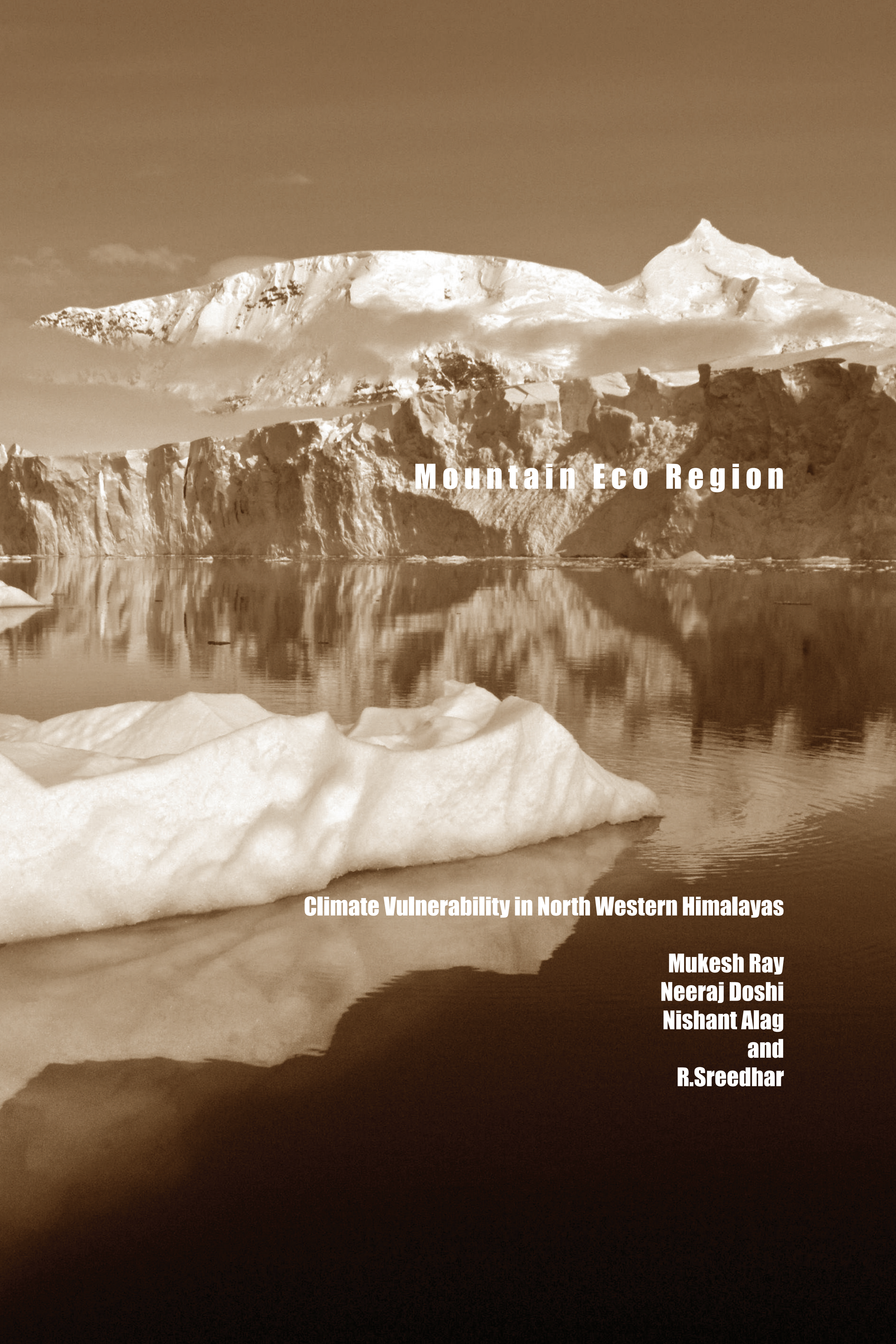

Mountain Eco Region

Climate Vulnerability in North Western Himalayas

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Mountain eco-systems are very sensitive to the habitat and climate change due to the interaction of tectonic, geomorphic, environmental and climate agents.

Temperatures, for instance, 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 global average temperature of 0.7 degrees over the last hundred years (Gravgaard, 2010). In another Himalayan region, the 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 by one degree in last decade (Srinivasan J, 2006). For this reason, Himalayas, alongwith other continental ice masses like 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. Recent instances include the disastrous cloud bursts near Leh in Ladakh and Kapkot in Uttarakhand, the shifting of apple orchards to higher altitudes and the arrival of mosquitoes at an altitude of 12700 ft. in Tsomgo in Sikkim. This vulnerability is critical for the local communities as they are highly dependent on natural resources for their livelihood.

As in other regions, the vulnerability of mountain communities in the Himalayas sits on top of other vulnerabilities. First, there is the geologically induced risk related to seismicity. There has been a sequence of earthquakes between 1991 and 1998 and in the current period about 500 micro-earthquakes across the Himalayas.

The second vulnerability is due to the impact of development projects by the State such as roads or power projects. Close to 100 power projects are coming up in each of the Himalayan states under a national programme for generating about 50,000 MW of hydro-power.

The vulnerability due to Climate Change at the local level is debated and it is difficult to isolate climate induced vulnerability. The data on risk and vulnerability is mostly consolidated and the models used are cumulative. The weather monitoring infrastructure too is thinly dispersed and monitoring at the basin level is not well planned. Thus basin level comprehensive planning has not evolved. However, regional models have given broad estimates of changes in temperature and some of the potential implications.

Thresholds for vulnerability in specific local contexts are still unknown and benchmarking has never been seriously attempted. There are still no well-defined determinants of vulnerability at the micro level as they vary with physiographic and other features. Correlating these with known micro-meteorological responses can produce empirical evidence to isolate changes due to global warming in a given context. These regions are industrialising rapidly, which besides contributing to the global problem, has resulted in local impacts causing unrest and discontent. Thus business-as-usual planning without a mountain perspective, is adding on to peoples vulnerabilities.

