Climate Vulnerability in North Western Himalayas

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Environics Trust, 2011

A Contribution to the Ongoing Nation-wide Climate Studies

Vulnerability in Various Ecoregions of India, 2011

Indian Network on Ethics and Climate Change (INECC)

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1.0 INTRODUCTION

Global warming induced climate change has triggered events such as melting glaciers, rising sea levels and changing weather patterns.This in turn has lead to storms, droughts, flash floods, cloudbursts, change in vegetation. Growing body of scientific evidence has established that this phenomenon is directly linked to unprecedented amount of GHG gases released in the atmosphere largely due to burning of fossil fuels since the beginning of industrialization in last century. The situation is likely to worsenas countries with low industrialization including China and India began to pursue the same path of carbon based economic growth.

However, the impact of climate change is not distributed evenly across the world. Mountain eco-systems are more sensitive to the habitat and climate change due to the interaction of tectonic, geomorphic, ecological and climate agents. For instance, temperatures are rising more rapidly in the Himalayas than the global average. Over the last decade the average temperature in Nepal has risen 0.6 degrees, compared with an increase in average temperatures globally of 0.7 degrees over the last hundred years (Gravgaard, 2010). In another Himalayan region, Tibetan Plateau, temperatures have gone up over three times the global average (Schell, 2010). On an average, surface air temperatures in the Himalayan region have gone up to 1.0 degree in last decade (Srinivasan J, 2006). For this reason, Himalayas, in addition to continental ice masses, Alaska, Patagonia and the Karakoram have been identified as critical regions in the world.

Communities inhabiting mountain ecosystems are particularly vulnerable to extreme weather conditions such as high temperatures, altering rainfall patterns, receding glaciers and permafrost thawing, etc. Recent instances include the disastrous cloud bursts in near Leh in Ladakh andKapkot, Uttarakhand, the apple orchards shifting towards higher altitude seeking lesser temperatures and arrival of mosquitoes even at an altitude of 12700 ft in Tsomgo in Sikkim. This vulnerability further exacerbates due to high dependency on natural resources for livelihoods.

Climate change is increasingly being debated at the local levels. The thresholds for vulnerability are still unknown in specific local contexts. Since benchmarking has never been seriously attempted, to isolate climate induced vulnerability becomes a daunting task. Mostly lumped data and cumulative models are adopted. Comprehensive basin level planning has not evolved since the monitoring itself is not well planned over the basin and the weather-monitoring infrastructure is thinly dispersed. However, we must concede that despite very limited data, the regional models have given broad estimates of changes in temperature and some of the potential implications.

There are still no well-defined determinants at the micro level as they vary with physiography and several other factors. Establishing them with known micro-meteorological responses can produce empirical evidences to isolate changes due to global warming in a particular context.It is also true that climate change is largely induced by industrialization as a major contributor of GHGs. It seems that these regions too, apart from the burden they face of the global pollution, will eventually industrialise. This cannot be achieved without physical developments and these are taking place rapidly. The enormity of the local impacts is leading to unrest and discontent. Business-As-Usual planning without a mountain perspective, particularly in the Himalayan States, is increasingly adding on to the vulnerabilities with varied multiplier effects.

This research is the Himalayan component of INECC coordinated researches across different eco-regimes in the country. The purpose of the study is to provide an overview, understand peoples perceptions and identify potential opportunities for action which could be undertaken by the civil society and the State. The Himalayan Mission on Climate, the Water and Agricultural Missions can incorporate the suggestions made for reducing risks and building resilience.

2.0 NORTH WESTERN HIMALAYAS- PHYSIOGRAPHIC FEATURES

The youngest mountain systems in the world comprising world's tallest peaks, the Himalaya are a wonderful and complex reality of Mother Nature. The region is one of the critical biodiversity hotspots of the world due to its unique geography and ecology. This mountain system runs from west to east covering an area of nearly 7.5 lakh km^2 (0.75 million km^2) spanning over 3,000 km in length and average width 300 km, and rising from low lying valleys to > 8,000 m. It stretches from northern Pakistan on the west to the northeastern region of India through Nepal and Bhutan. The range consists of three coextensive sub-ranges, with the northernmost, and highest, known as the Great or Inner Himalayas.

The Himalayan system has a distinctive climate of its own, which in turn has an immense impact on the climate of Indian subcontinent and Tibetan plateau. The range form a barrier preventing frigid, dry winds from arctic blowing south into the subcontinent which keeps it much warmer than corresponding temperate regions in the other continents. The barrier also stops monsoon winds from traveling north causing heavy rainfall in the Himalayan terai region. Similarly, they stop western disturbances in Iran from traveling further resulting in snow in Kashmir and rainfall in Punjab.

The variations in topographical features along Longitude, latitude and Altitude create climatic variations resulting in unique and rich biodiversity elements ranging from genes and ecosystems. There are over 13000 plant species in the Indian Himalayan Region (IHR) which constitutes the largest subgroup of the Himalaya with total area of 5.37 lakh km^2 (0.537 million km^2). The region as a whole supports nearly 50% of the total flowering plants in India of which 30% are endemic to the region. There are over 816 tree species, 675 wild edibles and over 1,740 species of medicinal value in IHR. Similarly, nearly 300 mammal species (12 endemic) and 979 birds (15 endemic) are recorded from the region. In addition, out of total 573 scheduled tribes in India, 171 inhabit the Himalayan region showcasing the great diversity of ethnic groups. Besides geographical advantage of the Himalayan region, the ecosystem services provided by it are of great and critical value. The IHR forest cover, which constitutes 42% of the total area acts as a carbon sink in addition to providing fruits and other benefits.

The Himalayan region contains the largest area under glaciers and permafrost outside of polar caps. In addition large part of this region receives seasonal snow. Together they form a unique reservoir from which 10 of Asia's largest rivers flow sustaining lives of billion plus people. Two of India's biggest rivers, Brahmaputra and Ganga flow from Himalaya forming rich deltas, which provides livelihood for close to 400 million people.

Though the Himalayan systems has supported and sustained civilizations that came about in its vicinity, it has recently started showing signs of stress both due to geological reasons and over exploitation of natural resources, current energy sources, population pressures and other related changes.

The impact of climate change is also very immediate and profound in these sensitive ecosystems. However, any negative impact on the Himalaya due to climate change will have damaging impact on the communities dependent on it through various means. Himalayan regions have been considered to be poor in economic terms (in terms of revenue generation but setting apart environmental services which is still poorly understood) so the easiest way out has been to promote concessional industrial development, largely in the plains without understanding the impact on air and water environments in such eco regions which have a direct bearing over micro climate (industrial pollutants equivalents to Carbon!). The current carbon market only notionally displaces the pollutant from one place to other and provides monetary incentives for this whereas it is the reverse if we see in context of Himalayas, incentives (tax holidays) are being provided to polluting industries to bring economic gain in the region. This may not be true across the region but there have been growing emphasis on industrialization, in the lower & middle Himalayas. The importance of understanding micro-climates is emphasized by a study on the Dabka catchment in Kumaon region indicating that local warming could be as high as 9 degrees celcius.

Table 1 - Variation in Key Meterological Parameters Dabka Catchment

	1985-1990	2005-2010	Change
Temperature (C)	18	27	9
Rainfall (mm)	2120	2000	120
Humidity (%)	60	52	8
Evoporation (mm)	535.57	602.43	66.86
Source			

Geographically, Himalayas have low density of population in the upper altitudes and ecosystem hierarchies provide a mutual interacting space among the biotic and abiotic components. and develop a need for just sustainability of the system thereby creating the need for ecological balance, any shift or imbalance impacts the ecosystem and not all components be able to adjust. Higher Himalayas hold resources such as glaciers, River systems (glacial as well as non-glacial), biodiversity, high altitude plants and species. In this context, several communities have a very limited period of opportunity to extract services from these regions like the nomadic communities like Gujjars andGaddis of Himachal or the Graziers (Bhainsiyas) of Uttarakhand.

The higher Himalayas are inhabitable, snow bound and have series of protected areas, the middle Himalayas and Valleys are dotted with hydroelectric projects, Reserve forests & submerged areas coupled with construction activity, the lower Himalayas too have protected areas – thus people have restricted geographical freedom. The whole issue of climate change in the Himalayan region is in protecting its resource integrity and fragility in whatever situation these exist and narrowing the misbalance and disintegration of closely dependent natural resources which can increase the vulnerability of the resources as well as the living beings (human beings and species).

Table 2 – North Western Himalayas District-wise Altitudinal Profiles and Key Features						
S.No.	State	Districts	Altitude Range	Predominant Altitudinal Range in District	Peaks Or Other Features	Less Predominant Altitudinal Profile in District
1	Himachal Pradesh	Bilaspur	300-1800m	300-900m	GovindSagar (Bhakhra), Parts of Mahasu valley	1350-1800 m
		Chamba	600 – 7500m	1800 – 4500	Kailash Peak (5656m)	
		Hamirpur	300 – 1350m	300 – 900	Parts of Mahasu valley	1350 - 1800
		Kangra	300 – 7500m	600 – 900	Pong Reservoir & Wetland	>900m
		Kinnaur	1350 – 7500m	1350 – 3000m, 3000 – 6000m	KinnarKailash (6050m) (Satluj Valley, Baspa Valley),	Above 6000m
		Kullu	1350 – 7500m	1350 – 1800	DeoTibba (6001m), Partly Rampur Valley	
		Lahaul&Spiti	3000 – 7500m	Lahut Valley, Sarchu Peak (5741m), Chenab Sub Basin, Mulkila (6417m)	Lahut&Spiti valley, Sarchu Peak (5741), Mulkila (6417)	
		Mandi	600 – 3000m	900 – 1800		
		Solan	300 – 3000m	300 – 600 & 1350 – 1800	Shiwalik&Mussourie Range	1800 – 3000m
		Sirmour	300 – 1800m	Shivalik&Mussourie Range – 300 – 600m & 1350 – 1800m	Shiwalik&Mussourie Range	
		Shimla	1350 – 6000m	1350 – 1800m, 1800 – 3000m	Nag Tibba, Part of Rampur Valley	3000 – 4500m
		Una	300 – 900m	300 – 600m		601 – 900m
2	Uttarakhand	Almora	600 – 3000m	900 – 1800		Few areas above 1800m
		Bageshwar	900 – 6000m	1800 – 3000		Few areas above 4500m
		Chamoli	900 – 6000m	4500 – 6000, 3000 – 4500 & 1350 – 1800m	Part of Great Himalaya, Zaskar Range, Nanda Devi (7817m), Dunagiri (7066m), Trishul (7120m), Mangtoli (6800m), Hathi Parbat (6727m),	

Table 2 – North Western Himalayas District-wise Altitudinal Profiles and Key Features

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					Mana(7272m), Kamet (7756m)	
		Champawat	150 – 3000m	900 – 1800m		Few areas between 1800 – 3000
		Dehradun	300 – 3000m	900 – 1800m	Doon Valley	Few areas between 1800 – 3000m
		Haridwar	150 – 1350m	150 – 600m	Bhabbar&Terai	
		Nainital	150 – 3000m	300 – 600m , 600 – 900m	Shiwalik Range & Higher hills	Few areas between 1800 – 3000m
		PauriGarhwal	300 – 3000m	900 – 1350m & 600 – 900m		Few areas between 1800 – 3000m
		Pitthoragarh	600 – 6000m	> 4500m, 900 – 1350m & 1800 – 3000m	Part of Great Himalaya – Nanda Kot (6861m), PanchChulhi (6984m)	
		Rudraprayag	900 – 6000m	1350 – 3000m, 3000 – 4500m		>4500 – 6000m
		Udham Singh Nagar	150 – 300m			
		TehriGarhwal	600 – 4500m	1800 – 3000m, 1350 – 1800m		Few upper regions adjoining Uttarkashi

