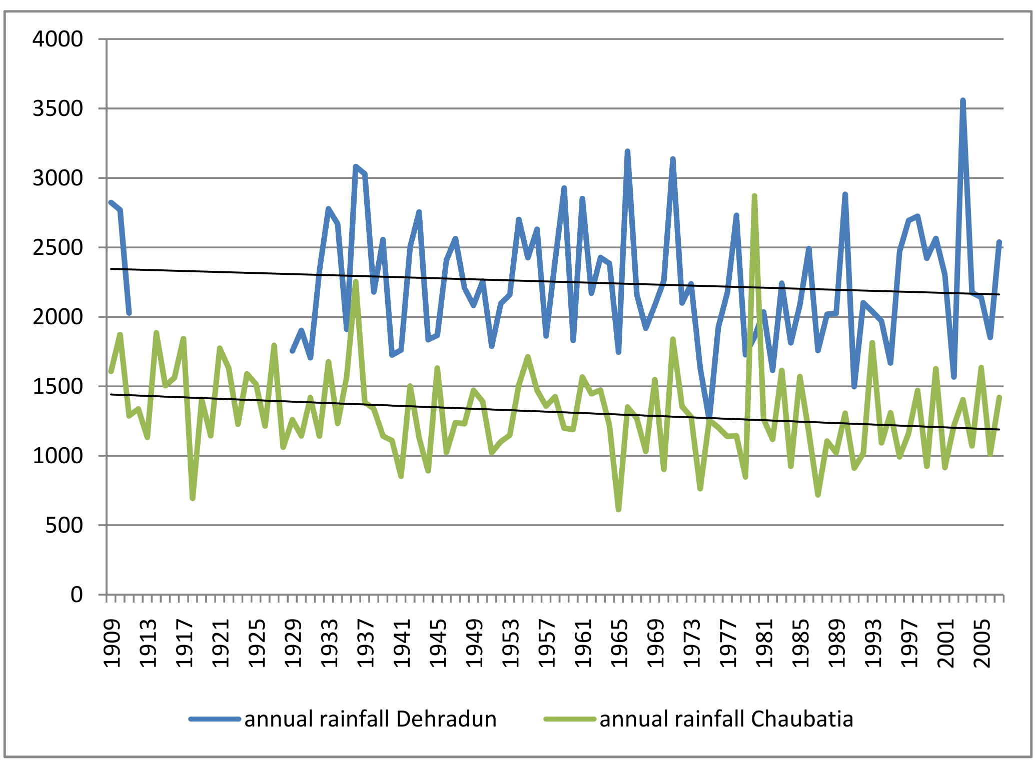


Figure 26 Variation of annual rainfall with time

The total annual rainfall for both Dehradun and Chaubatia shows a significant decline since 1909. This increasing aridity is the major source of concern among the people spoken to as well. It is an interesting point that this increase in aridity is felt despite it not being significantly warmer in winter. It seems to be indicated that a lack of humidity rather than a lack of condensation temperature is the cause of decreasing precipitation.

To sum up, the main observations from this analysis are as follows:

1. The maximum temperatures are increasing while the minimum temperatures are either constant or decreasing.
2. The 30-year cyclical nature of temperature is evident, but the increasing and decreasing trend still exists over the last century.
3. Total annual rainfall is declining

This analysis looked at changes in the quantum of precipitation and the variation in temperature over the last century. However, one aspect of climate change is also the shifting in the seasons within the year. This phenomenon was also observed by the people met with during our surveys. They mentioned later freeze and earlier thaws.

This observation needed to be verified and quantified with the data sets available.