Vulnerability and adaptation of the mountain communities to these vulnerabilities has to contend with nature determined environmental fragility as well as the impact of inappropriate development regimes. Most important is the total disconnect that local marginalized communities feel with the pathways and solutions, if at all, shown by the mainstream.

In the Himalayas, nature determined environmental fragility scores high. We have a Transient Environment where the glacial environment is transiting into fluvial environment which is more prone to avalanches, landslides and rapid change in surface morphology. As glacial recession is taking place at a faster pace, a new equilibrium at the cost of loss of entire habitats is possible.

Some of the geographical changes would bring in Transitional Environments where small triggers could lead to dramatic changes such as between the Bhabhar-Terai glacial margins. The region also abounds in Tectonically Unstable Environments along major thrust and fault lines. 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 any crisis scenarios that may arise.

While local communities have varied local responses to nature determined fragility, it is the impacts of Inappropriate Development Regimes that have been having a snowball effect on the vulnerabilities of local communities. Climate Change may be a global cause, but impacts of local development are more proximate making the impacts of climate change extremely difficult to recover from, particularly in Denuded Areas caused by past processes of inappropriate development and neglect. Mining for example has degraded the slopes or altered river regimes.

We also have Largely Modified Environments, where dam and power projects have been built. The submergence zones have significantly altered the local geography and meteorology. Urbanization across the mountains is also impacting local climate regimes. Large tracts of mining especially of limestone and ubiquitously of river bed materials have modified entire regions.

Finally, local communities percieve a complete lack of concern and appreciation by the mainstream of the subsistence environment. Communities in the rain-shadow areas, isolated valleys and forest villages have managed their livelihoods without damage to their environment or causing climate change. Yet these processes and systems do not find support in the mainstream scheme of things. This has lead to discontented environments particularly when they are being forced to give up their land and other resources for the very projects that destroy their livelihood. Large areas have been made inaccessible by reservoirs such as Tehri reservoir in the Pratapnagar block. There are also restrictions on their movements within and in the periphery of the Protected Areas.

Vulnerability and Adaptation to Climate Change as also others causes would therefore need to address this issue by enhancing people's livelihood in an economy which nurtures rather than destroys their habitat

NORTH WESTERN HIMALAYAS

Physiographic features of the Himalayas

The Himalayas, the youngest mountain system in the world is one of the critical biodiversity hotspots on this planet. This mountain system runs from west to east covering an area of nearly 7.5 lakh km2 spanning over 3,000 km in length, averaging 300 km in width, and rising from low lying valleys to more than 8,000 metres. 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 Greater Inner Himalayas.

The Himalayan system has a distinctive climate of its own, which in turn has an immense impact on the climate of the Indian subcontinent and Tibetan plateau. The range forms a barrier preventing cold dry winds from the arctic blowing south into the subcontinent. 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 eastward resulting in snow in Kashmir and rainfall in Punjab.

The variations in topographical features along longitude, latitude and altitude create climatic variations resulting in rich

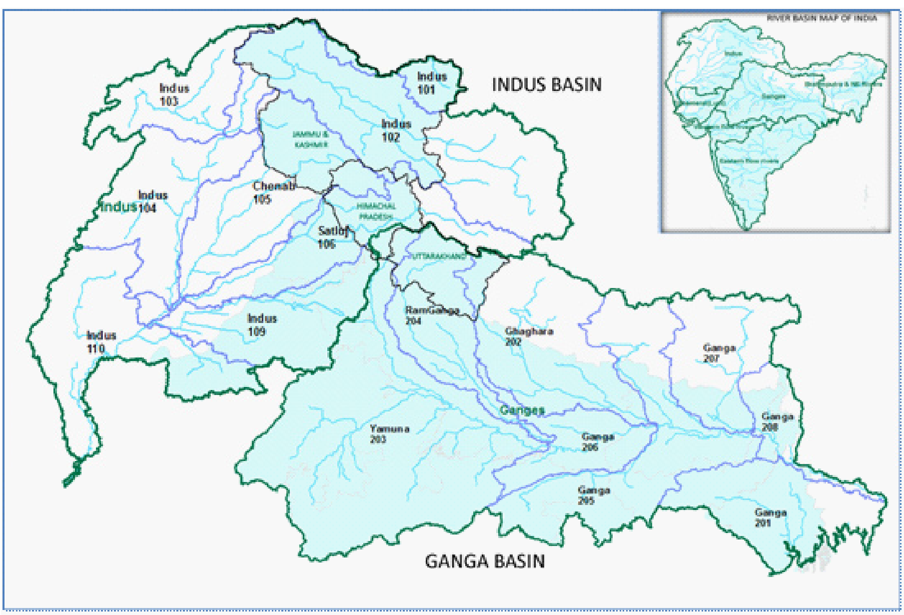


Fig. 1: Map Showing Indus and Ganga Basin. The region is drained by Indus-Chenab System, Chenab-Satluj system of Indus Basin and Yamuna-Ramganga-Ghaghara system of Ganga basin. Source: Hydrological Information System

and unique bio-diversity. There are over 13000 plant species in the Indian Himalayan region (IHR) which constitutes the largest subgroup of the Himalayas with total area of 5.37 lakh km2. 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 plants 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 this, the region provides ecosystem services of 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 non-timber forest produce

A large area of the region is under glaciers and permafrost, which feeds two of India's biggest rivers, Brahmaputra and Ganga which in turn form rich deltas providing livelihood for close to 400 million people.

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
Evaporation (mm)	535.5	602.4	66.9
Source: Pradeep K. Rawat, Int. J. Disaster Risk Sci. 2012, 3 (2): 98–112			

Having supported and sustained civilizations in its vicinity, the region is showing signs of stress due to geological reasons and over exploitation of natural resources, current energy needs, population pressures and other related changes. Climate Change will add to the immediate and profound impacts in this sensitive eco-system. From a modern economic point of view, the region is considered poor, with a result that despite the rich environmental services provided by the region, the area is marked for concessional industrial development in the plains without considering the impact on air and water environments in such eco regions. The impacts of monetary incentives are more severe on the micro-climate than the damage done by providing carbon credit, which only displaces pollutants from one place to another. In this case the incentives in the form of tax holidays and infrastructure support, are being provided to industries which are particularly polluting. For example a study on the Dabka catchment in Kumaon region (see table) shows that local warming could be as high as nine degrees celsius.