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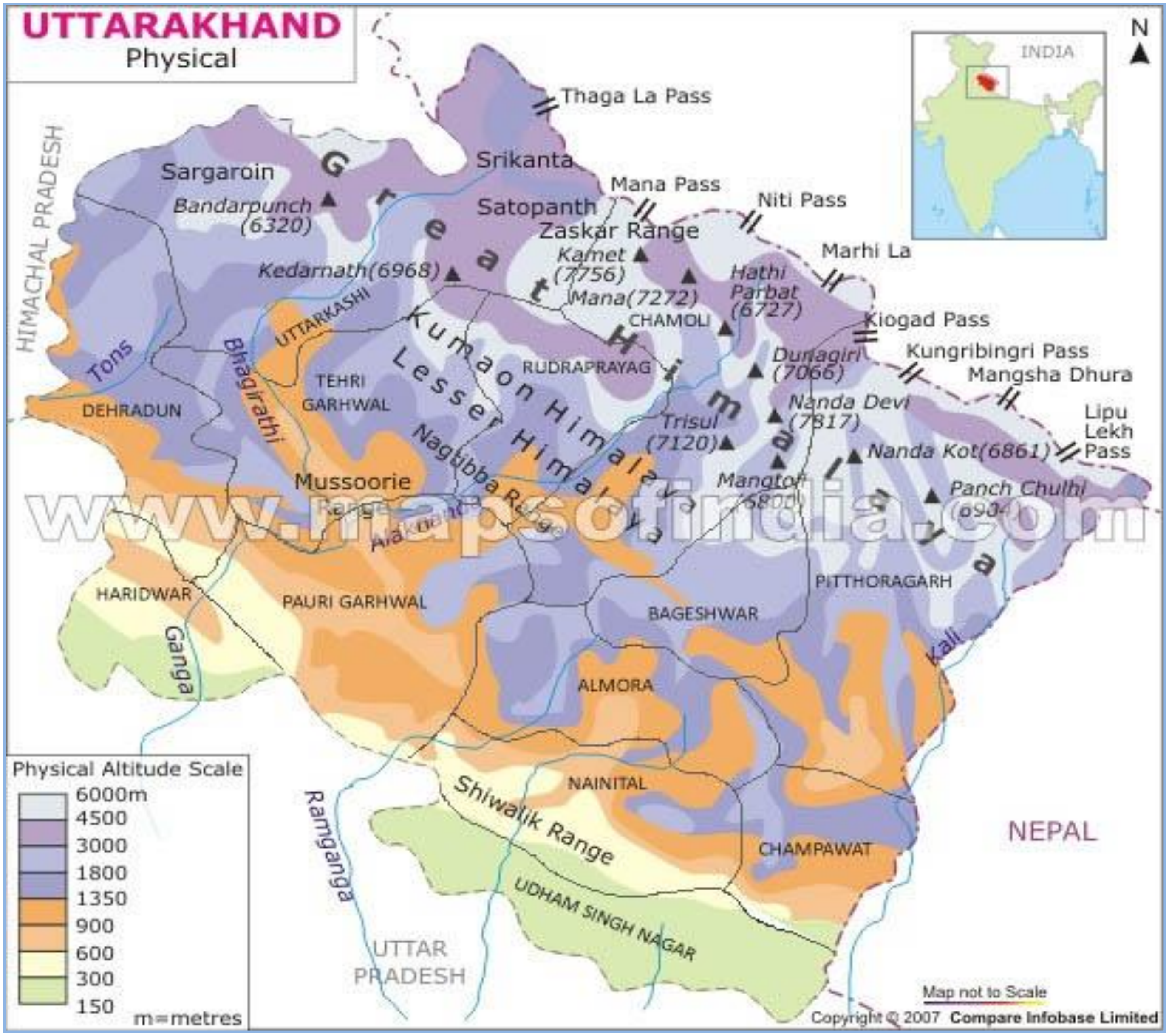
S.No.	State	Districts	Altitude Range	Predominant Altitudinal Range in District	Peaks Or Other Features	Less Predominant Altitudinal Profile in District
		Uttarkashi	900 – 6000m	4500 – 6000m, 3000 – 4500m, 1350 – 1800m	Kedarnath (6968m), Bandarpunch (6320m)	
3	Jammu & Kashmir	Anantnag	1350 – 6000m	1800 – 3000m, 4500 – 6000m		3000 – 4500m
		Baramulla	1350 – 6000m	1350 – 1800m		Very few parts >4500-6000m
		Budgam	1350 – 6000m	1800 – 3000m		
		Doda	900 – 6000m	1800 – 3000m	Zaskar Valley, Nunkun (7135)	4500 – 6000m, lower parts 900 1350m
		Jammu	150 – 3000m	150 -300m, 300 – 600m, 900 – 1350m		Some higher portions between 1800 – 3000m
		Kargil	1800 – 6000m	4500 – 6000m, 1800 – 3000m	Pirpanjal Range, Deosai Basin	
		Kathua	600 – 3000m	300- 600m, 600 – 900m		1800 – 3000m
		Kupwara	1350 – 6000m	1350 – 1800m followed by 1800 – 3000m		>4500m
		Leh&Ladakh	3000 – 6000 &> 6000m	3000 – 4500m, 4500 – 6000m	SaserKangri (7672), Aksal Basin, Kailash Range, East Ladakh Plateau	
		Pulwama	1350 – 3000m	1350 – 1800m, 1800 – 3000m		

Table 2 – North Western Himalayas District-wise Altitudinal Profiles and Key Features						
S.No.	State	Districts	Altitude Range	Predominant Altitudinal Range in District	Peaks Or Other Features	Less Predominant Altitudinal Profile in District
		Rajauri	600 – 3000m	600 – 900m		1800 – 3000m
		Udhampur	300 – 6000m	900 – 1350m		
Note: This table is a simple description of altitudinal variations that a district may have, these can be further clubbed into agro-climatic zones at a broader level.The altitude ranges are judged from the physiographic map available at www.mapsofindia.com – a certain margin of error is likely. Source: Analysed and Compiled by Environics Trust, 2011						

Figure 1 – Physiographic Features and altitudeof Peaks in Uttarakhand



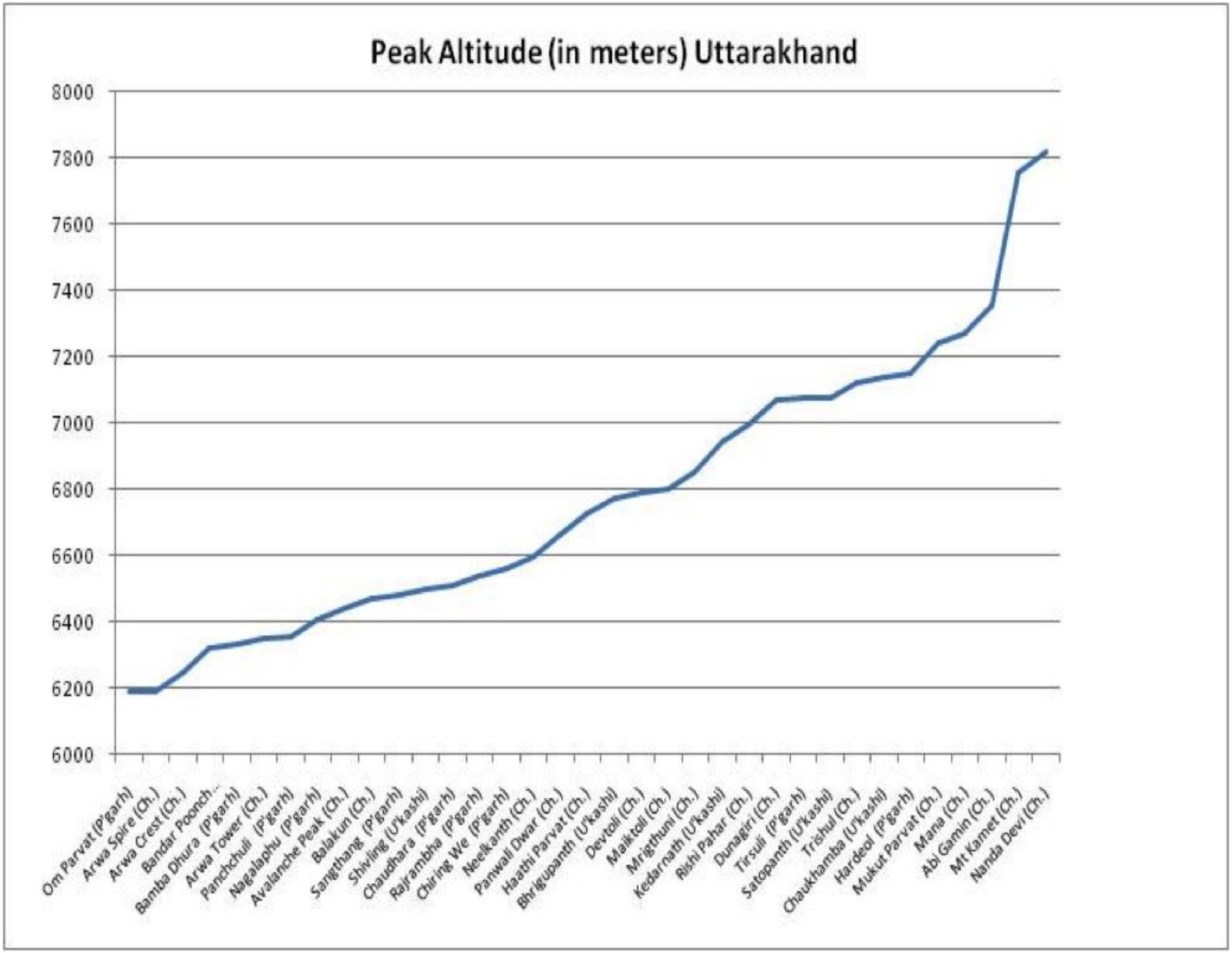
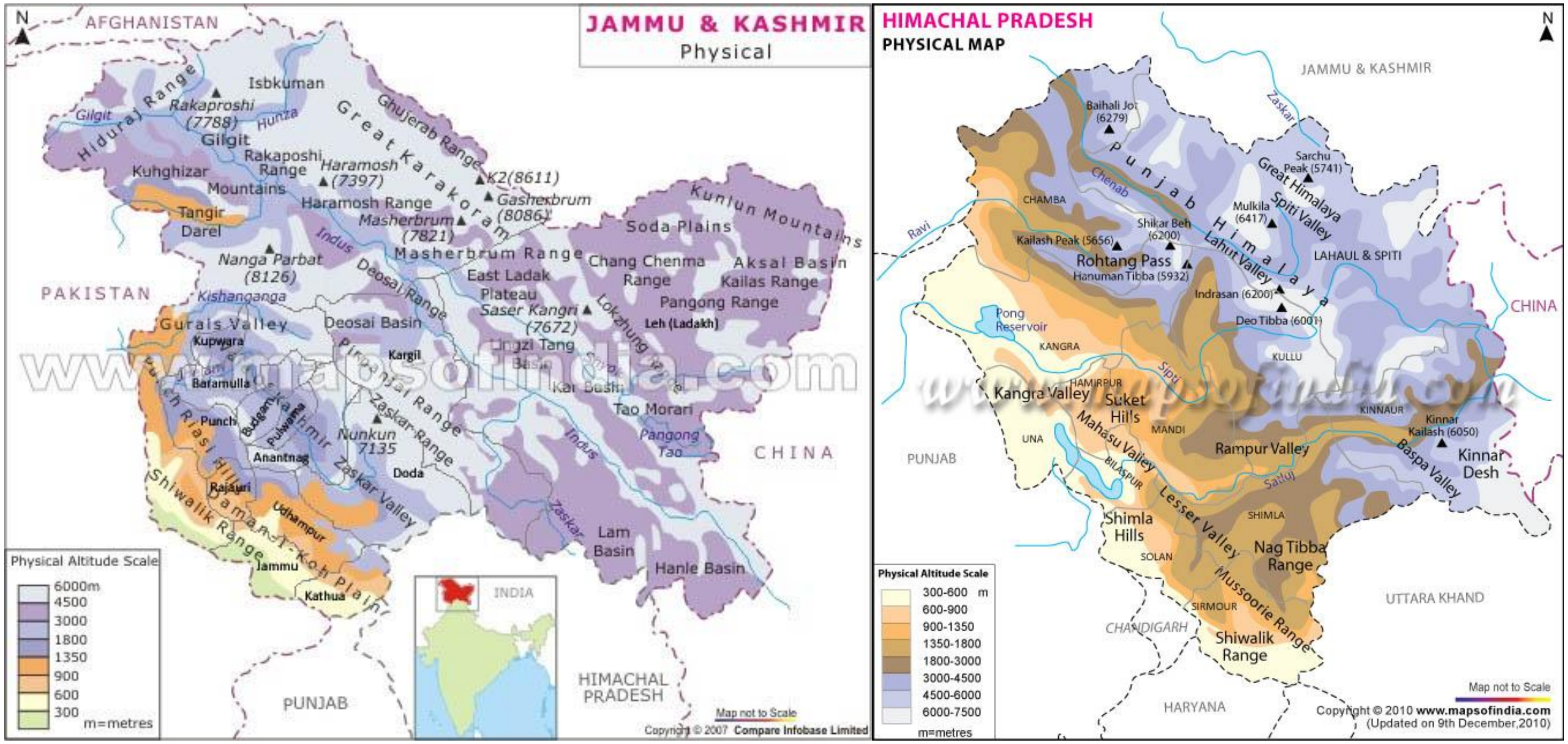

Peak Altitude (in meters) Uttarakhand
8000
7800
7600
7400
7200
7000
6800
6600
6400
6200
6000
Om Parvat (P'garh)
Arwa Spire (Ch.)
Arwa Crest (Ch.)
Bandar Poonch...
Bamba Dhura (P'garh)
Arwa Tower (Ch.)
Panchchuli (P'garh)
Nagalaphu (P'garh)
Avalanche Peak (Ch.)
Balakun (Ch.)
Sangthang (P'garh)
Shivling (U'kashi)
Chaudhara (P'garh)
Rajrambha (P'garh)
Chiring We (P'garh)
Neelkanth (Ch.)
Panwali Dwar (Ch.)
Haathi Parvat (Ch.)
Bhrigupanth (U'kashi)
Devtoli (Ch.)
Maiktoli (Ch.)
Mrigthuni (Ch.)
Kedarnath (U'kashi)
Rishi Pahar (Ch.)
Dunagiri (Ch.)
Tirsuli (P'garh)
Satopanth (U'kashi)
Trishul (Ch.)
Chaukhamba (U'kashi)
Hardeol (P'garh)
Mukut Parvat (Ch.)
Mana (Ch.)
Abi Gamin (Ch.)
Mt Kamet (Ch.)
Nanda Devi (Ch.)

Figure 2 – Physiographic Features of Jammu & Kashmir and Himachal Pradesh



3.0 VULNERABILITY OF THE NORTH WESTERN HIMALAYAS

3.1 Seismic Vulnerabilty

The northward drift of India from 71 Ma ago to present time indicates such a long movement such a huge land mass that the orogenic activity at the junction of these plates involving a huge momentum of impact. The Collision of the Indian continent with Eurasia is estimated to have occurred at about 55 million years ago and is relentless. Considering the inferred location of the landmass at this period to be around the present day equator, the drift has accelerated and greater must be the impact on the margins. It may be noted that the Indian landmass has simultaneously rotated counter-clockwise (Adapted from USGS).