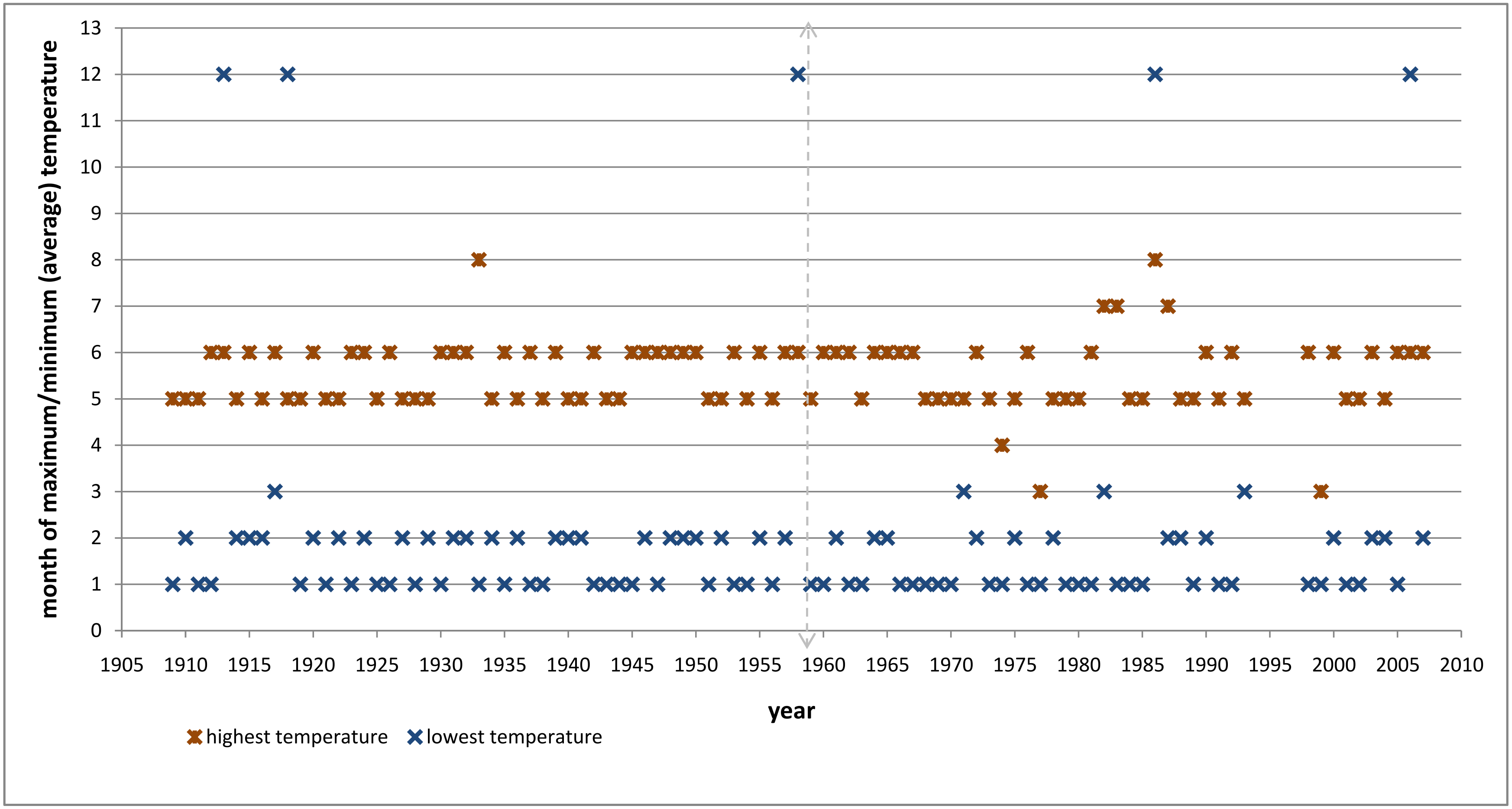
Alternative methods of studying the shift in seasons were explored. These methods were as follows:

1. Monthly plots for all the years: This has been done for the months of January and June However, this too gives us the variation in temperature and not the shift in seasons.
2. Distribution of temperatures across the year. For example, if the average winter temperature is 5°C, then a plot of the months in which this appears across the data set will indicate a shift in winter. As we have monthly average and extreme temperatures, it was difficult to select a particular temperature range that was both narrow enough to reflect change, and broad enough to allow for the data available.
3. Occurrence of the maximum and minimum temperatures in a year as per the month they occur in. This method was followed for both temperature and precipitation.