This study focuses on the north western Himalayas that is the Ganga basin and parts of the Indus basin falling mainly in the States of Uttarakhand, Himachal and Jammu and Kashmir. It looks at vulnerability at different altitudes because the variation is high.

District-wise Altitudinal Profiles, Key Features and development activities

Table 2: Altitude Profiles: Predominantly low altitude districts			
Districts	Altitude Range	Peaks or Other Features	Development Activities
Udham Singh Nagar, UK	150 – 300m		Distilleries & other Industries
Haridwar. UK	150 – 1350m	Bhabbar & Terai	Industries (IEE), stone crushing
Una,, HP	300 – 900m		Industries
Nainital, UK	150 – 3000m	Shivalik Range & Higher hills	Industrial belts, Urban centres
Kathua, JK	600 – 3000m		
Bilaspur ,HP	300-1800m	Govind Sagar (Bhakhra), Parts of Mahasu valley	Cement plants, Bhakra reservoir, river bed mining
Hamirpur, HP	300 – 1350m	Parts of Mahasu valley	Industries
Kangra, HP	300 – 7500m	Pong Reservoir & Wetland	HEP
Rajauri, JK	600 – 3000m		
Champawat, UK	150 – 3000m		Mining, deforestation
Udham-pur, JK	300 – 6000m		
Solan, HP	300 – 3000m	Shivalik & Mussourie Range	
Sirmour, HP	300 – 1800m	Shivalik & Mussourie Range	Mining in 2 blocks, Industrial belt in paonta
Pauri Garhwal, UK	300 – 3000m		
Jammu, JK	150 – 3000m		

At the lower altitude upto 4000 feet, the area is rapidly urbansing. On the foothills of the Shivaliks, in Uttarakhand alone, we have 63 so called urban centres where after the formation of the state, fresh incentives were given to industry. The entire Baddi Barotiwala Nalagarh stretch is highly industrialised along with cement and mining activities. Mining and industrialisation in Himachal is also heavy.

Table 3: Altitude Profiles: Predominantly mid altitude districts			
Districts	Altitude Range	Peaks or Other Features	Development Activities
Almora, UK	600 – 3000m		Mining
Mandi, HP	600 – 3000m		Cement, Industrialisation k
Dehradun,UK	300 – 3000m	Doon Valley	Industrial estate, Urban Centre
Kullu, HP	1350 – 7500m	Deo Tibba (6001m), Partly Rampur Valley	HEPs
Shimla, HP	1350 – 6000m	Nag Tibba, Part of Rampur Valley	
Kinnaur,HP	1350 – 7500m	Kinnar Kailash (6050m) (Satluj Valley, Baspa Valley),	HEPs
Bageshwar,UK	900 – 6000m		Mining, HEP
Pitthoragarh,UK	600 – 6000m	Part of Great Himalaya – Nanda Kot (6861m), Panch Chulhi (6984m)	Mining, HEP
Rudraprayag,UK	900 – 6000m		HEP
Baramulla, JK	1350 – 6000m		Industry

The mid attitude between 4000 and 10,000 ft. comes under rain shadow. The area is therefore more vulnerable to fluctuation in rainfall. Thus high-value agriculture and horticulture is affected. The apple orchards have moved from about 3500-4000 ft. to 7000-8000 ft. Thus northern districts like Kinaur, Chamoli and even Lahual Spiti have begun to grow apples. There is increasing urban-

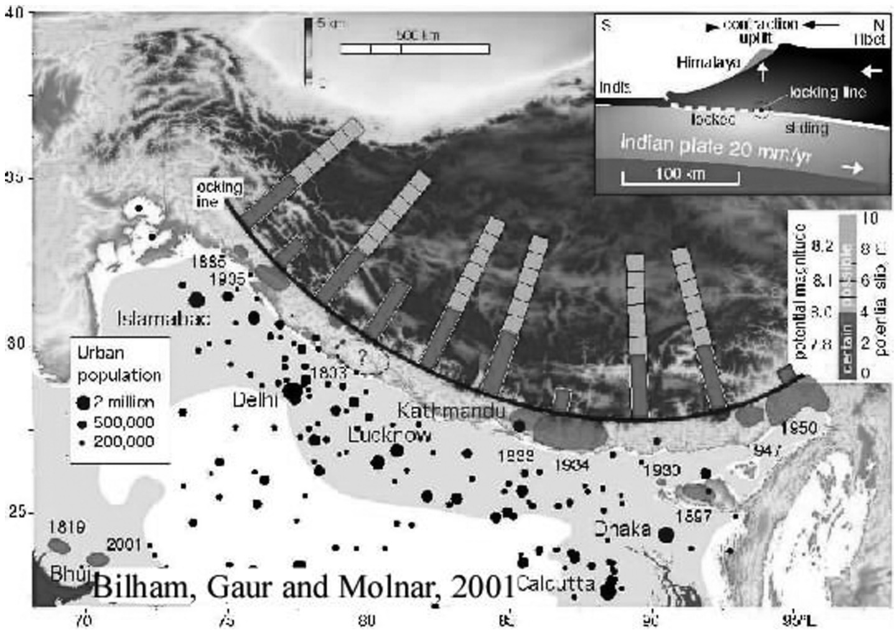
ization and physical development in all the areas especially in the Uttarakhand. Small urban towns and infrastructure like roads are being built. Farming is becoming vulnerable to these changes. The pastoral communities, particularly the nomadic groups are being marginalized. They can graze only for a few months as water is not accessible at these altitudes and the grazing cycles is disturbed.
The middle Himalayas and Valleys are dotted with hydroelectric projects, reserve forests and submerged areas coupled with construction activity
The high altitude areas beyond 10000 ft and into the Tibetan plateau hold resources such as glaciers, river systems (glacial as well as non-glacial), biodiverse high altitude plants and species. The low density of population and ecosystem hierarchies provide a mutual interacting space among the biotic and abiotic components making for a unique ecological balance. Any shift or imbalance will impact the ecosystem as not all components will be able to adjust. It is within this context that several communities who normally need environmental services from these regions like the nomadic Gujjar community and Gaddis of Himachal or the Graziers (Bhainsiyas) of Uttarakhand are vulnerable. Thus the main concern in the Himalayan region in the face of climate change is protection of whatever resource integrity that exists and narrowing narrowing the misbalance and disintegration of closely dependent natural resources which can increase the vulnerability of the resources as well as the living beings

The higher Himalayas are inhabitable as they are snow bound. There are also a series of protected areas in this Belt. The middle Himalayas are dotted with hydroelectric projects, submerged areas and reserved forests. The lower Himalayas too have protected areas. Thus peoples' geographic freedom is restricted.