It is this flight of India of the Indian Sub-continent and its continuous subduction that has given rise to the tallest mountain ranges in the world and continues to be a region that abounds in seismic activity.Roger and Bilham's (2001) view of the Indo-Asian collision zone shows the estimated slip potential along the Himalaya and urban populations south of the Himalaya (U.N. sources). Shaded areas with dates next to them surround epicenters and zones of rupture of major earthquakes in the Himalaya and the Kutch region, where the 2001 Bhuj earthquake occurred. Red segments along the bars show the slip potential on a scale of 1 to 10 meters, that is, the potential slip that has accumulated since the last recorded great earthquake, or since 1800. The pink portions show possible additional slip permitted by ignorance of the preceding historic record. Great earthquakes may have occurred in the Kashmir region in the mid 16th century and in Nepal in the 13th century. The bars are not intended to indicate the locus of specific future great earthquakes, but are simply spaced at equal 220-km intervals, the approximate rupture length of the 1934 and 1950 earthquakes. Black circles show population centers in the region; in the Ganges Plain, the region extending ~300 km south and southeast of the Himalaya, the urban population alone exceeds 40 million. The inset is a simplified cross section through the Himalaya indicates the transition between the locked, shallow portions of the fault that rupture in great earthquakes, and the deeper zone where India slides beneath Southern Tibet without earthquakes. Between them, vertical movement, horizontal contraction, and micro earthquake seismicity are currently concentrated.

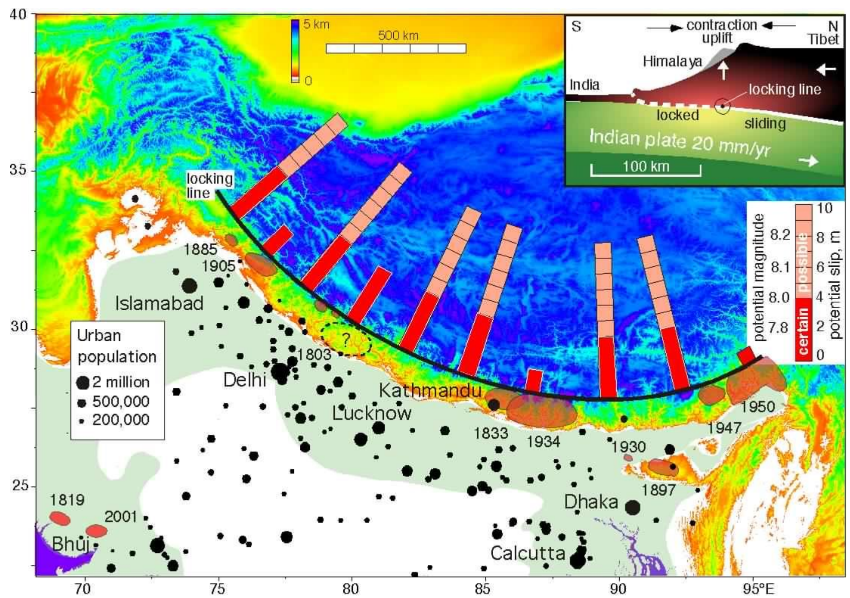


Figure - 3 Seismic Events

In 2001 Bilham et al estimated the present-day slip potential of the Himalaya by assuming that the currently observed convergence rate had prevailed for 200 years, and by calculating the accumulated slip that would be released at various points along the arc since the last earthquake at each of those points, should an earthquake occur there today (Bilham et al., 2001). The extension of the historical record to 1500, and geological evidence for surface rupture in a large earthquake in 1400 (Wesnowsky et al 1999, Kumar et al, 2001) permits a revised estimate of this slip potential. Its accuracy depends on the following assumptions: that we know of all significant earthquakes since 1500, that present geodetic convergence rates have prevailed for the past 500 years, and that no slow earthquakes have released slip during or after large earthquakes. Despite the different along-arc lengths of segments shown, the segment estimates do not necessarily represent the segment size of future earthquakes. Each trapezoidal figure represents the slip developed since the previous known earthquake at that location. We have no way of knowing whether a future earthquake will rupture the same area. Using the slip and rupture area of each of these regions we can estimate the magnitude of an earthquake should it occur today.

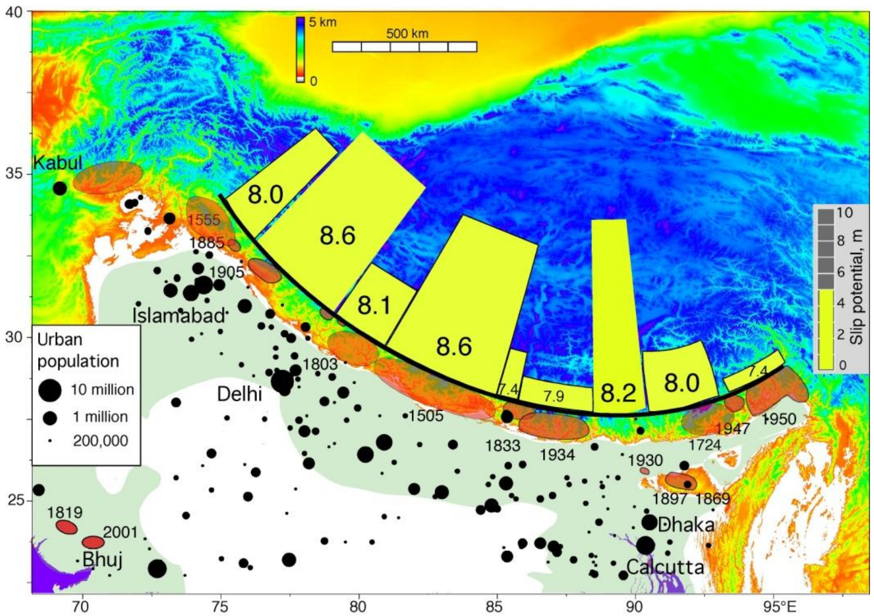


Figure - 4 Seismic Vulnerability

We know less about earthquakes in the eastern Himalaya than those in the west, and it is possible that we have underestimated seismic slip potential there. The 1897 earthquake reduced stresses in the region, but only for a 120 km long segment of eastern Bhutan. We know with certainty of no large earthquakes in western Bhutan with the exception of the 1713 earthquake that damaged several monasteries. The along-strike extent of this earthquake is unknown (Ambraseys and Jackson, 2003).

The huge number of vulnerable population is clear from the map that indicates urban population and slip potential in the Himalaya, based on elapsed time since the last major earthquake in various sectors along the arc since 1400 and the GPS-derived convergence rate across the Himalaya. The height of each trapezoid is proportional to the current slip potential in meters, and the numbers refer to the potential size of earthquake should the same segment length slip as is currently believed to have occurred in the last earthquake. The slip potential in the eastern Himalaya is tentative since the effects of the 1897 Shillong earthquake are uncertain and we know of no great historical earthquakes in Bhutan with the exception of a possible event in 1713.

3.2 Modification of Glacial Systems and Reduction in Snowfall

The Himalayan region contains the largest area under glaciers and permafrost outside of polar caps. In addition large part of this region receives seasonal snow. Together they form a unique reservoir from which 10 of Asia's largest rivers flow sustaining lives of billion plus people. Two of India's biggest rivers, Brahmaputra and Ganga flow from Himalaya forming rich deltas, which provides livelihood for close to 400 million people. The great Himalayan System contains 116,180 km2 of glacial ice, the largest area outside Polar regions (Owen et al. 2002). These glaciers feed 5-45% of 10 of biggest rivers in Asia including Ganga, Amu Darya, Indus, Brahmaputra, Irrawaddy, Salween, Mekong, Yangtze, Yellow, and Tarim. Collectively, these basins provide water for about 1.3 billion people (J. Xu et al. 2007; Bates et al., 2008). Almost 500 Million people are dependent upon the plains of Ganga, 10% of the total humanity (IPCC, 2007). According to 4th assessment study of IPCC, Himalayan glaciers are melting at a faster pace since late seventies. A recent study done by ISRO using Satellite images concluded that almost 75% of Himalayan Glaciers are receding at a faster rate.

Glaciers are the source of several Himalayan Rivers and these vary in size and spread, even glaciers in adjacent regions with similar climatic conditions have shown contrasting results. Deglaciation and glacier characteristics like glacier area, size, debris etc. play an important role in determining or analysing the on-spot as well as downstream impacts that may occur as result of melting of ice at a rapid pace. The Space Application Centre (Department of Space) in collaboration with MoEF carried out a study on Glaciers, which is as recent as May 2011.

The results indicate that almost >75% glaciers have shown retreat and some of the key features can be summarized below:

Table – 3 Glaciers in the Himalayas – Change Monitoring 2011

	No. of glaciers Monitored	Retreat	Advance	No Change
Fluctuations in different basins based on SoI maps and satellite images	2630	2047	435	148
		77.83 %	16.53%	5.62%
Fluctuations based on Satellite images	2190	1673	158	359
		76.39%	7.21%	16.39%

Source: Snow and Glaciers of the Himalayas, 2011

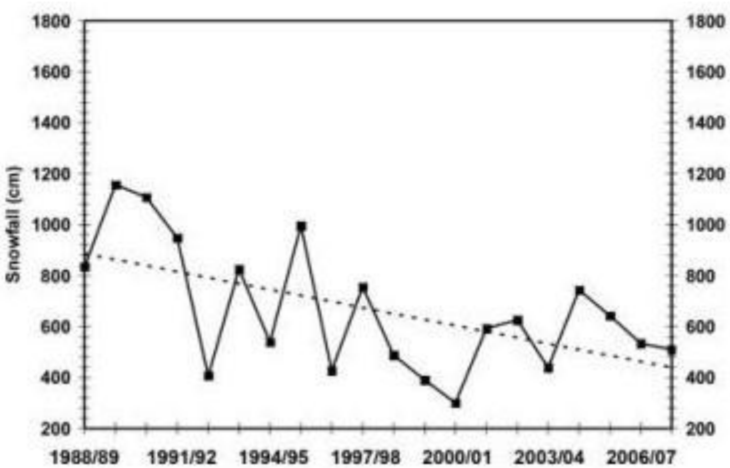


Figure 5 - Lowering of Snowfall

- **Nubra Basin** – Interpretation of glaciers in this basin indicates that the glaciers of this basin are very large in size as compared to other basins which indicates that the response time is slow and retreat is less
- **Teesta Basin -** There is almost no retreat in this basin. It shows that basins of eastern Himalaya show no or very less retreat than western Himalayas
- **Spiti Basin** – *Interpretation of glaciers in this basin indicate that there is rapid retreat after 2001 and this is the highest among all basins!*
- **Alaknanda& Bhagirathi Basin -** Glacier retreat for this basin after 1990 is much rapid whereas glaciers in Bhagirathi basin which is adjacent to Alaknanda basin has shown slow retreat after 1990.
- **Bhaga& Chandra Basin -** Bhaga basin is located in similar climatic conditions as Chandra basin but glaciers of Bhaga basin show higher rate of retreat as glaciers here are debris free. Another reason is the small size of glaciers indicating smaller depth

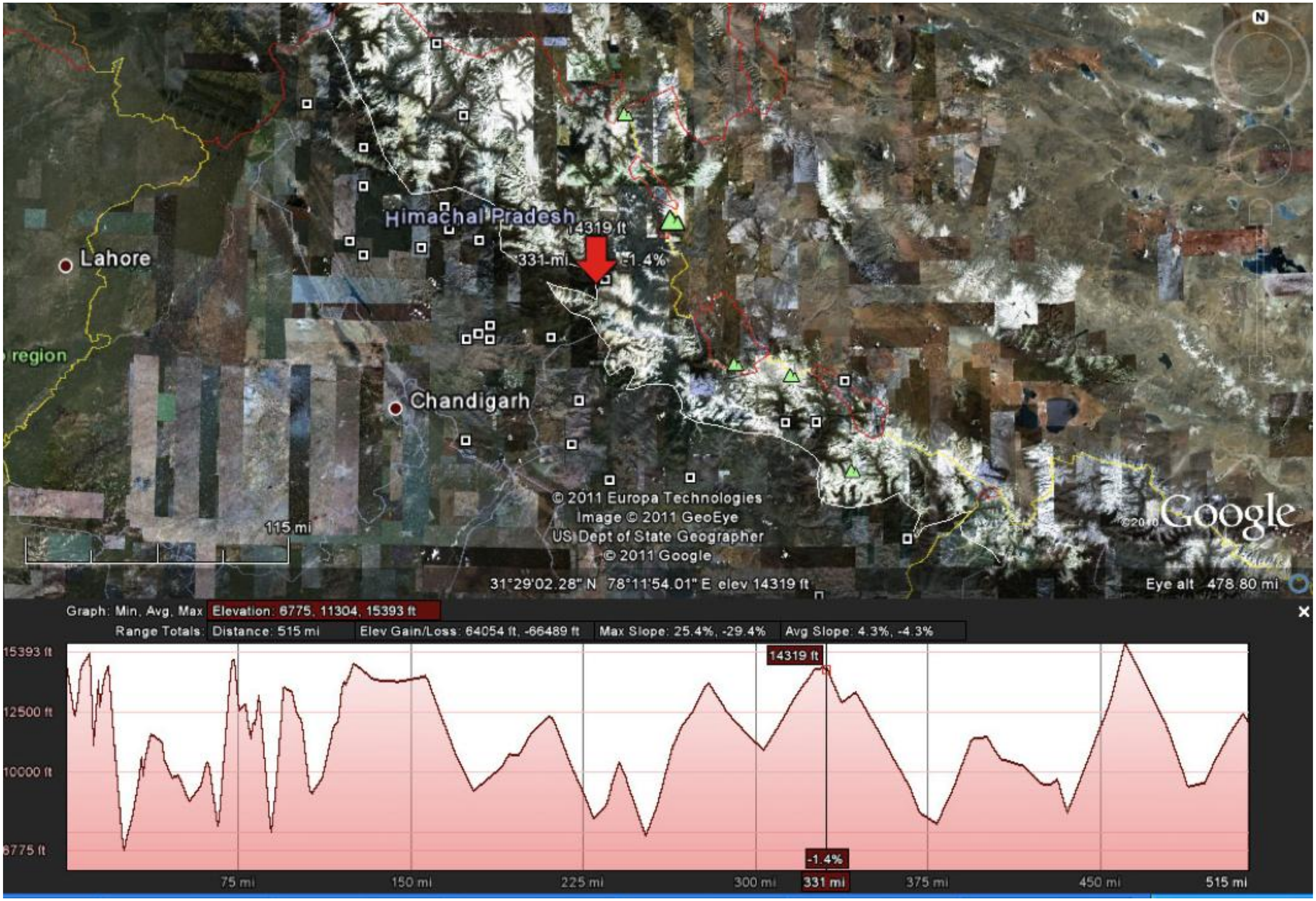
The study relied upon the topographic maps of Survey of India and Satellite imageries, the monitoring results were compared from 1962 – 2001 and thereafter in some cases as recent as 2007. The following table has been compiled in a simple manner to understand the state of these glaciers in different river basins in Himalayas with indications of retreat, advance and no change.