Accordingly, the data was sorted for the months in which the maximum and minimum temperature in a year occurred. In addition, the months with the maximum amount of rainfall as also the maximum number of rainy days in a month. This data was plotted to determine if there is actually a shift in seasons.

Extreme weather patterns were studied by plotting the heaviest rainfall in 24 hours over the years, and determining if a trend is visible.

The data set obtained has monthly figures- essentially a least count of a month. However, ongoing climate change is a gradual process. It is likely that several shifts are contained within the month. Similarly, it is also probable that fluctuations in temperature are absorbed during the computation of average highs and lows.



month of maximum/minimum (average) temperature
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
year
highest temperature
lowest temperature

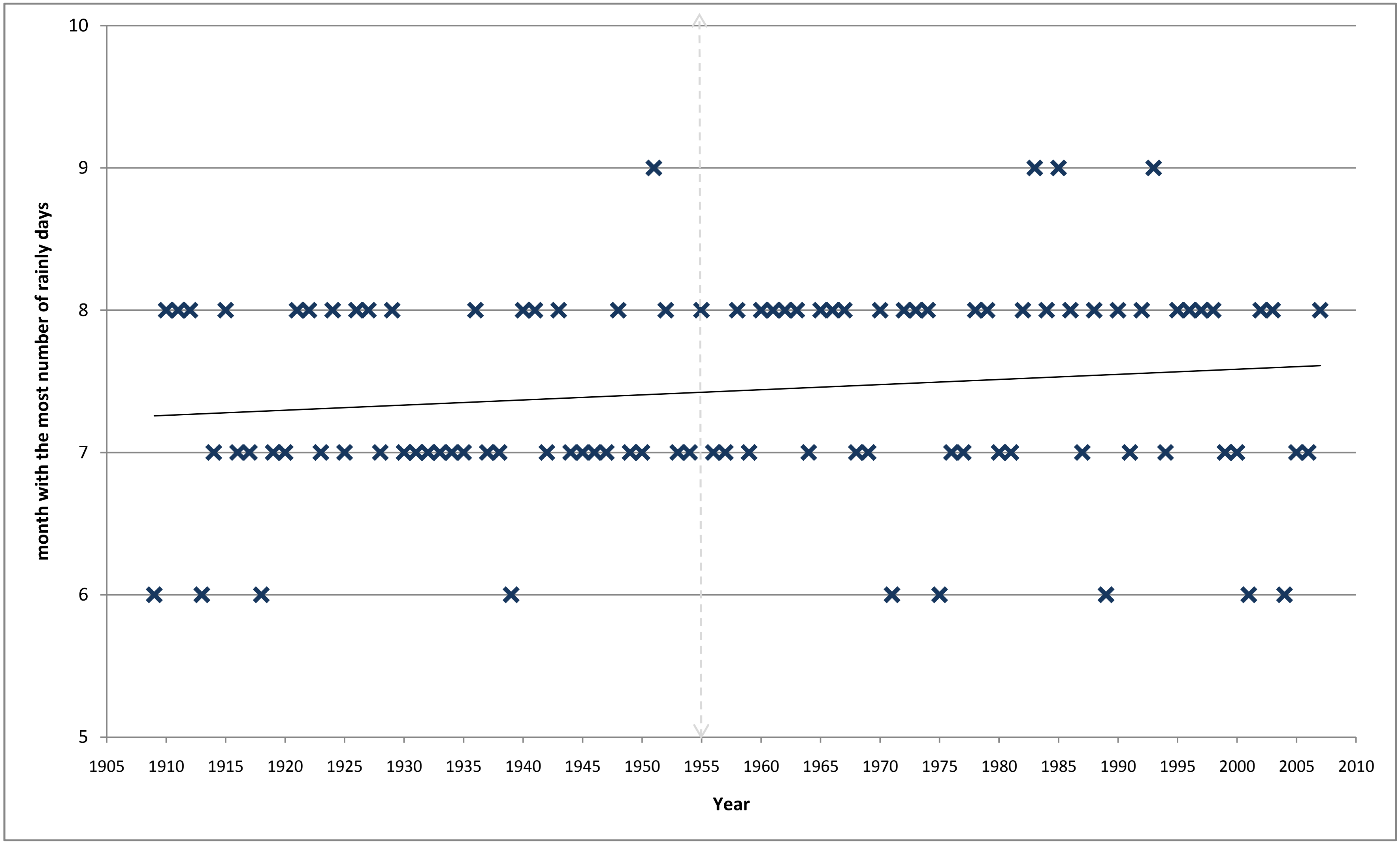
Figure 28 illustrates the distribution of the warmest and coldest months every year. The observations from this illustration are as follows:

1. The coldest months are usually January or February, while the hottest are either May or June. All but 9 years for the coldest month and 8 years for the hottest month (or 90% of the total readings) fall in this pattern.
2. There is no significant trend towards later or earlier occurrence of seasons. However, as discussed earlier, it is probable that any shifts have been hidden in the relatively broad sample size.
3. However, it is clear that there is an **increase in the frequency of variation**. The data range is from January 1909 to December 2007, or for 99 years. If we compare variation for the earlier half of the century with the latter, we get the following

parameter	**1909-1958**	**1959-2007**
Maximum temperature	4	5
Minimum temperature	1	6

This variation is accelerating, as is evident on comparing the last 30 years (1975 onwards)

parameter	**1975-2007**
Maximum temperature	5
Minimum temperature	4



10
9
8
7
6
5
month with the most number of rainly days
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

An analysis of the distribution of rainy days (figure 29) also confirms this trend of increasing variability. In addition, there is a slight shift towards the later months as is seen from the rising trendline in the same figure.

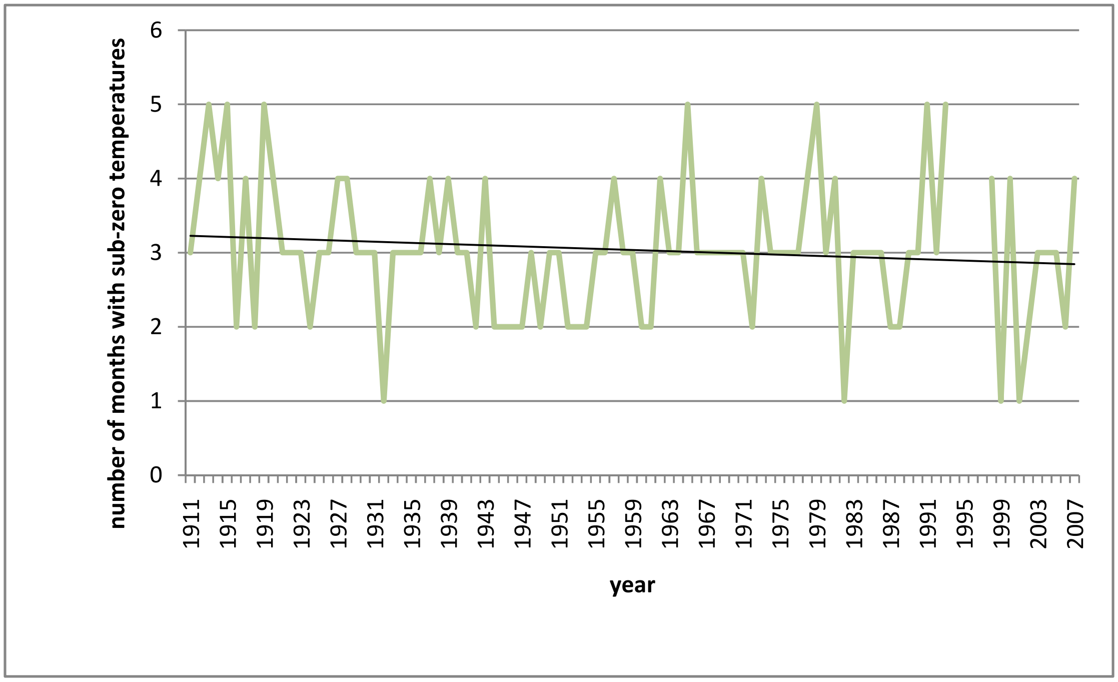


Figure 29 Chart showing number of months with sub-zero temperatures per winter

The months of maximum rainfall and wettest month were compared as this could be an indicator of increasing storms, as opposed to a sustained and steady precipitation. However, a significant trend towards intense storms is not visible in this data.

There also appears to be a **decrease in the length of the winter season** as seen in figure 30. This figure plots the number of months where the temperature fell below 0°C atleast once. Here, the winters have been considered rather than the months, and so for example, freezing in December 2003 will be considered a part of winter ’04.

The graph is centered around a winter period of 3 months, with a deviation of one month being common. A look at peaks beyond this deviation shows that in the period from 1911 to 1958 (approximately half the data range), there are three instances where the winters were longer than 4 months, and only one short winter. On the other hand, the period from 1959 to 2006 shows that there were four winters longer than normal, and crucially three that were of shorter duration. This indicates **increasing variability combined with the trend of decreasing length of winters**. As seen in figure 28, here too there is a further acceleration in the last 30 years.