Table 4: Altitude Profiles: Predominantly high altitude districts			
Districts	Altitude Range	Peaks or Other Features	Development Activities
Chamba, HP	600 – 7500m	Kailash Peak (5656m)	HEPs
Tehri Garhwal, UK	600 – 4500m		
Pulwama, JK	1350 – 3000m	Rice bowl	Tourism
Budgam, JK	1350 – 6000m		
Doda, JK	900 – 6000m	Zaskar Valley, Nunkun (7135) Fir, Deodar forests	Tourism
Anantnag, JK	1350 – 6000m		
Chamba,HP	600 - 7500	Kailash Peak (5656m)	
Leh & Ladakh,, JK	3000 – 6000 &> 6000m	Saser Kangri (7672), Aksal Basin, Kailash Range, East Ladakh Plateau	
Chamoli,UK	900 – 6000m	Part of Great Himalaya, Zaskar Range, Nanda Devi (7817m), Dunagiri (7066m), Trishul (7120m), Mangtoli (6800m), Hathi Parbat (6727m), Mana (7272m), Kamet (7756m)	Mining, HEP
Lahaul & Spiti, HP	3000 – 7500m	Lahut & Spiti valley, Sarchu Peak (5741), Mulkila (6417)	Tourism
Uttarkashi,UK	900 – 6000m	Kedarnath (6968m), Bandarpunch (6320m)	HEP
Kargil, JK	1800 – 6000m	Pirpanjal Range, Deosai Basin	
Kupwara	1350 – 6000m		

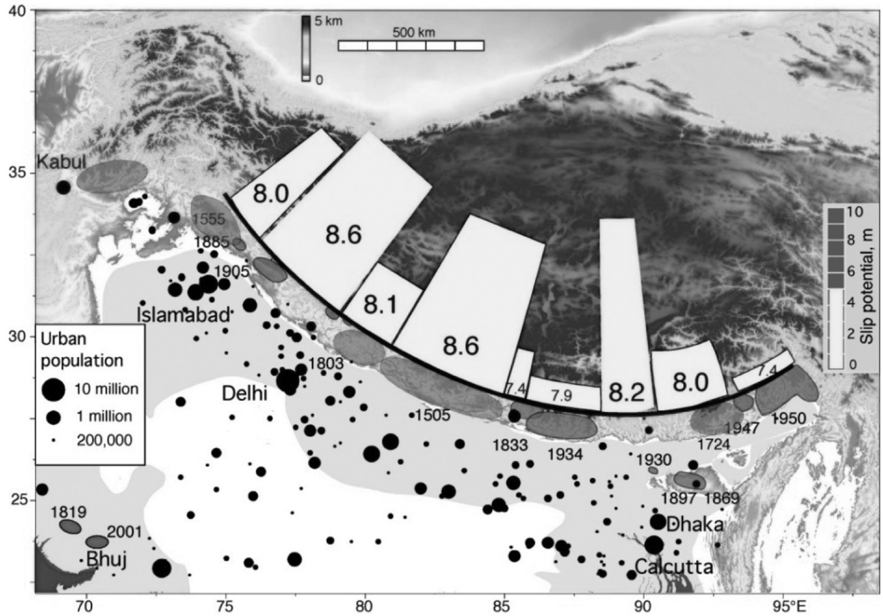
NATURE DRIVEN ENVIRONMENTAL VULNERABILITY

Seismicity



The Himalayas owes its origin to the northward drift of the Indian landmass which started 71 million years ago, and clashed with the Eurasian land mass pushing it upward to form the Himalayas. The inset in map is a graphic cross section through the Himalayas which indicate the transition between the locked, shallow portions of the "fault" that rupture causing the great earthquakes, and the deeper zones where India slides beneath Southern Tibet without earthquakes It is the ongoing subduction of the Indian landmass that makes the region an active seismic zone.

This map by Roger Bilham shows that the extent of the activity. The grey cloud-shaped areas with dates show the epicenters and zones of rupture during the different earthquakes recorded. The bars indicate his estimate of the magnitude of potential "slip" that has accumulated since the last great earthquake or since 1800 (darker portion=certain, lighter bars=possible). (They do not represent the location of past or future earthquakes). The sizes of the black dots represent the urban population. The region, extending upto 300 km south and southeast of the Himalayas, has an urban population which exceeds 40 million.



The second figure shows a recalculation of the slip potential basing it on historical records going back to 1500 and geological evidence of rupture during the earthquake in 1400. Each trapezoidal figure represents the slip developed since the previous known earthquake at that location. Scientists 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.

They also know less about earthquakes in the eastern Himalayas than those in the west and it is possible that scientists have underestimated the seismic slip potential there (Ambraseys and Jackson, 2003).

Modification of Glacial Systems and Reduction in Snowfall

The glacial systems, the permafrost and the seasonal snow in the Himalayas form an unique reservoir from which 10 of Asia's largest rivers flow sustaining the lives of billion plus people. The Himalayan glacial system contains 116,180 km2 of ice, the largest area outside the Polar regions (Owen et al., 2002). These glaciers feed 5% to 45% of 10 of the 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).

Glaciers

According to the fourth assessment study of IPCC, the Himalayan glaciers are melting at a faster pace since late seventies. The Space Application Centre (Department of Space) in collaboration with MoEF carried out a study on Glaciers, as recently as May 2011. The results indicate that almost 75% of the glaciers have shown a retreat.