Evidence from a recent snowfall study show reduced snowfall over western Himalayas (Dimri& Kumar, 2008). Yet another study concluded decreasing trend of snowfall over all the mountain ranges with different magnitude. The study noted a decrease in total seasonal snowfall of 280cm over the entire western Himalaya between 1988/89 and 2007/08 (Shekhar.et.al. 2010).

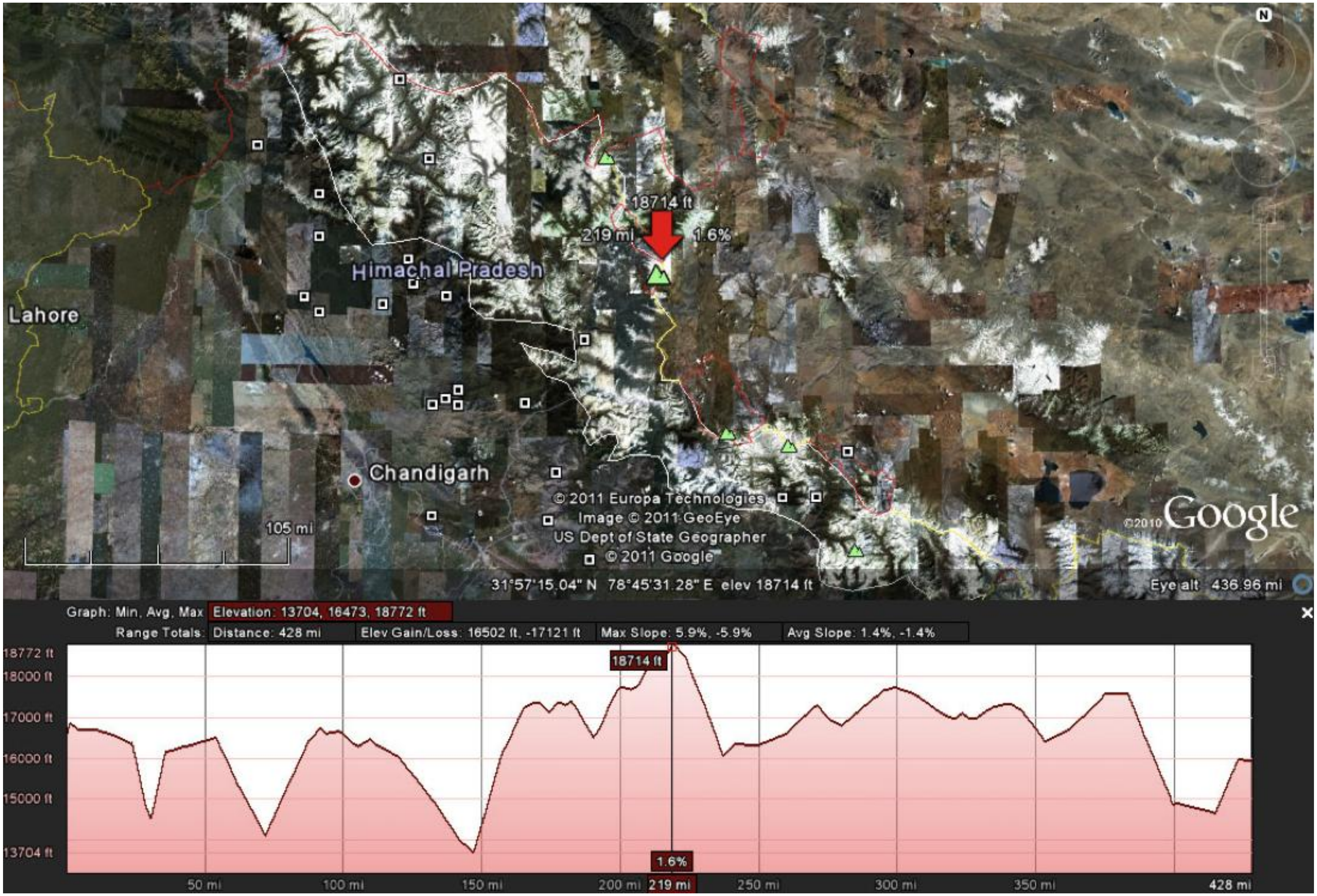
Table 4 - Assessment of Status of Glaciers in different River Basins of Himalayas			
River Basin	Coverage	Trend in Glacier Area Estimation	Status of Studied Glaciers
Suru	215 glaciers studied	17% loss in area (During 1962 to 2001 the area of glaciers was 568 & 474 km^2)	Rapid retreat
Zanskar	631 glaciers studied	15% loss in area (During 1962 to 2001 the area of glaciers was 1107 & 940 km^2 respectively)	578 showed retreat *(91.6%)* *Rapid retreat after 1990*
Spiti	337 glaciers studied	16% loss in area (During 1962 to 2001 the area of glaciers was 474 & 396 km^2 respectively)	169 showed retreat *(50%)* *Rapid retreat after 2001 and this is the highest among all basins!*
Parbati	90 glaciers studied	20% loss in area	
Nubra	31 glaciers monitored	6% loss in area (During 1962 to 2001 the area of glaciers was 2150 & 2026 km^2 respectively)	This indicates that the glaciers of this basin are very large in size as compared to other basins which indicates that the response time is slow and retreat is less
Chandra	Bara Shigri, ChotaShigri, Hamta and SamudraTapu glaciers	20% loss in area (During 1961 to 2001 the area of glaciers was 696 & 554 Sq.km. respectively)	
Miyar	165 glaciers monitored between 1962-2001.		80 showed retreat *(49%)* 78 advanced and 7 had no change in glacier area
Bhaga	111 glaciers (most of which located on ManaliLeh road) studied	30% loss in area (During 1961 to 2001 the area of the glaciers was 363 & 254 sq.km. respectively)	108 glaciers showed retreat whereas 3 do not show any change. *Overall: 98% showed retreat*

Table 4 - Assessment of Status of Glaciers in different River Basins of Himalayas			
River Basin	Coverage	Trend in Glacier Area Estimation	Status of Studied Glaciers
# This basin is located in similar climatic conditions as Chandra basin but glaciers of this basin show higher rate of retreat as glaciers here are debris free. Another reason is the small size of glaciers indicating smaller depth			
Warwan	230 glaciers studied	18% loss in area (During 1962 to 2001 the area of glaciers was 740km^2& 608km^2 respectively)	180 showed retreat *(78%)* 15 showed no change 35 glaciers advanced There has been a declining trend of glacier retreat after 2001 *Overall: 78% glaciers show retreat*
Bhut (adjacent to Warwan Basin)	143 glaciers studied	7% loss in area (During 1962 to 2001 the area of glaciers was 450 & 417 km^2 respectively)	74 showed retreat *(52%)* 29 showed no change 40 glaciers advanced *Overall: 52% glaciers show retreat* *Glacier retreat after 2001 is rapid* *Adjacent but contrasting trends!*
Alaknanda *(Satopanth&BhagirathKharak are 2 large glaciers of this basin)*	274 glaciers studied	14% loss in area (During 1962 to 2001 the area of glaciers was 1047 & 905 km^2 respectively)	243 showed retreat *(88.68%)* 4 showed no change 27 glaciers advanced Glacier retreat for this basin after 1990 is much rapid.
Bhagirathi *(Gangotri group of glaciers is largest glacier of this basin)*	183 glaciers studied	11% loss in area (During 1962 to 2001 the area of glaciers was 1218 & 1074 km^2 respectively)	117 showed retreat *(64%)* 39 showed no change 27 glaciers advanced Glacier retreat has been slow after 1990 *Adjacent but contrasting trends*
Gauri Ganga (Milam Glacier)	29 glaciers studied	4% loss in area (During 1962 to 2001 the area of glaciers was 272 & 261 km^2)	Most glaciers of this basin show retreat
Dhauliganga	104 glaciers studied	16% loss in area	
Teesta	34 glaciers studied	1% loss in area (During 1990 to 2004 the area of glaciers was 305 & 301 km^2 respectively)	This basin is located at a lower altitude than others and covered with debris.

Table 4 - Assessment of Status of Glaciers in different River Basins of Himalayas			
River Basin	Coverage	Trend in Glacier Area Estimation	Status of Studied Glaciers
There is almost no retreat in this basin. Basins of eastern Himalaya show no or very less retreat than western Himalayas.			
Source: Snow and Glaciers of the Himalayas (Study carried out under the joint project of MoEF and Department of Space), Space Application Centre, Ahmedabad (May 2011); Monitoring done through topographic maps of Survey of India by SAC			



Himachal Pradesh
14319 ft
331 mi
-1.4%
Lahore
region
Chandigarh
115 mi
© 2011 Europa Technologies
Image © 2011 GeoEye
US Dept of State Geographer
© 2011 Google
31°29'02.28" N 78°11'54.01" E elev 14319 ft
Eye alt 478.80 mi
Google
Graph: Min, Avg, Max Elevation: 6775, 11304, 15393 ft
Range Totals: Distance: 515 mi
Elev Gain/Loss: 64054 ft, -66489 ft
Max Slope: 25.4%, -29.4%
Avg Slope: 4.3%, -4.3%
15393 ft
12500 ft
10000 ft
6775 ft
75 mi
150 mi
225 mi
300 mi
331 mi
375 mi
450 mi
515 mi



Schematic image of the glacier margin - lower (southern) indicating elevation range 6775' to 15,393' and upper (northern) with elevation range between 13,704' – 18,772'

3.3 Rainfall

Himalayas also known as the water towers of Asia are a huge source of water for not only the communities living in the mountain region, but also for the rest of Asia, as it feeds ten river basins in the region eg, Brahmaputra, Yangtze, Indus, Ganges etc. Climate change is projected to have severe adverse effects on water availability in the region with overall changes in precipitation patterns. The total amount may increase in some areas and be less in others, leading to water stress and droughts. Precipitation may also increase in intensity with more falling over a shorter time resulting in a higher incidence and intensity of floods in the river basins and a higher proportion of runoff and reduction in groundwater recharge, again reducing storage. When the consequences of climate change are superimposed on the high degree of intra-annual rainfall variability in the region, it is clear that the threat of water scarcity could pose a serious challenge to the approximately 1.3 billion people living in the ten river basins that have their origins in the Himalayas.

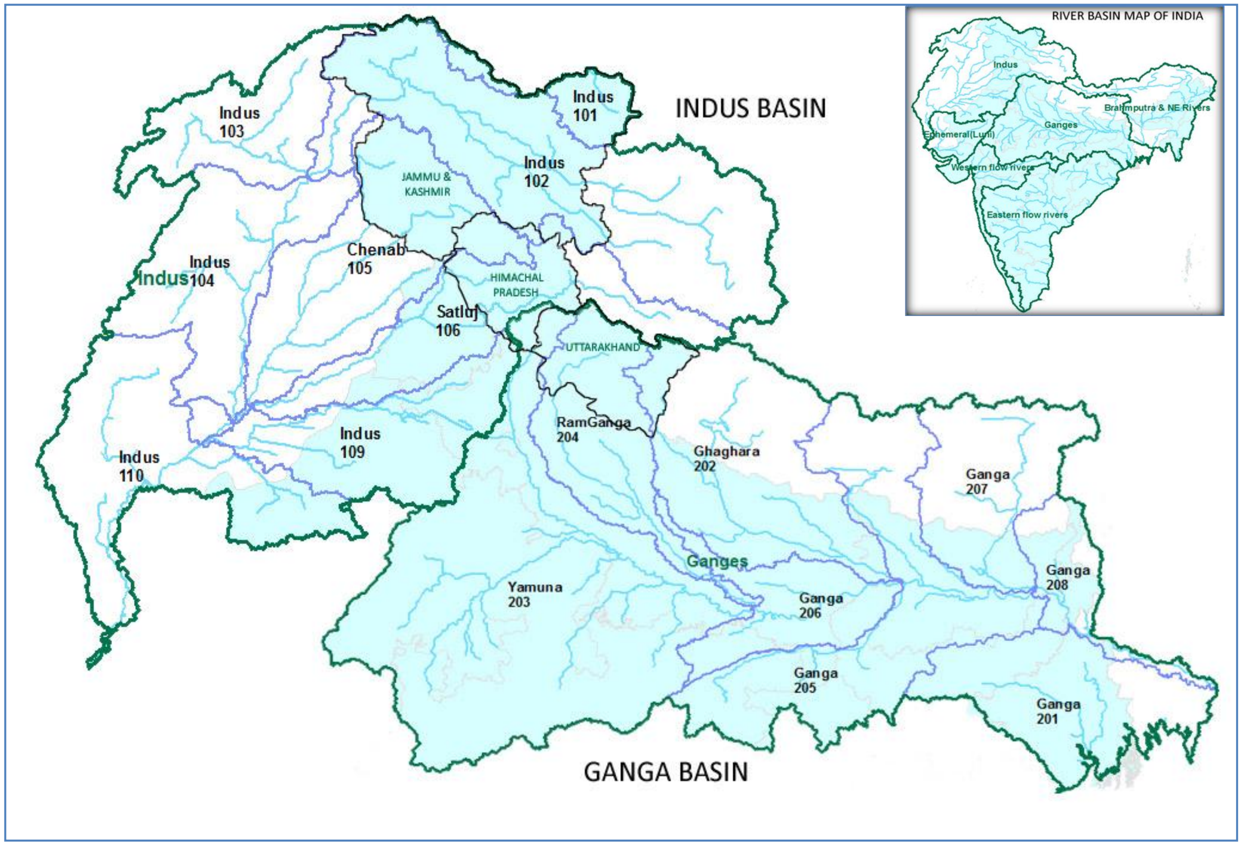
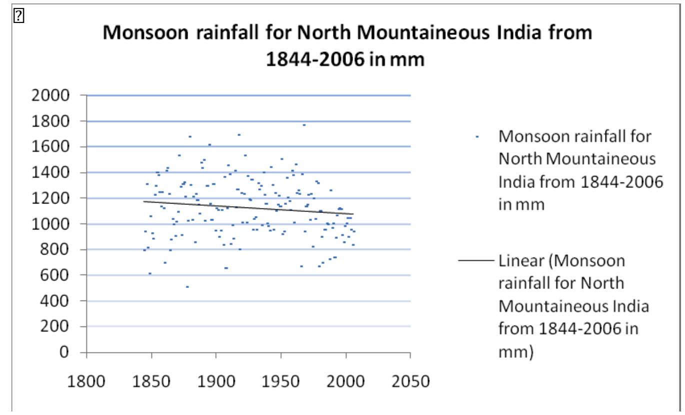