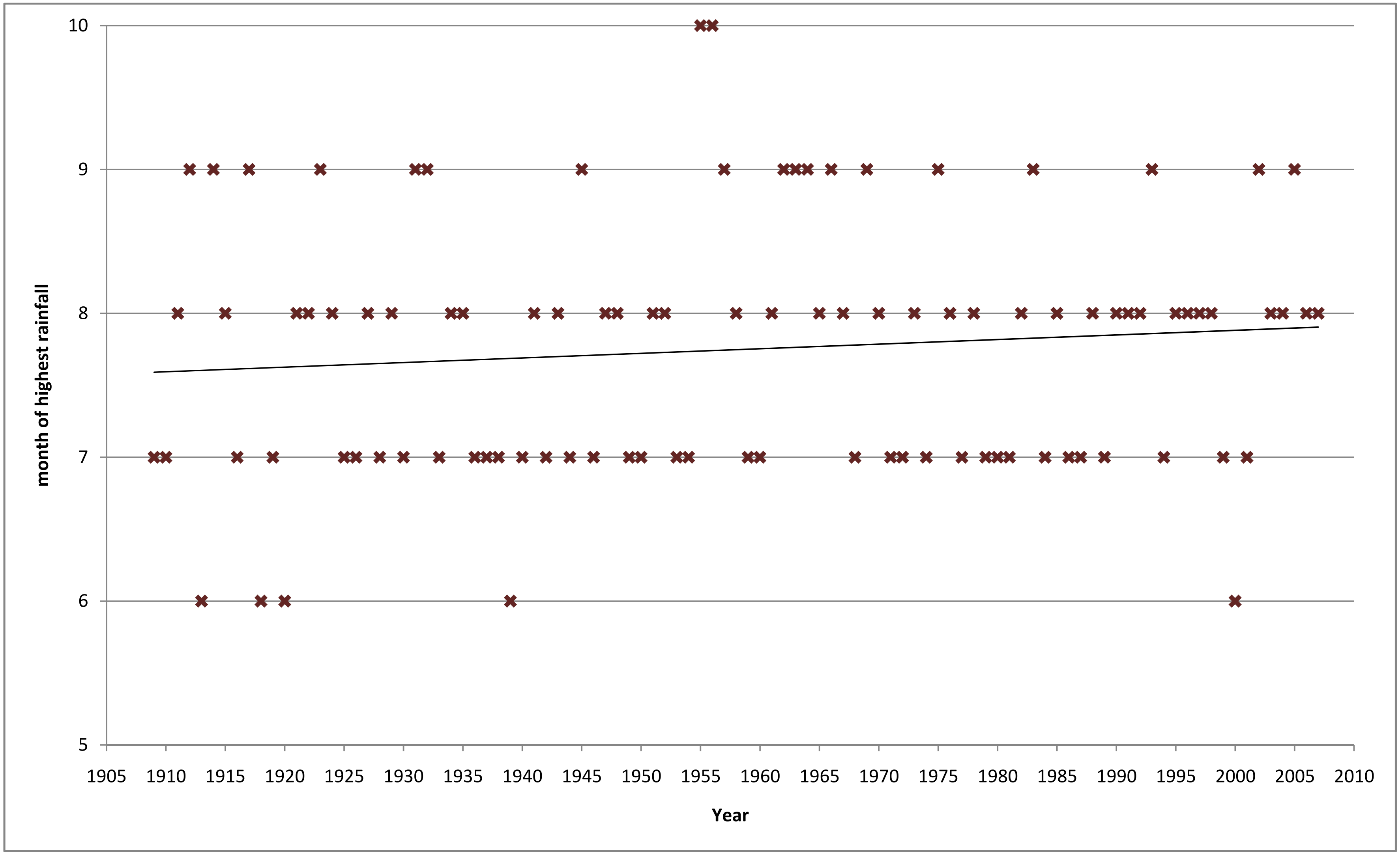


Figure 301 month with the highest quantum of rainfall in Chaubatia (1909-2007)

Figure 31 shows a definite shift in the pattern of rainfall with the peaks (period of heaviest rainfall) tending towards later months. In addition, there is a trend of increasing variability consistent with the other parameters studied. As July and August are the months that show the heaviest rainfall in most cases, the number of years in which rainfall occurred outside these months was counted for the periods 1909-1955 and 1956-2007.

Parameter	1909-1955	1956-2007
Earlier peak	4	1
Later peak	7	11

This table illustrates both **increasing variability as well as a shift towards later monsoons**.

5. Discussion:

5.1. Field Surveys

The two valleys visited are experiencing stress due to both anthropogenic factors as well as those due to climate change. Separating them is a challenge, as in some cases is identifying the cause and the effect. Among the anthropogenic factors, increasing population and market demand are accelerating environmental degradation and a shift in agricultural practices. Climate change is leading to a decrease in winter rainfall, lack of freezing temperatures and increase in the frequency of extreme weather events.

The Bhagirathi valley is primarily dependent on orchards, tourism, pastoralism and agriculture. Of these, the apple orchards are most vulnerable to climate change. According to Mr.Charan Singh, an apple grower in the village of Harsil, apple trees need 1600 hours of freezing. The lack of cold winters is leading to a decline in the fruit. In addition, untimely hailstorms are also decimating the crop. Increasing aridity is also leading to a proliferation of pests.