Table 5: Glaciers in the Himalayas – Change Monitoring 2011				
	Glaciers monitored	In Retreat	Advance	No Change
Fluctuation based on SoI maps and satellite images	2630	2047	435	148
		77.83 %	16.53%	5.62%
Fluctuation based on Satellite images	2190	1673	158	359
		76.39%	7.21%	16.39%
Source: Snow and Glaciers of the Himalayas, 2011				

However, each glacier, even those in adjacent areas with similar conditions have shown contrasting results. The nature of on the spot and downstream impacts resulting from melting of ice at a rapid pace and deglaciation depends on glacier characteristics like glacier area, size, debris etc. The ISRO study based on which the following table is made, interpreted that

- The glaciers of **Nubra Basin** are very large in size as compared to other basins which indicates that the response time is slow and retreat is less. (#)
- There is almost no retreat in the lower altitude **Teesta Basin** . The basins of eastern Himalayas show little or no retreat compared to the western Himalayas.
- There has been a rapid retreat in the **Spiti Basin** after 2001 and this is the highest among all basins!
- The glacial retreat in the **Alaknanda basin** has been rapid after 1990, whereas the adjacent Bhagirathi Basin - has shown slow retreat after 1990.(@)
- The glaciers of the **Bhaga basin** which is located in similar climatic conditions as the **Chandra basin** show higher rate of retreat as the glaciers here are debris free. Another reason is the small size of the glaciers indicating smaller depth.(+)

Table 6 Status of Glaciers in different River Basins by Numbers

Basin	No of glaciers in basin			Status
	No	Retreat	Advance	
Nubra	31			large glacier#
Bhagirathi ~	183	117 (64%)	27	
Zanskar	631	578 (91%)		
Alaknanda @	274	243 (88%)	27	
Warwan	230	180(78%)	35	15 no change
Chandra *	4*			
Suru	215			Rapid retreat
Spiti	337	169(50%)		highest rate
Bhut	143	74(52%)	40	Adj.to Warwan
Bhaga +	111	108 (98%)		3 no change
Gauri Ganga	29			Most showing retreat
Parbati	90			
Miyar	165	80(49%)	78	7 no change
Dhauliganga	104			
Teesta &	34			
Source: Jt. Study of MoEF and Department of Space, Space Application Centre, Ahmedabad (May 2011); Monitoring done through topographic maps of Survey of India by SAC				

Table 6a: Status of Glaciers in different River Basins by Area

Basin	Area in Sq km			Recent changes
	1962	2001	% change	
Nubra	2150	2026	6% loss	
Bhagirathi ~	1218	1074	11%	retreat slow after 1990
Zanskar	1107	940	15% loss	Rapid after 1990
Alaknanda @	1047	905	14%	rapid after 1990
Warwan	740	608	18% loss	declining post 2001
Chandra *	696	554	20% loss	
Suru	568	474	17% loss	
Spiti	474	396	16% loss	rapid after 2001
Bhut	450	417	7% loss	rapid after 2001
Bhaga +	363	254	30% loss	

Gauri Ganga	272	261	4% loss	
Parbati			20% loss	
Miyar				
Dhauliganga			16% loss	
Teesta &	305	301	1% loss	
Source: Jt. Study of MoEF and Department of Space, Space Application Centre, Ahmedabad (May 2011); Monitoring done through topographic maps of Survey of India by SAC and satellite imageries and compared from 1962 to 2001 and thereafter in some cases as recent as 2007.				

Snowfall

Evidence from a recent snowfall study show reduced snowfall over western Himalayas (Dimri & Kumar, 2008). Yet another study concluded a decreasing trend of snowfall over all the mountain ranges with different magnitude. The study noted a

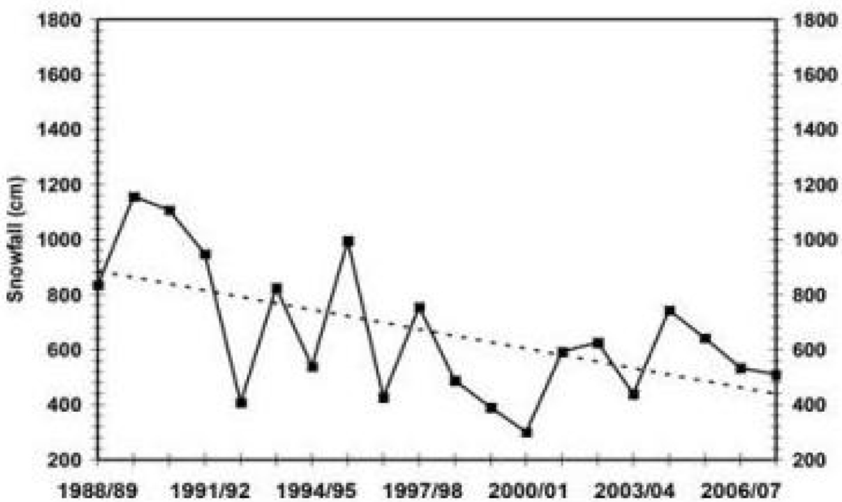
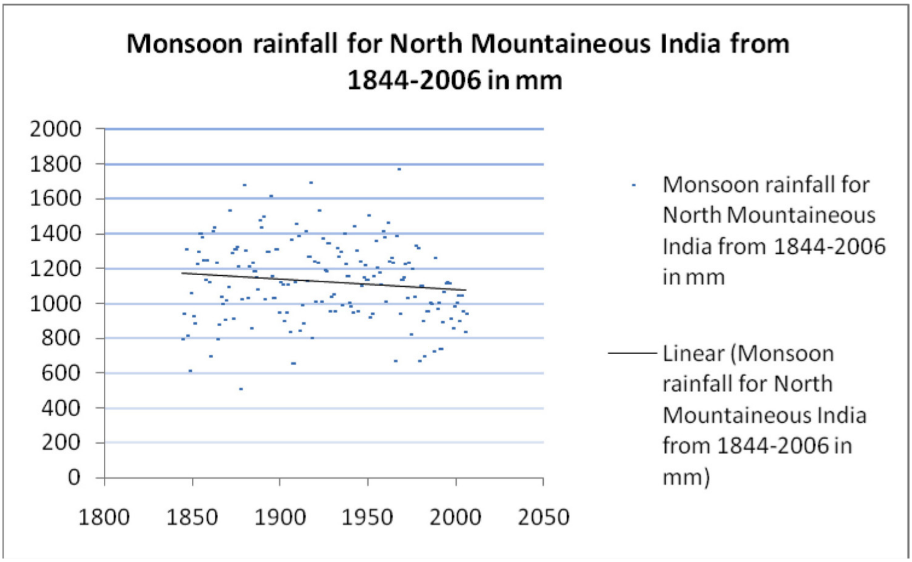