Fig. 1: Map Showing Indus and Ganga Basin. The region is drained by Indus-Chenab System, Chenab-Satluj system of Indus Basin and Yamuna-Ramganga-Ghaghara system of Ganga basin. Source: Hydrological Information System

Rainfall finds an important place in the highly rainfed regions in the Himalayas (in the range of 70-80%) and increasingly erratic weather changes in particular time and space has given hardships to the farming community, impacting the productivity (especially in the mid hills where maximum agricultural land is available) and making farmers more risk prone to such eventualities. The traditional practice of multiple cropping has largely been replaced with single crop owing to market demands and turning towards cash crops, the agricultural diversity is reducing thus adding on to the vulnerability of the hill farming community.



There is a scientific consensus that rainfall in western Himalayas is getting more erratic, but there is considerable disagreement over the duration of monsoon and the amount of yearly precipitation in different locations in the region. Decreasing trend of annual rainfall (-29.7 to -2.1 cm/100 years) has been observed at Srinagar, Shimla, Mussoorie,Mukteshwar and Joshimath whereas increasing trend at Dehradun, Pauri, Nainital, Almora&Pithoragarh (3.8 to 28.7 cm/100 years) has been observed in last century (Borgaonkar et al. 1998).

However, the monsoon rainfall in all of the northern mountainous India (primarily western Himalayas and some part of PirPanjal) has declined by almost 10% between 1844 and 2006.

Table – 5 District wise Comparison of Annual Normal Rainfall with Frequency of Annual Rainfall in District

Districts	Average Annual Rainfall Normals (mm)	No. of Years of Data	Percentage of Cases (years as in Col.III) occurring compared to Rainfall Normals		
			Normal	Excess	Low
Bilaspur	1256.7	37	18.92	40.54	40.54
Chamba	1355.1	35	5.71	37.14	57.14
Hamirpur	1462.6	32	15.63	40.63	43.75
Kangra	1852.3	39	5.13	30.77	64.10
Mandi	1564.6	45	13.33	42.22	44.44
Sirmour	1688.7	46	8.70	47.83	43.48
Una	1209	31	12.90	58.06	29.03

Note: This is based annual rainfall in the District Data for the period 1951-1999 based on the years for which data is available

Source: Compiled from Various District Tables from the Climatological Summaries of States Series – No. 15 (Climate of Himachal Pradesh), Indian Meteorological Department

Table 6 - Frequency of Annual Rainfall in the Districts of Himachal Pradesh

Range in mm	401-500	501-600	601-700	701-800	801-900	901-1000	1001-1100	1101-1200	1201-1300	1301-1400	1401-1500	1501-1600	1601-1700	1701-1800	1801-1900
	LOWER THAN DISTRICT NORMALS								WITHIN DISTRICT NORMALS						
Bilaspur	1	0	1	1	3	2	4	3	7 (1256.7)	2	3	6	0	0	1

Chamba	1	2	2	2	5	1	1	4	2	2 (1355.1)	4	1	3	1	0
Hamirpur	NR	NR	1	0	0	0	3	1	4	5	5 (1462.6)	4	1	3	2
Kangra	NR	NR	NR	NR	NR		3	1	4	3	1	5	5	3	2 (1852.3)
Mandi	NR	NR	1	0	1	0	2	5	2	3	6	6 (1564.6)	4	4	2
Sirmour	NR	NR	1	0	1	0	0	4	4	1	6	3	4 (1688.7)	4	6
Una	1	1	2	4	2	1	4	3	4 (1209)	3	4	0	0	0	0
Total Occurrences	3	3	8	7	12	4	17	21	27	19	29	25	17	15	13

The number of rainy days and the rainfall ranges are presented to indicate the number of occasions of drift from the normal and the extremes of rainfall witnessed in this 48-year period.

Range in mm	1901-2000	2001-2100	2101-2200	2201-2300	2301-2400	2401-2500	2501-2600	2601-2700	2701-2800	2801-2900	2901-3000	3001-3100	3101-3200	3201-3300	3301-3400
	EXCESS THAN DISTRICT NORMALS														
Bilaspur	1	1	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Chamba	1	0	3	NR		NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Hamirpur	1	1	1	NR		NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Kangra	4	4	1	2	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Mandi	1	4	0	3	0	NR	NR	NR	NR	NR	NR	NR	NR	NR	1
Sirmour	4	2	1	0	2	0	1	0	1	1	NR	NR	NR	NR	
Una	1	0	0	0	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	
Total	13	12	7	5	4	0	1	0	1	1	NR	NR	NR	NR	1

- NR is Not Reported or Not Occurred at respective range for a particular district
- Average number of rainy days (days with rainfall of 2.5mm or more)

- Shaded cells indicate Annual Rainfall Normal Value (within parenthesis) falling in that frequency class for a particular District – Frequency class less than this cell represent lesser than normal and more than this cell represent excess than normal

Table – 7Rainfall in Recent Years and Variations from the Normal								
District	2006	2007	2008	2009	2010	Normal	Excess	Low
Bilaspur	1348	1250.7	1298.7	1029.1	1069.7	1	2	2
% to District Normal	107.265	99.5226	103.342	81.8891	85.1198			
Hamirpur	1591.3	1416.6	1418.7	1162.8	1246.4		1	4
% to District Normal	117.43	104.538	104.693	85.8092	91.9785			
Kangra	1766.6	1610	1805.3	1209.9	1611.2			5
% to District Normal	120.785	110.078	123.431	82.7225	110.16			
Mandi	1265.2	1472.3	1300.5	965.2	1483.6			5
% to District Normal	80.8641	94.1007	83.1203	61.6899	94.823			
Sirmour	1378.2	1276.3	1422.1	974.9	1903.9		1	4
% to District Normal	81.6131	75.5788	84.2127	57.7308	112.744			
Una	1308.5	1244.3	1471.5	1212.2	1182.3		4	1
% to District Normal	108.23	102.92	121.712	100.265	97.7916			

This indicates that the rainfall has varied from the normal in most cases in the recent past.

2.4 Extreme Weather Events – The case of Cloudbursts

Extreme weather events leading to cloudbursts are a phenomenon known in the Himalayas and have devastating consequences. The following table is a compilation of reported cloudbursts which indicate the huge vulnerability to the communities.

Table – 8 Cloudbursts in Recent Times							
S.No.	**Location**	**Villages / Place**	**Loss of Life**	**Missing**	**Injured**	**Extreme Event**	**Date of Event**
HP	Chirgaon		200			Cloudburst – splash of water broke Andhra River banks and ran through Chirgaon	16.08.1997

HP	Gursa area of Kullu Sub Division	Shillagarh, Rauli (bridge at beas)	40	25	30		17.07.2003
UKD	Badrinath Shrine	Lambagad close to Vishnuprayag	17		18	Cloudburst triggered landslide	24.07.2004
HP	Sangla Valley, Kinnaur	Ghanvi					16.08.2007
HP	Sirmour	Sadhauara bridge				Bridge lost cutting business linkage	16.08.2007
HP	Sirmour	Rajgarh Tehsil				building damages	03.06.2008
HP	Kullu	Manikaran				Bridges, vehicles, machinery and other equipments at the under construction Parbati Hydro Electric Project have been washed away.	08.07.2010
J&K	Leh	Choglamsar, Saboo, Phyang, Nimoo and Shapoo	>200		1000's		06.08.2010
UKD	Munisyari, Pithoragarh	La, Gherna, LeluNahar	30	50		Heavy downpour, triggering landslide	18.08. 2010
UKD	Bageshwar	Kapkot	18 – 20		>30		19.08.2010
HP	Kullu	Tharaman village					23.08.2010
HP	Sangla (Kinnaur)	KaamruNala and BarangNala				Over 50 bighas of agricultural land and apple orchards were washed away but no loss of life was reported	24.09.2010
HP	Chamba	Udaipur					01.06.2011
J&K	Doda	Assar-Baggar Region	3				09.06.2011
HP	Mandi	Dhundi area	8		22	Labourers trapped during construction of a snow gallery to connect the Rohtang tunnel	21.07.2011
HP	Mandi	Manjhainalah near Athamille area					06.08.2011

HP	Pandoh (Mandi)					Flash flood in SambhalNallah triggered by cloud burst in Balidhar forest range (uphills)	06.08.2011

2.6 Other Special Weather Phenomena

There has been an increasing trend in hailstorms. Hailstorms could be extremely destructive depending upon the specific period of the event. There is increasing evidence of hailstorms affecting the horticulture as well as agricultural crops. In higher altitudes when hailstorms hit in the flowering season many fruit yielding trees bear very little fruit and in the season of ripening they injure the fruit reducing its market value considerably.IMD (Indian Meteorological Department) observations show that events of extreme rainfall have increased by 50% during the past 50 years. Most extreme events since weather record keeping starting in 1850s have been noticed in the last decade.

The response of state has been to procure anti hail guns to disperse the hail and minimize the damage but it is still to be ascertained as to how far such hazard management measures safeguard the farming community in the hills. The table below is indicative of mean number of days when such weather hazards occur during a year and more details of the specific impacts on land based production systems are analysed across the region. It is significant that the implications are spread across the various physiographic zones and is diverse and complex.

Table – 9 Special Weather Phenomena (Mean no. of Days)

District	Thunder	Hail	Dust Storm	Snow	Fog
Bilaspur	18.8	0.8	1.9	0	19.4
Chamba	17.7	0.4	0		0.5
Dalhousie	10.5	3.1	0.4		9.5
Kangra	44.2	0.1	0.1	2.7	0.8
Kullu (Manali)	1.7	0	0	0	0.5
Kullu (Bhuntar)	61.9	2.9	0.2		1.2
Mandi	17.9	0.3	2.6	0.1	15.3
Mandi (S'nagar)	80.7	2.8	2.4	0.2	23.1
Shimla	14.4	2.7	0.5		3.6
Sirmour	2.2	0.3	0.3	0	1.2

Source: Compiled from Various District Tables from the Climatological Summaries of States Series – No. 15 (Climate of Himachal Pradesh), Indian Meteorological Department

Flash floods are one of the most common forms of natural disaster in the Hindu Kush-Himalayan (HKH) region. They consist of a sudden and very strong surge of water, usually along a riverbed or dry gully, which can carry rocks, soil, and other debris. Whereas 'normal' riverine floods can to some extent be predicted, offering opportunities for preparation and avoidance, flash floods are sudden, usually unexpected, and allow little time to react. Individual flash floods may last from several minutes to several days and may happen anywhere, but are more common in mountain catchments. Although flash floods generally affect smaller areas and populations than riverine floods, their unexpected and intense nature means that they pose a significant risk to people and infrastructure, leading to death and destruction. The Himalayan region is particularly vulnerable to this type of flood as a result of the steep slopes, high rate of surface erosion, and intense seasonal precipitation, particularly during the summer monsoon in the central and eastern Himalayas and in winter in the western Himalayas. Changing watershed and environmental conditions (including climate) are increasing this vulnerability.

Flash floods can be caused by a variety of factors. The main direct causes in the Himalayan region are intense rainfall events, landslide dam outbursts, glacial lake outbursts, rapid melting of snow and ice, sudden release of water stored in glaciers, and failure of artificial structures such as dams and levees. Most flash flood events take place in remote, isolated catchments where the central government's reach is limited or non-existent.

Livelihood stress due to decline in water sources

Ujagar Singh from village Deedbagad in Sirmaur District of Himachal Pradesh had installed gharat (water Powered Mill) in early 1980's to grind grains (wheat, maize, jowar and Millet,etc). His gharat has stopped working for last few years as the stream, which is used to power the turbine, is reduced to a trickle indicating reduced and erratic precipitation pattern. According to Ujagar ji, his land is indicated as irrigated in revenue records but in reality he is forced to do rain fed farming because most of the mountain streams have receded due to continuous decline in the amount of rainfall in last decade.