Villagers in the Bhagirathi valley have also begun cultivating tomatoes and other vegetables. However, the relative influence of market demand and of climate change needs to be assessed. In the Pindar valley, aridity is the main factor leading to a decline of crops. Most farmers here grow wheat and potatoes and only one farmer in Khati had begun to cultivate vegetables other than potatoes.

The pastoralists in either valley have not deviated significantly from their traditional calendar. However, they reported a lessening in snowfall. Many of the shepherds described an absence of snow where earlier they would find it. Pastoralism on the whole is decreasing, with fewer people electing to rear goats. However, the interviews suggest that a shift in focus to providing services to tourists may be the cause rather than climate change.

The residents of the valleys mentioned a decrease in the availability of herbs and other non-timber forest products. However, in this case too, the relative influence of over-exploitation and climate change is a matter for further study. In the case of the brahma-kamal, for instance, over-exploitation seems to be a key cause. Similarly, the composition of the Kafni Bugyal is changing due to human interference. However, changes in flowering times are directly influenced by the changing climate. The early flowering of rhododendron in the Pindar valley is directly linked to rising temperatures. Similarly, the observed lack of regeneration in oak (at Dharali), and deodar (Mukhba, Jaspur) can be indicators of a lack of the freezing temperatures required by the seeds[19].