Figure 5 - Lowering of Snowfall

decrease in total seasonal snowfall of 280cm over the entire western Himalayas between 1988/89 and 2007/08 (Shekhar.et.al. 2010).

Rainfall

Climate Change induces change in the precipitation pattern. The total rainfall may increase in some areas and decrease 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. Higher intensity precipitation will also increase proportion of runoff and reduce groundwater recharge. The high degree of intra-annual rainfall variability caused by climate change in this area will induce water scarcity for more months in the year affecting approximately 1.3 billion people living in the ten river basins that have their origins in the Himalayas.



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

However, the monsoon rainfall in all of northern mountainous India (primarily western Himalayas and some part of Pir Panjal) has declined by almost 10% between 1844 and 2006. Rainfall is important as rain-fed farming is pre-dominant in nearly 70% to 80% of the Himalayas. The increasingly erratic weather changes will impact productivity especially in the mid hill region where agriculture is concentrated.

Farmer are prone to risk of ill-timed rains, excessive rains, frequent floods and heavy run-offs. The traditional practice of multiple cropping has largely been replaced with a single cash crop owing to market demands. Agricultural diversity is reducing thus adding to the vulnerability of the hill farming community.

Table 7: Year of variation in Rainfall

Districts	Normal Average Annual Rainfall (mm)	No. of Years of Data	Percentage of years of		
			Normal Rainfall	Excess Rainfall	Deficit rainfall
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	1209.0	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

The below table shows the number of rainy days in the year for different annual rainfall ranges in each district of Himachal Pradesh. The average normal rainfall for the district is indicated in bracketed figures in the grey cells. It is clear from the table that as we moved away from the normal annual rainfall, the number of rainy days reduces. This means that when there is a shortage of rain (below normal marked in black figures on light grey), the drought is for longer period, and when there is excess rainfall (excess rainfall marked in white figure on dark grey background) the downpour is heavy and intense

Table 8: No. of rainy days for different ranges in annual rainfall in districts of Himachal Pradesh

Range in mm	Bilaspur (1256.7)	Chamba (1355.1)	Hamirpur (1462.6)	Kangra (1852.3)	Mandi (1564.6)	Sirmour (1688.7)	Una (1209)	Total Occurrence
401-500	1	1	NR	NR	NR	NR	1	3
501-600	0	2	NR	NR	NR	NR	1	3
601-700	1	2	1	NR	1	1	2	8
701-800	1	2	0	NR	0	0	4	7
801-900	3	5	0	NR	1	1	2	12
901-1000	2	1	0		0	0	1	4
1001-1100	4	1	3	3	2	0	4	17
1101-1200	3	4	1	1	5	4	3	21
1201-1300	7	2	4	4	2	4	4	27
1301-1400	2	2	5	3	3	1	3	19
1401-1500	3	4	5	1	6	6	4	29
1501-1600	6	1	4	5	6	3	0	25
1601-1700	0	3	1	5	4	4	0	17
1701-1800	0	1	3	3	4	4	0	15
1801-1900	1	0	2	2	2	6	0	13
1901-2000	1	1	1	4	1	4	1	13
2001-2100	1	0	1	4	4	2	0	12
2101-2200	1	3	1	1	0	1	0	7
2201-2300	NR	NR	NR	2	3	0	0	5
2301-2400	NR			1	0	2	1	4
2401-2500	NR	NR	NR	NR	NR	0	NR	0
2501-2600	NR	NR	NR	NR	NR	1	NR	1
2601-2700	NR	NR	NR	NR	NR	0	NR	0
2701-2800	NR	NR	NR	NR	NR	1	NR	1
2801-2900	NR	NR	NR	NR	NR	1	NR	1
2901-3000	NR	NR	NR	NR	NR	NR	NR	NR
3001-3100	NR	NR	NR	NR	NR	NR	NR	NR
3101-3200	NR	NR	NR	NR	NR	NR	NR	NR
3201-3300	NR	NR	NR	NR	NR	NR	NR	NR
3301-3400	NR	NR	NR	NR	1			1

NR is Not Reported or Not Occurred at respective range for a particular district.
Rainy days= days with rainfall of 2.5mm or more.

Table 9: Rainfall in recent years, and variations from thenormal rainfall in each district of Himachal Pradesh

Year		Bilaspur (1256.7)	Chamba (1355.1)	Hamirpur (1462.6)	Kangra (1852.3)	Mandi (1564.6)	Sirmour (1688.7)	Una (1209)
2006	In mm	1348		1591	1767	1265	1378	1309
	% to N	107		117	121	81	82	108
2007	In mm	1251		1417	1610	1472	1276	1244
	% to N	100		105	110	94	76	103
2008	In mm	1299		1419	1805	1301	1422	1472
	% to N	103		105	123	83	84	122
2009	In mm	1029		1163	1210	965	975	1212
	% to N	82		86	83	62	58	100
2010	In mm	1070		1246	1611	1484	1904	1182
	% to N	85		92	110	95	113	98
Normal +/- 5%		2						3
Excess > +5%		1		3	4		1	2
Deficit < -5%		2		2	1	5	4	

The data indicates that the deviation in rainfall occurrence from the normal is higher in recent years. It also shows that except for 2009 when there was a shortfall in all the districts, every year there were some districts which received deficient rainfall when others had excess. Thus there are location based differences at any given moment of time, thereby indicating the need for local-level response and therefore local level planning to adapt to these variations.