Table –10 Vulnerabilities and Impacts on Land Based Production Systems in the Himalayas

Crop (Value & Food Security)	Popular Belts / Eco Regions	Scale	Fragility	Remarks / Quotes
Apple	Grown in Mid to high hill climates. Fruit belts in Shimla, Kullu, ChambaKinnaur, Sirmour and Mandi districts	Apple farming extends to over 1 lakh hectare and forms almost 45 – 50% of the land under fruits. The total fruit production in the state during 2007-08 was 712 million tonnes, out of which apple production was 592 million.	During July 2009, over 30 per cent crops at heights between 4000ft to 5500 ft were damaged due to hailstorm.	As per government, almost 900 crores worth of crop is lost over the last three years. Kothgarh-Thanedar is one of the prominent apple growing belts in District Shimla which is severely impacted this year. Cherry, pear and peach are also affected.
Apple		Dry season in the valley is progressing has created a disturbance in the sowing and growth of different	The period when chilling temperatures are required for the crop, Kullu region observed dry cold wave.	*There is still no evaluation on the estimation of 1^0C increase in temperature in Himalayas as to what additional resources*

Table –10 Vulnerabilities and Impacts on Land Based Production Systems in the Himalayas				
Crop (Value & Food Security)	**Popular Belts / Eco Regions**	**Scale**	**Fragility**	**Remarks / Quotes**
		crops and will also severely affect the fruit crops if the trend continues		*will be compromised like water, crop area, forest fires etc.*
Replacement for Apple		Farmers in Himachal Pradesh are moving from cultivation of traditional crops like apples to growing the more exotic nectarine. Nectarine can grow at low altitudes.	Nectarine cultivation has proved to be a better source of income, as the yield is good. *This suggests a kind of adaptation measure by planting the exotic species from USA*	With the expansion of other horticulture crops like cherry, kiwi, apricots, strawberry, olive, almonds and plums is targeted to replace vulnerable crops like apple which is by far the major contributor of horticultural produce (>80%)
Replacement for Apple	High reaches of Shimla, Kullu, Mandi, Chamba, Kinnaur and Lahaul and Spiti are ideal for cherry cultivation Cherry (flowering March-April)	As per horticulture department estimates, at least *10,000 farmers*, most of them with small land holdings, grow cherries over an area of *374 hectares*. The areas are more prone to weather uncertainties like erratic rainfall, hailstorms and even long dry cold spells.	Explaining the rationale for opting for cherry cultivation, Dogar said fruit required less care than apple and fetched almost the same price. 'A 20 kilogram box of apples on an average sells for Rs.400, whereas cherry fetches anything from Rs.200-Rs.300.'	It is estimated that the annual fruit industry is worth about Rs.2,000crore. Dwindling production continues - Himachal Pradesh produced 453 tonnes of cherry in 2008-09, though it was higher in 2007-08 - 698 tonnes
Kiwi	Shimla, Kullu, ChambaKinnaur, and Mandi districts	Four different varieties of Kiwi fruit being cultivated in the hilly state (Hayward, Monty, Bruno, Allison)	Subsidies given 22,000/hectare & export to megacities in India	High export potential but is not a usual staple crop

Table –10 Vulnerabilities and Impacts on Land Based Production Systems in the Himalayas				
Crop (Value & Food Security)	**Popular Belts / Eco Regions**	**Scale**	**Fragility**	**Remarks / Quotes**
Oranges		Due to the change in weather, we are facing a lot of problems from the last eight to ten years. It's not raining on time because of which the plants are getting dried. The orange cultivation in this area is almost finished," said Ramesh Pathania, an orange grower	The orange is grown in over *25,000* hectares of land in the State. Out of this, 80 percent cultivation is done in Kangra valley.	
Strawberries	Sirmour in the temperate zone accounts for 90% of the estimated production in the state of Himachal Pradesh.	Prominent belt along Poanta – DhaulaKuan but it is also grown in lower/mid hills of Kullu, Kangra, Una and Shimla.		High value crops are taking a leap forward and most of them find markets outside the state.
Crop	**Popular Belts / Eco Regions**	**Scale**	**Fragility**	**Remarks / Quotes**
Off Season Vegetables	Shimla, Solan, Sirmour, Kullu, Una and Kangra (off- season vegetables - cabbage, cauliflower, peas, tomato etc.).	Between April to June, cauliflower is grown in Theog and Matiyana areas of Shimla and tomato is grown in Solan district of the state. Solan belt is popularly known as the area of Red Gold because of its tomato production	Off-season vegetable production, which was nearly 34-35 thousand tons earlier, has now increased to 10 Lakh tons	Farmers are increasingly looking forward to off season vegetables as these fetch high prices when the production period is over elsewhere.

Table –10 Vulnerabilities and Impacts on Land Based Production Systems in the Himalayas				
Crop (Value & Food Security)	**Popular Belts / Eco Regions**	**Scale**	**Fragility**	**Remarks / Quotes**
Vegetables		The drought like situation in Kandaghat area of Himachal Pradesh has damaged a major area of vegetable crops.Over 60 percent of the crops have been damaged, delaying the transplantation in the area.	tomato, capsicum, brinjal and cauliflower and our economy depends on these vegetables	However, there has been an increase in vegetable cultivation area from 25,000 hectares to 50,000 hectares in the state during the last few years.
Wheat and Cereal Crops	This temperate mid zone occupies approximately 32% of geographical area and 37% of cultivated area (Himachal Pradesh) and ranges from 650 m – 1800 m which means 5-6 Himalayan Districts *(refer table above).* This belt is also good for cash crops like off season vegetable, ginger and high quality seeds.	As per National Wheat Research Centre's analysis a long dry spell affected the wheat crop in the lower hills. Now, heavy rain accompanied with hailstorm and high velocity winds is flattening the ripe wheat crop.'	He said as per preliminary estimates, the yield of the wheat this year is expected to fall 20-30 percent due to hostile weather at the time of harvesting. About 81 percent of the total cultivated area in the state is rainfed. Rice, wheat and maize are the important cereal crops	The uncertain weather patterns have kept the farmers guessing and there is no adaptative measure as this is a rainfed area and bringing in other crops would mean more investments and also know how. Ginger is grown in Kadukhal (district tehri), *Ginger production in HP rose to 21,267 tonner in 2010-11 which is an increase of over 6000 tonner from the previous year*

Table –10 Vulnerabilities and Impacts on Land Based Production Systems in the Himalayas				
Crop (Value & Food Security)	**Popular Belts / Eco Regions**	**Scale**	**Fragility**	**Remarks / Quotes**
Forest Fires	As reported in 2009, the meteorological office (HP) stated that the mean maximum and mininimum was 1 – 4^{0}C above average.	In 2009 alone, over 650 incidents of forest fires were reported from Shimla, Solan, Sirmaur, Bilaspur, Mandi, Kangra, Hamirpur, Una and Mandi districts whereas the number was 572 in 2008. Fires could break out due to the long dry spell and unprecedented hot weather. It is estimated that around 7900 hectares of forest land has been destroyed due to unprecedented fires.	In a report by Council for Science, Technology and Environment, there are 447 reported species in Himachal (out of 1228 reported species in India). Similarly, 77 species of mammels (snow leopard to Himalayan Tahr) are found here. The storehouse of biodiversity also supports 3,120 species of flowering plants, including 187 species of medicinal plants	Looking this from the backdrop of biodiversity, which is quite rich in this Himalayan State, the results coupled with this factor (forest fires) may also displace or force migration to other regions. E:g Himachal is home to 36% of country's bird species.
Source: Compiled from archives of News Items and Reports (largely pertaining to Himachal Pradesh) by Environics Trust *Note: Remarks by Environics Trust with Quotes from News items*				

3.7 Irrational Development Activities

A number of irrational development activities are exacerbating the vulnerability of the communities and also causing a huge discontent among the local communities. There are a number of such situations where people have been showing resistance and the State and the economic powers are pushing towards this form of development. A small selection of the spread and nature of activities indicates that hydropower, mining and forestry significantly increase the risk to the communities.

Table 11: Irrational Development Activities			
State	Districts	Predominant Altitudinal Profile	Irrational Development Activities
UKD	Udham Singh Nagar	150 - 300m	Distilleries and Other industries

UKD	Haridwar	150 – 600m	Industries (IEE), Stone Crushing
UKD	Champawat	900 – 1800m	Mining, Deforestation
UKD	Nainital	300 – 600m , 600 – 900m	Industrial belts, Urban Centre
UKD	Dehradun	900 – 1800m	Industrial estate, Urban Centre
UKD	Almora	900 – 1800	Mining
UKD	Pitthoragarh	> 4500m, 900 – 1350m & 1800 – 3000m	Mining, HEPs
UKD	Bageshwar	1800 – 3000	Mining, HEPs
UKD	Chamoli	4500 – 6000, 3000 – 4500 & 1350 – 1800m	Mining, HEPs
UKD	Rudraprayag	1350 – 3000m, 3000 – 4500m	HEPs
UKD	Uttarkashi	4500 – 6000m, 3000 – 4500m, 1350 – 1800m	HEPs
HP	Una	300 – 600m	Industries
HP	Hamirpur	300 – 900	Industries
HP	Sirmour	Shivalik & Mussourie Range – 300 – 600m & 1350 – 1800m	Mining in 2 blocks, Industrial belt in Paonta
HP	Bilaspur	300-900m	Cement Plants, Bhakhra's Govind Sagar Reservoir, River Bed Mining
HP	Solan	300 – 600 & 1350 – 1800	Mining & cement, Industries, Urban Centre, River Bed Mining, Industrial Hubs (Kala Amb, Baddi)
HP	Mandi	900 – 1800	Cement, Industrialisation on pick
HP	Kangra	600 – 900	HEPs
HP	Chamba	1800 – 4500	HEPs
HP	Kinnaur	1350 – 3000m, 3000 – 6000m	HEPs
HP	Kullu	1350 – 1800	HEPs
HP	Lahaul & Spiti	Lahut Valley, Sarchu Peak (5741m), Chenab Sub Basin, Mulkila (6417m)	Tourism
Compiled by Environics Trust			

We briefly explore hydropower and forestry aspects.

The Case of Hydropower

Himalayas are understood to be the large storehouse of hydro power. The intensity and the manner in which projects are being constructed and under consideration indicate that the ecosystems are significantly disturbed and would add to the vulnerability. Several projects on the same stream disobey the very principle of natural resource services by making the river non-functional and tend to challenge the local climate profiles. Environmental flows for instance has been arrived at by fixing a certain percentage of the average seasonal flow but it does not justify the environmental needs of living beings in its catchment or dependent on it. Another issue is of reservoirs created induces anaerobic decomposition of biomass in absence of oxygen[1] thereby producing methane gas which stays longer in the environment and traps heat and has a Global Warming Potential (GWP) of 25 times than CO_2. Accumulation of organic matter and no possibility of fish to live, coupled with increasing average temperatures, raises the per unit emissions of GHGs. With proximity to the glacial environment, the vulnerability increase manifolds in terms of faster rate of melting thereby sometimes imposing flood conditions and depletion of ice with thinner stock or ice sheets for the lean periods.

A glimpse through few of the hydro electric projects would indicate that these projects are being built across the landscape, right from the lesser to middle to higher Himalayas (3800 m) and a sample of 35 such projects show that almost 80% have reservoirs or storage component.

Table 12 A selection of hydroprojects indicating implications in different altitudes

Sl. No.	Project Name	Catchment sq.km.	Installed Capacity MW	Altitude	Tail Race Tunnel	Head Race Tunnel	Diversion Tunnel	Reservoir	Submergence
1	Kotlibhel H.E. (Stage-II)	21375	440	390	1975	810	380	yes	
2	Kotlibhel H.E. (Stage-1B)	11453	280	670	1520	280	445	yes	
3	Kotlibhel H.E. (Stage-1A)	7887	240	680	252	165	425	yes	
4	KalikaDantu H.E.	3385	230	730	130	5.2		yes	46
5	SingoliBhatwari	650	60	760					
6	KhartoliLumtiTalli H.E.	1855	55	920	220	1000	705	yes	80
7	Baram small hydel scheme	75	1.5	975					
8	Chunni Semi	600	24	1080					
9	RupsiabagarKhasiyabara H.E.	1235	260	1200	45	7220	715	yes	22.4
10	Gohana Tal H.E.	211	60	1200	940	9000	280	yes	24.6
11	Phata-Byung small hydel scheme	133	10.8	1240					
12	Jimbagad small hydel scheme	95	7.7	1300					
13	Devsari H.E.	1115	300	1320	1080	7370	450	yes	522
14	GarbaTawaghat H.E.	1367	630	1440	268	13150	760	yes	14.6
15	Birahi ganga small hydel scheme-	214	5.6	1476					

[1] http://www.sciencedaily.com/releases/2010/10/101011090139.htm&http://www.internationalrivers.org/climate-change/reservoir-emissions/reservoir-emissions-excerpt-silenced-rivers

Table 12 A selection of hydroprojects indicating implications in different altitudes									
Sl. No.	Project Name	Catchment sq.km.	Installed Capacity MW	Altitude	Tail Race Tunnel	Head Race Tunnel	Diversion Tunnel	Reservoir	Submergence
	II								
16	Gaurikund small hydel scheme	65	18.6	1600					
17	Urthing-Sobla	1063	280	1762		4150		yes	36
18	Rambara-Gaurikund	65	24	2040					
19	Karmoli HE	1605	140	2160	600	8600	350	yes	9.94
20	Bogudiyar-SirkariBhyol H.E.	935	170	2160	280	2350		yes	19.43
21	Rishi Ganga-II	680	35	2240	300	3240	230	yes	1.66
22	SelaUrthing H.E.	921	230	2240	30	2010	300	yes	15.72
23	Rishi Ganga-I H.E.	599	70	2320	706	3310	350	yes	6.2
24	SirkariBhyolRupsiabagar H.E.	1160	210	2320	370	800	550	yes	12.8
25	JelamTamak	1510	60	2420	320	5700	250	yes	13.9
26	Harsil H.E.	3235	210	2480	280	5060		yes	91.56
27	MapangBogudiyar H.E.	829	200	2720	300	3520	480	yes	24.2
28	Bokang Baling H.E.	691	330	2750	295	9400	490	yes	132.5
29	MalariJelam H.E.	1343	55	2760	816	4500	240	yes	10.45
30	BhaironGhati HE	2660	65	2800	190	5100	500	yes	13.27
31	ChhungerChal H.E.	850	240	2800	147	3545	530	yes	13.2
32	Badrinath H.E.	1265	140	2920	340	2840	300	yes	3.74
33	Jadhgana H.E.	1679	50	2960	290	1100	400	yes	8.35
34	Gangotri H.E.	944	55	3160	450	5200	400	yes	24.96
35	Deodi H.E.	544	60	3240	1030	4800	300	yes	5.6
Source: Rational Energy Development in Uttarakhand, Environics Trust (2005-06)									

Run of the river schemes, which are meant to allow the free flow of river, are not the types being implemented in the Himalayas. It is actually a misnomer. These are still storage based diversion schemes where water is diverted through a head race tunnel (HRT), these schemes have resulted in kilometers of river stretch going dry. CH_4being a much more potential harmful gas, the current scheme of things need a cumulative assessment and rethinking on rationalization of energy as these schemes have high natural resource diversion potential i.e. farming land and forest land directly impinging over the rights and livelihoods of the population directly involved in collection, land based activities and chain of such activities dependent upon them.