[19] Rana, J.C. and Sharma S.K, Impact of climate change on western Himalayan region and adaptive strategies thereof, presented at National Conference On Forestry Solutions**:** Strategies For Mitigation And Adaptation Of The Impacts Of Climate Change In Western Himalayan Mountain States, Shimla, HP, November 19 to 21 2009

5.2. Weather Data Analysis:

The charts, particularly the analysis of the shift in temperature and rainfall indicates that there is a change that goes beyond usual cyclical variation. The increase in maximum temperatures and the decrease in minimum temperatures indicates that seasons are becoming more intense. Increasing aridity is a very real phenomenon, and furthermore, one that has far-reaching consequences for the ecosystem.

The analysis done of shifts in the occurrence of high and low temperatures strongly indicates that weather is becoming increasingly unpredictable. Both temperature and precipitation trends are shifting from the normal.

Monsoons too are occurring later than they earlier did. This coupled with the increasing aridity and fewer freezes means that the traditional means of agriculture is no longer viable. It is necessary to adapt to these changes in the weather. However, merely shifting the agricultural calendar will not serve the purpose, as this will not account for the increasing variability.

This uncertainty in the weather is a strong argument for focusing on increasing the resilience of the communities and ecosystems to enable them to adapt to unpredictable change.[20]

6. Recommendations

The study indicates that climate change is causing drier winters in the Himalayas. The lack of precipitation impacts both orchards and farms with one needing snowfall for freezing and the other needing water for growth. In addition to this direct impact on productivity, there are some indications that this leads to increased pest attacks. In addition to these direct impacts, the composition of the forests and bugyals is changing.

The increasing intensity of monsoons is confirmed by both community reports and analysis of the weather data. Frequent episodes of heavy rainfall lead to landslides, which block connectivity to urban areas and markets. This further decreases livelihood options as well as making it difficult for villagers to access health care in emergencies. A focus on ensuring this connectivity will not only safeguard existing livelihoods, but also, if this work is done through NREGA or similar schemes, will generate basic employment in the area. Similarly, watershed development will both generate livelihood and also conserve scarce

Climate change is an ongoing process and its impacts are yet evolving. Addressing the symptoms of climate change is likely to be inefficient, as this method does not take into account shifting goals and environments. For example, a major problem faced by the apple growers is increasing aridity. One way of addressing this could be by considering irrigation techniques. However, studies indicate that increasing warmth could also result in increasing snowmelt, which will increase the availability of moisture. It can be speculated that this increase in warm and humid conditions will further result in increase of fungal diseases. The provision of irrigation systems will have done nothing to address this problem.

Similarly, we also need to recognise that at this point we cannot predict the impact of observed changes. For example, apple flowering is occurring earlier than usual. As of now, this does not have an appreciable impact on the crop calendar. However, what will be the impact of this phenomenon if this trend continues? Will pollinators be able to adapt quickly enough to ensure their survival as well as the viability of apple farming? This is a question

[20] Tompkins, E. L. and W. N. Adger. 2004. Does adaptive management of natural resources enhance resilience to climate change? Ecology and Society **9**(2): 10. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art10/

that cannot be answered at this point. It follows that this is a change that cannot be addressed till its impacts are known, by which time it might be too late.

In this case, increasing the adaptive capacity of communities and ecosystems would be the recommended goal. Some strategies to achieve this would be to decrease their reliance on winter rainfall, and also on a single crop. Thus, their vulnerability to changes in either of these factors- which the current study indicates is a major source of concern- will be reduced, and consequently the resilience of the communities to climate impact is strengthened. Specific methods to decrease reliance on winter rainfall would be establishing an efficient irrigation and grey water reuse system, and drought-resistant agriculture methods like the system of wheat intensification in unirrigated areas. Studies conducted by PSI conclusively prove that crops grown under this system are less vulnerable to drought than conventional crops. Organic farming, with a focus on intercropping will decrease community reliance on a single crop.