Flash Floods

Flash floods are sudden and strong surges of water, usually along a riverbed or dry gully, carrying rocks, soil, and other debris. Since they are sudden, usually unexpected, they allow little time for response. Although flash floods generally affect smaller pockets and populations than riverine floods, their unexpected and intense nature pose a significant risk to people and infrastructure, leading to death and destruction. Flash floods can occur anywhere but they are more common in mountain terrains. The Himalayan region is particularly vulnerable to this type of flood due to the steep slopes and high rate of surface erosion. The intense seasonal precipitation, particularly during the summer monsoon in the central and eastern Himalayas and in winter in the western Himalayas triggers these individual flash floods which may last from a few minutes to several days. Changing watershed and environmental conditions (including climate) are increasing this vulnerability. While the main cause of flash floods is the 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 may also trigger flash floods. Most flash flood events take place in remote, isolated catchments where the reach of official machinery is limited or non-existent.

Cloud bursts

Cloud bursts have particularly severe consequences, each incident leaving a trail of destruction, where several families are unable to recover from the disaster, setting them back several years. The following table is a compilation of reported cloudbursts which indicate the huge vulnerability to the communities.

Table 10: Recent Cloudbursts (Loss : L=Lives, M=Missong, I=Injured)

Date	Description	L	M	I	Area	Division	State
16.08. 1997	Cloudburst – splash of water broke Andhra River banks and ran through Chirgaon	200				Chirgaon	HP
17.07. 2003		40	25	30	Shillagarh, Rauli (bridge at Beas)	Gursa area of Kullu Sub Div.	HP
24.07. 2004	Cloudburst triggered landslide	17		18	Lambagad close to Vishnuprayag	Badrinath Shrine	UKD
16.08. 2007					Ghanvi	Sangla Valley, Kinnaur	HP
16.08. 2007	Bridge broken, cutting off business linkage				Sadhauara bridge	Sirmour	HP
03.06. 2008	building damages				Rajgarh Tehsil	Sirmour	HP
08.07. 2010	Bridges, Vehicles, Equipments at under construction Parbati H.E P washed away.				Manikaran	Kullu	HP
06.08. 2010		>200		1000's	Choglamsar, Saboo, Phyang, Nimoo and Shapoo	Leh	J&K
18.08. 2010	Heavy downpour, triggering landslide	30	50		La, Gherna, Lelu Nahar	Munisyari, Pithoragarh	UKD
19.08. 2010		18 – 20		>30	Kapkot	Bageshwar	UKD
23.08. 2010					Tharaman village	Kullu	HP
24.09. 2010	Over 50 bighas of agri. land & apple orchards washed away				Kaamru Nala and Barang Nala	Sangla (Kinnaur)	HP
01.06. 2011					Udaipur	Chamba	HP
09.06. 2011		3			Assar-Baggar Region	Doda	J&K
21.07. 2011	Labourers trapped while snow gallery construction to connect Rohtang tunnel was underway	8		22	Dhundi area	Mandi	HP
06.08. 2011					Manjhainalah near Athamille area	Mandi	HP
06.08. 2011	Flash flood in Sambhal Nallah after cloud burst				Balidhar forest range (uphills)	Pandoh (Mandi)	HP

Other Special Weather Phenomena

Most of the extreme weather events since weather record keeping started in 1850s, have occurred in the last decade. The table below is indicative of mean number of days when weather hazards such as thunder storms, hail storms, dust storms, heavy snowfall and fog have occurred.

Table – 11 Special Weather Phenomena (Mean no. of Days)

District	Thunder storm	Hail Storm	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 of the Climatological Summaries of States: Series – No. 15 (Climate of Himachal Pradesh), Indian Meteorological Department

There has been an increasing trend in hailstorms, which are affecting the horticulture as well as agricultural crops. In higher altitudes when hailstorms occur during the flowering season, the fruit yields are affected. In the ripening season, they injure the fruit reducing its market value considerably. The response of the state has been to use anti hail guns to disperse the hail-stones and minimize the damage. The efficacy of such a step is still to be ascertained.

VULNERABILITY RELATING TO INAPPROPRIATE DEVELOPMENT REGIMES

A number of irrational development activities are exacerbating the vulnerability of the communities. As mentioned earlier urbanisation and rapid industrialisation and mining in the lower plains have increased pollution levels. In the mid-altitudes, we have a large number of hydro projects and commercial forestry which have displaced local communities.

The Case of Hydropower

Himalayas are viewed as a storehouse of hydro power. But the intensity and manner in which projects are being built across the landscape, right from the lower to middle and higher Himalayas (3800 m), has disturbed the ecosystem. Several projects have made the rivers non-functional destroying the eco-services provided by the river and changing local climate profiles. We are led to believe that these are run of the river schemes, which are meant to allow the free flow of river. But that is not the type of project being implemented in the Himalayas. These are still storage based diversion schemes where water is diverted through a head race tunnel (HRT), which have resulted in kilometers of river stretch going dry. Further, the calculation of the flow is done in a manner which does not take into account the environmental needs of living beings in its catchment area or are dependent on it. A sample of 35 such projects (see table below) show that almost 80% have reservoirs or storage component. The reservoirs induce anaerobic decomposition of biomass thereby producing methane gas which stays longer in the environment and traps heat and has a Global Warming Potential (GWP) of 25 times more than CO2. Accumulation of organic matter in the rivers, coupled with increasing average temperatures, has raised the per unit emissions of GHGs. With proximity to the glacial environment, the vulnerability increases manifold as there is faster melting creating flood conditions and depleting ice stock affecting the flow in the lean periods.