Issues around Afforestation and Deforestation

Compensatory afforestation being the counter measure for replacing (& displacing or decrease in the carbon stock) the carbon sink hits hard on rights of people in one sense and make them vulnerable to seek other options of livelihood security in another sense. Natural forests once replaced could never be brought back with same value and quality and promotes monoculture which works commercially but not socially, the vulnerability further rises for the people and for the species. The relentless rise of man-animal conflicts is indicative of this reducing space for communities and wildlife. While the communities loose their forests and grazing lands, the net present value (NPV) of forests on account of diversion goes to the state treasury.

Table – 13 Forest Area Diverted for Non-Forest Purposes

	No. of Cases Approved	Area Diverted (Ha)	Proposals for 0 - 5 ha		Proposals for 5 - 10 ha		Proposals for 10 - 20 ha		Proposals for 20 - 40 ha		Proposals for >40ha	
			No. of Cases	Area Diverted	No. of Cases	Area Diverted	No. of Cases	Area Diverted	No. of Cases	Area Diverted	No. of Cases	Area Diverted
UKD	3493	62627	3071	3337	202	1459	108	1465	32	851	80	55515
HP	1240	11131	1046	1657	58	406	42	620	34	939	60	7509

Note:

1. In case of Himachal Pradesh, >60% of forest land diversion took place on account of Hydro Electric Projects and Transmission Lines alone followed next by Roads (18%) and Mining (8%). Another fact is that large chunks of forest i.e. >40 hectares formed the major diversion category in terms of area. Out of total diversion, 67% formed this category (see last column)
2. In case of Uttarakhand, the case of diversion of large forest lands (>40 hectares) is much more i.e. 89% but this is a cumulative assessment including Uttar Pradesh.
    a. As per the Forest Department, the forest area diverted for non-forest use (from year 09.11.2000 – 31.03.2010) is 15,072 hectares. Almost 20% of the area is diverted for Hydro Electric Projects and Transmission followed by Roads (29%) and mining (26%)

Source: Table A19.2, Indian Infrastructure Report 2009, 3i Network; State of Environment Report, 2004, Environics Trust & Forest Statistics, Forest Department, Government of Uttarakhand (2009-10)

The situations, which are of concern relate to regions that are naturally fragile, regions which have had to face up the challenges of inappropriate development regimes and communities which perceive a lack of mainstream concern. These have to be particularly kept in mind in identifying future action in specific areas. Briefly they are:

4.1 Nature Determined Environmental Fragility

1.Transient Environments

The periglacial regions where the geographical evolution of glacial environments into fluvial environment is currently taking place is a region, which is prone to avalanches, landslides and rapid change in surface morphology. As the glacial recession is taking place perhaps at a faster pace such eventualities should be kept in mind.

At a more localized level the paleo-slides which have been put to human use and their history forgotten would also be sites where the natural processes would find equilibrium and this will affect some communities.

2. Transitional Environments

The varied geographical situations brings about several transitional environments which are prone to dramatic changes with small triggers often beyond the resilience of the systems such as between Bhabhar-Terai, glacial margins etc.

3. Tectonically Unstable Environments

The regions along the major thrust and fault belts are intrinsically unstable and will be continually prone to impacts from **seismic events**, small or large.The possibility of human intervention to avoid impacts in these zones is minimal and the best effort would be to understand them in greater detail and address situations where it may snowball into a crisis.

4.2 Inappropriate Development Regimes

1. Denuded Areas

A number of areas are affected by denudation because of past processes of inappropriate development or neglect such as several areas where mining has degraded the slopes or altered river regimes.The huge costs and time for recovery is well known from the experience of mining in Doon Valley.

2. Largely Modified Environments

The region where dam iand power projects are built and the submergence zones have significantly altered the local geography and meteorology and lead to different kinds of problems to be faced. Large tracts have also been allowed for mining especially of limestone and ubiquitously of river bed materials. The urbanization across the mountains is also impacting local climate regimes.

4.3 Lack of Mainstream Concern Perceived by Communities

1. Subsistence Environments

Regions in the rain-shadow areas, isolated valleys and forest villages where the communities have to precariously manage their existence need particular concern and attention than regular process can support.

2. Discontented Environments

At every period in history there are communities, which are discontented with the ongoing social dynamics particularly when they find themselves helpless and the mainstream is unconcerned about their core problems. The communities who are being involuntarily forced to give up their land and other resources for the power projects, mines and other purposes are constantly struggling. The cut-off zones of reservoirs such as Pratapnagar block which has become really more isolated with the coming up of the Tehri reservoir and the mindless restrictions placed on travel in some parts of the region are making these communities extremely discontented. So is the case with people within or the periphery of the Protected Areas.

5.0 REDUCING RISKS DUE TO CLIMATE CHANGE

Vulnerability due to climate change has been defined as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change such as climate variability and extremes. (IPCC 2007). In case of Himalayas, most communities are highly depended on the natural resources that are sensitive to the changing climate, and therefore are highly vulnerable to climate change.

Risks due to climate change = Vulnerability to climate change – resilience of a society towards these impacts – adaptive capacity of the society.

Vulnerability here is a function of exposure to the impacts of changing climate and sensitivity to these impacts

In this case, resilience can be explained as the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (www.resalliance.org). Likewise, adaptive Capacity is the ability of a system to adjust to climate change, to moderate potential damage, to take advantage of opportunities, and to cope with the consequences (IPCC 2007).

In order to reduce the risks due to climate change, a three pronged approach needs to be followed in which vulnerability needs to be reduced and resilience and adaptive capacity of the society needs to be improved.

A. **Reducing Vulnerability -** The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.

1. Crop insurance

Crop insurance is a financial risk reduction tool for safeguarding farmers against crop losses due to natural calamities and hazards.It is a service that is usually purchased by agricultural producers, including farmers and others to protect themselves from losses caused by natural calamities and fall of revenue due to declines in the prices of agricultural commodities. This instrument has been already tested in India with a fair degree of success and is currently implemented under the name of National Agriculture Insurance Scheme (NAIS). Agriculture Insurance Company of India, an Indian government-owned company, is the implementing agency the scheme is compulsory for all the farmers who take agricultural loans from any financial institution. It is voluntary for all other farmers. The premium is subsidized for small and marginal farmers.

Crop insurance can be of enormous help for communities living in Himalayas, as most of them are directly dependent on agriculture for their livelihood and are at great risks against climate variability and change. With the help of agriculture extension services and a network of civil society organizations, such instruments could be available to most farmers in the region. Though this instrument will not increase the yield or profitability in a normal year, it will surely reduce the burden of failed crops in case of a natural hazard and calamity.

2. Early warning system

The Himalayan region is one of the world's most complex, dynamic, and intensive hotspots in terms of risk from natural hazards including earthquakes, floods, landslides, droughts, and wildfires. It is a region of fragile ecosystems that are very sensitive to changes in climatic conditions and exceptionally vulnerable to natural hazards. Examples of recent disasters in the region include the earthquake in Sichuan, China; cyclone Nargis in Myanmar; the outbreak of the Koshi barrage embankment in Nepal; and the 2010 floods in Pakistan. They all serve to remind us of the devastating and catastrophic effects natural hazards can have on the lives of people in this region.

A voluntary initiative led by the APRSAF (Asia-Pacific Regional Space Agency Forum) to support disaster management in the Asia-Pacific region using web-GIS technology and space-based technology such as earth observation satellite data. Currently, five countries -- Japan, India, Thailand, Taiwan, and Korea -- are providing earth observation data to Sentinel Asia members during major disasters. In the Himalayan area, Internet services are limited and access to satellite data can be difficult, therefore Sentinel Asia uses local mirroring and transfers data from the Japan Central Server to users' local mirrored servers, not only via the Internet but also using the communications satellite JAXA WINDS (wide-band Internetworking engineering test and demonstration satellites 'KIZUNA'). The WINDS system can transmit at 155 Megabytes per second using the WINDS satellite (AmarnathGiriraj and BasantaShrestha, 2011). When a Country/region in Himalayas asks for support in an emergency situation, Sentinel Asia provides appropriate products through JAXA receiving system to its nodal agency ICIMOD (a regional knowledge centre based in Nepal), which process the data and forwards it to the concerned governments.

In order to protect people from such catastrophic events, there is an urgent need to have comprehensive disaster management units that has access to satellite data. In this regard, earth observation data facilitate the monitoring of an event as a disaster unfolds and can provide vital information and services for disaster management. Earth observation satellites provide comprehensive and multi-temporal coverage of large areas in real time and at frequent intervals, which can be used for detailed monitoring, damage assessment, and long-term relief management. However, a system is needed to provide rapid access to earth observation data in a usable form to those on the ground during an emergency.

3. Flash flood prevention

When flash floods strike, external help may take several days to reach affected communities, during which time they are left to cope on their own. Technological advances and institutional arrangements for disaster risk management are gradually improving in the Himalayan region, but this process takes time. In areas where flash floods can be expected, it is essential to build the capacity of communities to manage the risks from disaster by themselves. Individual households usually have strategies in place, but the effectiveness of these individual efforts can be enhanced manyfold if they are coordinated. As Himalayan communities face such events on a regular basis, there is plethora of indigenous knowledge that can be used to create a community-based flash flood risk management plan.

It is difficult to predict the exact location, magnitude, and extent of most flash floods, thus it is rarely useful to carry out large-scale structural measures like building of embankments, dams, and levees. But there are many non-structural measures that can help to reduce the impact of floods, ranging from land use planning, construction codes, and soil management and acquisition policies, through insurance, awareness raising, public information, and emergency systems, to post-catastrophe recovery plans. Such non-structural measures are generally sustainable and less expensive. Small-scale structural measures like check dams, small-scale levees using local materials, and sand bag embankments can also be useful. The best solution is usually a combination of small-scale structural and non-structural measures (Arun B Shrestha, 2010)

4. Managing water resources

To understand the potential of water storage for climate change adaptation in the Himalayan region, it is necessary to look at the natural storage systems in the cryosphere and the biosphere, as well as examining constructed systems. The natural systems in the cryosphere include snow, ice, and the glacial lakes. The natural systems in the biosphere include soil moisture, groundwater aquifers, and natural water bodies and wetlands. The constructed systems include artificial ponds and tanks, as well as small and large reservoirs. In addition, there are constructed systems designed to augment existing natural storage, like groundwater recharge systems, bunds, and temporary runoff collection areas. A comprehensive ecosystem framework is needed to explore the potential and opportunities at the river basin level holistically. Different types of natural and artificial storage systems are discussed in the following.

Ice and Snow: Glaciers, ice-fields, and snow packs provide important intra- and inter-annual water storage facilities. Snow can store water for anything from hours to years, but perhaps most important is its storage on a multi-monthly basis, thereby retaining water from the wet to the dry part of the year. Glaciers are also crucial. A glacier is a complex physical feature in which water as a liquid can be stored on, in, under, and adjacent to the ice. Water can be stored in a glacier as snow, firn (perennial snow), and ice, thereby delaying the release of water from the glacier by anything from hours, to days, weeks, months, years, decades, or even centuries.

Thus, both snow packs and glaciers provide important water storage facilities in the greater Himalayan region. However, the contribution of meltwater from snow and ice to the rivers of the greater Himalayas still needs to be understood much better. In general, the relative contribution is larger in the west, for example in the Indus and Amu Darya basins, while in the east where large parts of the meltwater coincide with abundant runoff derived from monsoon precipitation, meltwater contributes a relatively smaller proportion.

In order to cope with changing climate we need to fill the current knowledge gap in understanding the response of glacier systems to climate change. There is an urgent need to develop and institutionalize glacier mass balance monitoring schemes exchange information on glacier research and monitoring.

Natural Wetlands: There are around 665 sq.km of wetlands within the Himalayan region, which soak up the snow and ice melt-waters of the Himalayas, and release them steadily to the streams that feed rivers. This helps to regulate flow and prevent flash floods that could endanger the livelihoods of people living downstream.

Additionally numerous glacial lakes have formed in the Himalayan region due to the retreat of valley glaciers in recent times. According to an estimate, there are 8790 glacial lakes with a total area of around 800 sq.km, in Bhutan, Nepal, and selected areas of China, India, and Pakistan. These lakes may also have the potential to be used to increase water storage capacity, provided appropriate technology is available to mitigate GLOF (glacial lake outburst flood) risks. We need to explore the range of mitigation measures that could be taken against potential GLOFs along the lines of the initiatives in the Andes in South America, to make such water-harvesting safe.

The current state of knowledge in regards vulnerability of natural wetlands is minimal and this gap needs to be filled by extensive research of the wetlands in the region. Institutions in the region need to collaborate with the civil society organizations and communities to create mechanisms in which communities could participate in such research studies and provide indigenous knowledge towards wetland conservation. A mechanism in which downstream user rewards the upstream communities for wetland conservation and management could lead to proper conservation of the wetlands.

Watershed management

Soil moisture plays a vital role as a natural system of water storage. For soil moisture, the frequency and intensity of rainfall are at least as important as the total amount of precipitation. Watershed management, through improved land cover and water conservation practices, can help to maintain soil moisture and support rainwater harvesting. It could play a crucial role in improving infiltration so that groundwater percolation can be increased to help aquifer recharge. This is often achieved by low tillage farming and mulching in farmlands and by increasing humus on topsoil in forests. Additionally, surface water runoff can be stored in built structures such as ponds and tanks, which is an age-old practice in the region. Therefore, there is a need to study the traditional institutions of water storage management, which is likely to bring valuable information on watershed management. As there is already rich knowledge available with the community on this issue, an approach based on participation of community members and local civil society organizations is likely to succeed in creating sustainable watershed.

Groundwater Aquifers

Ground water aquifers are natural sources of water, which gets recharged during rains, and provide water during the dry spells. They act as the lifeline of the mountain communities by providing much needed water for drinking and agriculture during dry spells and therefore many of the villages are situated near to an active aquifer. However, in recent times, due to changing climate and mismanaged developmental activities the flow of water in most of the aquifers is going down and some only provide water during the rains (when it is not needed). Saving aquifers is of paramount importance in reducing communities' vulnerability in Himalayan region.

In order to protect aquifers there are several traditional steps that could be undertaken like planting broad leafy tress (e.g. Oak), which also have a wide network of roots that could hold water in the aquifers for a longer time. Bio-diverse forest over the natural aquifers can help in reducing run off and retain water for longer period to support the need of community during dry spells. In addition, developmental projects like roads, canals etc should not destroy the natural aquifersHowever, there is very limited scientific knowledge about the groundwater aquifer systems in the Himalayan region, and detailed studies need to be conducted in different parts of Himalaya to have a comprehensive knowledge of the system. In addition, mechanisms need to be developed by communities to manage the aquifers by sharing the costs and benefits fairly.

Reservoirs

Since constructed reservoirs can have a wide range of capacity for water storage, it would be helpful to think in terms of small and large reservoirs. The standard definition of small dams is for structures less than 15 metres high with an embankment volume generally less than 0.75 million cu.m. Small reservoirs can be built at a low cost in a short period. Their proximity to the point of use makes them easily manageable by the local community. Though the evaporation loss in these small reservoirs is high due to the high surface area to volume ratio, the humidity is spread across the region. Large dams can store huge amount of water and lose relatively less water due to evaporation, but have very significant losses to communities. They lead to huge submergence areas and lead to large displacements of populations. Sedimentation may also be the greatest challenge facing existing large reservoirs. In addition, seismic risks and GLOF risks are also important.

In past India and China has constructed numerous dams in the Himalayan region, perils of which are still felt among people who were affected by these projects. Any new large dam would only add to the problems in the already vulnerable region. However, if the natural lakes are used to harness and store glacial and snow meltwater at high altitude, it could provide solutions to both water stress and perils of dams. A detailed study needs to be conducted in order to map the potential natural lakes that could be used for this purpose. In order to use them effectively there is a need of active community participation. A mechanism need to be developed in which, community has a significant control over the maintenance and running of the reservoir and allocating water to local farms and families.

B. Increase Resilience

1. *Enhancing observational and monitoring network*

One of the most crucial needs and gap areas is the availability of reliable and authentic data on the Himalayan Ecosystem. The systematic collection of data and information about the Himalayan mountain system is critical for improved understanding of climate change, and its trends and impacts, and for predicting future scenario. Data and information derived from earth observation are proving increasingly vital for gaining insights about regional status and trends, especially about climatic and broader environmental changes, and their implications at the global level. Earth observation information products and services are essential for determining adaptation strategies and appropriate development interventions for the benefit of mountain communities in the HKH region. Earth observation has a special significance in this region, with its high degree of inaccessibility and severe weather conditions.

The use of remote sensing data and techniques and geographic information system (GIS) data, complemented by field verification, is an effective method for the mapping and inventorying of glaciers in the region. These methods are continuously improving and converging so that it becomes increasingly easy to compare and exchange data worldwide. It is vital to adequately augment the initiatives for long-term ecological and weather monitoring across the region so as to address the issue of knowledge gaps.

The key areas for observation and monitoring are

a. Physical systems
i) Glaciers (glacial & seasonal snow cover)
ii) Snowmelt dynamics and its contribution to river water flows.
iii) Water issues (regional water basins to location specific recharge issues)
iv) Weather and climate trends – relevant datasets (establishment of 'weather towers')
v) Land degradation, land use land
vi) Energy systems (alternate energy and energy efficiency)

b. Biological systems
i) Critical habitats (ecotones, wetlands, alpines, etc.) and species (native, endemic, and economically valuable, etc.)
ii) Ecosystem structure, diversity, resilience
iii) Ecosystem functions (including carbon sequestration and water relations)

Few steps in enhancing observational network

To enhance meteorological observations over the western Himalayas, 26 surface observatories and 2 upper air stations have been set up. A mountain meteorology program has been started at NCMRWF, the India Meteorological Department (IMD) and the Snow and Avalanche Study Establishment (SASE) at Manali for the purpose of forecasting, providing training and development of snow climatology etc. Currently, mountain weather forecasting over the Western Himalayas is carried out through a combination of various products viz., regional/ mesoscale model outputs, global model products, in situ observations, and satellite observations along with synoptic conditions by collaborative efforts between National Centre for medium range weather forecasting (NCMRWF), IMD and SASE.

2. *Seed Management*

Like other parts of India, Himalayas also stored thousands of varieties of seeds of cereals, millets, pulses, vegetables, fruits, flowers etc. Owing to its difficult terrain, Himalayan agricultural fields did not experience green revolution in 1960s-70s, and were able to protect the rich variety of seeds. Post 1980s like most other places farmers in Himalayas also moved away from the practice of saving and exchanging seeds with their neighbors and families, to buying seeds from the market and slowly their own indigenous knowledge systems related to farming and seed saving slowly became irrelevant. Result — crop diversity suffered. In a land that once had thousands varieties of rice, it is difficult to find anything outside a few popular varieties in the markets today. Fortunately owning to the harsh terrain, Himalayan region still have more biodiverse farming than any other part of India.

As weather systems are becoming more and more unpredictable, there is arising an urgent need of seeds that are more robust and are able to survive the uncertainty in the weather pattern. The seeds that have evolved over thousands of years of farming are most likely to survive weather anomalies. It would be critical at this point to create seed banks of local indigenous varieties of seeds to save them from extinction; their loss could be an absolute loss of genetic diversity in Himalayan agriculture and would be an end to any further research on indigenous varieties.

Currently farmers are highly dependent on market for seeds and are sometimes dictated by markets forces to choose certain kind of seeds or to pay higher prices. To protect farmers from this cycle, agriculture extension services can institutionalize the seed banks under the ownership of farmers. Extension service should not only popularize local seeds, but also work towards research in local varieties that are more robust.

3. *Crop diversification*

Population pressures coupled with recent changes in socio-cultural change from subsistence to market economy has resulted in farmers emphasizing on cash crop. It also means replacement of staple food crops by cash crops and of multipurpose agroforestry trees by fruit trees. This fact corroborated by primary data, which revealed more and more farmers moving to cash crops and monoculture farming. In addition, in Himachal Pradesh and J&K extension of agricultural land is through replacement diverse forests by apple orchards. Simultaneously, Improvement in accessibility and supply of staple food grains at subsidized price by the government means that farmers have benefitted financially from growing cash crops. That said, loss of agro biodiversity means more risks to local livelihood in the wake of fall in market price/ demand, termination of government subsidy on staple foods, less diverse food basket, pest outbreak in a cash crop dominated landscape and climate changes induced variability. As we notices from esearch that most of the farmers in the study area were suffering pest and wild animal attack, which means direct loss in total income. Increased application of fertilizers temporarily leads to higher production but at high input costs and more resilient pests.Increasing agro biodiversity using crop diversification and economic benefits from non-timber forests produce can increase resilience of mountain communities and check degradation of forests. Farmers in the hill are known to grow a variety of crops triggered by a sense of securing survival in isolated settlements in a highly variable and uncertain biophysical environment. High level of crop yields (e.g. 6.5 t ha^{-1} of wheat and 14 t ha^{-1} of potato) and food sufficiency in many villages insulated from external forces due to extreme inaccessibility (Chandrasekhar 2003, Semwal*et al*. 2003a) testify the potential of indigenous knowledge.

It is thus suggested that policies and incentives favoring Indigenous innovations such as cultivation of medicinal plant and native varieties of staple food crops and traditional practices to cope up with the variability and uncertainty arising due to changing climate.

4. *Alternative Livelihoods*

The majority of people in the Himalayas depend on subsistence agriculture and natural resources for their livelihoods. However, traditional agriculture no longer serves as a sufficient livelihood option fulfilling the needs of most mountain communities. In recent years, economic growth, shifting population dynamics, and climate change have taken place so rapidly and intensely that the vulnerability of mountain farming communities have increased manifolds. The changing global environment and societal changes mean that opportunities need to be generated locally for mountain people to strengthen and adapt niche product and service systems to tackle the chronic and growing poverty.

The Himalayan region are endowed with an extensive variety of high value, low volume products, such as non-timber forest products (NTFPs), medicinal and aromatic plants (MAPs), and honeybee products, and are suitable for cultivating temperate and off-season crops. However, the primary producers and collectors of these products generally receive a relatively low share of the returns due to insufficient knowledge of market chains, lack of processing facilities, inadequate quality control, and similar factors. The same holds true for mountain tourism, which, despite its enormous potential within the region, not only remains largely underdeveloped, but also rarely benefits the local population in the form of sustainable and non-exploitive employment and supply of services and local products. Despite the relevance for mountain people's livelihoods, and the quick growth of trade in NTFPs and MAPs, national and regional policies have not been adequately developed, adapted, or implemented in the region. There is significant scope to generate more income locally by supporting mountain people to generate new livelihood options and add value to high value products and services.

Using a combination of indigenous knowledge and modern scientific knowledge, new avenues of livelihood could be generated from existing resources and provide much needed economic security to the mountain communities. Additionally, a supportive role by local cooperative, government agencies, civil society organizations etc can provide technical knowhow, credit, market linkages and insurance to the communities and create a diversified livelihood scenario.

C. Enhancing Adaptive Capacity

Adaptive Capacity definition: Adaptive capacity in the context of human and environmental system could be defined as the ability to respond and recover to a specific changing context. The Inter-governmental Panel on Climate Change (2007) states that adaptive capacity is the degree to which individuals or groups can adapt to risk at any given time. In our context, adaptive capacity of the mountain communities inhabiting western Himalaya refers to the set of factors decision making ability, access to financial, technological and information resources, infrastructure, robustness of local institutions, political influence, strength of social networks and collective action that enables them to respond to climate change.

Our interaction with the communities and the growing research suggests that strengthening social networks and collective action could be key to enhance adaptive capacity of the mountain communities. In terms of climate change, collective action is at the core of adaptation decisions related to the management of resources associated with agriculture, forestry and other resource dependent livelihoods (Adger, 2003) and strength of social networks mark the quality of collective actions.

There are already many instances of Organizations facilitating the formation of a voluntary collective of locals (SHGs, etc.) to pursue shared interest and have demonstrated the For instance, Environics Trust brought together a group of farmers in Baramulla district of Jammu and Kashmir to train them in mushroom production. In addition to providing financial resources, the trust also developed market access for the produce. It helped farmers to reduce their vulnerability from impact of climate change on agricultural production. In addition, if social networks are strengthened, they will ensure replication and scaling of such activities. In a similar case, an NGO helped create a women collective which specializes in Jam and honey production in spare time. The additional income thus generates ensures well-being of the family and community in scarce times. A more imaginative example would be creating a seed bank cooperative, which preserves resilient and diverse seed varieties collectively owned by the community.

Thus, it can be argued that collective action could enhances social networks which can serve to reduce economic vulnerability of the community, provides a framework from which to discern and solve problems, contributes to individual and collective empowerment which can strengthen links with local government and facilitate quicker action in times of disaster and natural hazards.

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Indian Network on Ethics and Climate Change

INECC is a loosely structured national network comprising of individuals and organisation representatives interested in the climate issue from a micro-macro perspective. It connects the issues of climate change to larger sustainable development and social justice concerns. In this context INECC perceives policy changes in favour of communities who are most impacted by the climate crisis.

The key ***objectives*** of INECC are:

1. • To facilitate the voice of the marginalized majority from specific local contexts to be considered for policy action;
2. • To undertake research and documentation on the issues relating to climate change, sustainable communities and its implications especially for marginalised communities;
3. • To undertake educational and other programmes with, and on behalf, of marginalized social groups and communities on causes, responses and other dimensions of climate justice.
4. • To explore and undertake pilot initiatives towards promotion of sustainable development technologies and practices;
5. • To focus on environmental ethics for individual and social action
6. • To shape perceptions of the youth around this agenda specifically on the key issue of social justice