Table 12 A selection of hydro-electric projects								
Project Name	Catchment sq.km.	Capacity MW	Altitude	Tail Race Tunnel	Head Race Tunnel	Diversion Tunnel	Reservoir	Submergence
Kotlibhel (Stage-II)	21375	440	390	1975	810	380	Y	
Kotlibhel. (Stage-1B)	11453	280	670	1520	280	445	Y	
Kotlibhel (Stage-1A)	7887	240	680	252	165	425	Y	
Kalika Dantu	3385	230	730	130	5.2		Y	46
Singoli Bhatwari	650	60	760					
Khartoli Lumti Talli	1855	55	920	220	1000	705	Y	80
Baram small H S	75	1.5	975					
Chunni Semi H S	600	24	1080					
Rupsiabagar Khasiyabara	1235	260	1200	45	7220	715	Y	22.4
Gohana Tal	211	60	1200	940	9000	280	Y	24.6
Phata-Byung small HS	133	10.8	1240					
Jimbagad small HS	95	7.7	1300					
Devsari	1115	300	1320	1080	7370	450	Y	522
Garba Tawaghat.	1367	630	1440	268	13150	760	Y	14.6
Birahi ganga small HS-II	214	5.6	1476					
Gaurikund small HS	65	18.6	1600					
Urthing-Sobla	1063	280	1762		4150		Y	36
Rambara-Gaurikund	65	24	2040					
Karmoli	1605	140	2160	600	8600	350	Y	9.94
Bogudiyar-Sirkari Bhyol	935	170	2160	280	2350		Y	19.43
Rishi Ganga-II	680	35	2240	300	3240	230	Y	1.66
Sela Urthing H.E.	921	230	2240	30	2010	300	Y	15.72
Rishi Ganga-I H.E.	599	70	2320	706	3310	350	Y	6.2
Sirkari Bhyol Rupsiabagar	1160	210	2320	370	800	550	Y	12.8
Jelam Tamak	1510	60	2420	320	5700	250	Y	13.9
Harsil.	3235	210	2480	280	5060		Y	91.56
Mapang Bogudiyar.	829	200	2720	300	3520	480	Y	24.2
Bokang Baling	691	330	2750	295	9400	490	Y	132.5
Malari Jelam	1343	55	2760	816	4500	240	Y	10.45

Table 12 A selection of hydro-electric projects								
Project Name	Catchment sq.km.	Capacity MW	Altitude	Tail Race Tunnel	Head Race Tunnel	Diversion Tunnel	Reservoir	Submergence
Bhairon Ghati	2660	65	2800	190	5100	500	Y	13.27
Chhunger Chal	850	240	2800	147	3545	530	Y	13.2
Badrinath	1265	140	2920	340	2840	300	Y	3.74
Jadhgana	1679	50	2960	290	1100	400	Y	8.35
Gangotri	944	55	3160	450	5200	400	Y	24.96
Deodi H.E.	544	60	3240	1030	4800	300	Y	5.6
Source: Rational Energy Development in Uttarakhand, Environics Trust (2005-06)								

In the current scheme of things and in view of the potential climate impacts, there is a need for cumulative assessment and rethinking of these schemes as they have the potential to destroy high value natural resources, including farm land and forest land which directly impinge upon the rights and livelihoods of the population. In a recent case in Sikkim, the massive landslides that occurred was linked to the tunneling of the power project. Such incidents increase vulnerability and may cause death and destruction as their incidence and severity would increase due to climate change.

Issues around Afforestation and Deforestation

Large areas of forests are being diverted for non-forest purposes, thereby impacting climate change. 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%). In Himachal Pradesh, more than 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%). The table below shows that most of these (67%) are in areas of more than 40 hectares. In Uttarakhand, the diversion of large forests for Hydro Electric Projects is much more at 89%.

Compensatory afforestation that is being done to replace submerged forests delivers a double whammy to people displaced by the hydro-electric projects. They no longer seem to have access to their forest lands, and the species grown are not appropriate to their needs. Natural forests once replaced can never be brought back in terms of value and quality. It promotes monocultures which work commercially but not socially. The vulnerability further increases for the people and for other species. The relentless rise of man-animal conflicts is indicative of this reducing space for communities and wildlife. While the communities lose their forests and grazing lands, the net present value (NPV) of forests on account of diversion goes to the state treasury. Similarly, afforestation as part of developing carbon sinks or schemes like REDD+ undermines the rights of people making them vulnerable and forcing them to seek other livelihood options.

Table – 13 Forest Area Diverted for Non-Forest Purposes

		UKD	HP
No. of Cases Approved		3493	1240
Area Diverted (Ha)		62627	11131
Proposals for 0 - 5 ha	No.	3071	1046
	Area Diverted	3337	1657
Proposals for 5 - 10 ha	No.	202	58
	Area Diverted	1459	406
Proposals for10 - 20 ha	No.	108	42
	Area Diverted	1465	620
Proposals for20 - 40 ha	No.	32	34
	Area Diverted	851	939
Proposals for> 40 ha	No.	80	60
	Area Diverted	55515	7509

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)

VULNERABILITY OF LAND BASED LIVELIHOOD AND COMMUNITIES

There are still carbon neutral settlements at higher altitudes in the Himalayas, where the state development has not been able to reach. They practice organic agriculture, gathering and grazing (Some of them don’t even use fertilizer). The people are self-sufficient and they do not extract resources or energy from outside.

The temperate mid zones which range between 650m -1800m have seen large tracts of forests giving way to hydel power projects. People have gone in for intensive agriculture and horticulture particularly for cash crops. Apple is grown in mid to high hill climates and the fruit belt covers Shimla, Kullu, Chamba Kinnaur, Sirmour and Mandi districts. In Himachal Pradesh alone, apple farming extends to over 1 lakh hectares and forms almost 45 – 50% of the land under fruit cultivation. The total fruit production in the state during 2007-08 was 712 million tonnes, out of which apple production was 592 million. About 81 percent of the total cultivated area in the state is rainfed. Rice, wheat and maize are the important cereal crops. This belt is also suitable for for cash crops like off season vegetable and ginger. Ginger is grown in Kadukhal (Tehri district) and its production in HP rose to 21,267 tonnes in 2010-11 which is an increase of over 6000 tonnes from the previous year. In these mid altitudes, we see monoculture in both forest and agriculture. And the majority of farmers, about 6,28,000 of them are small farmers owning less than one hectare of land. The uncertain weather patterns keep these farmers guessing and there is little that they can do as their farms are rainfed and growing other crops involve investments and know how which they can ill-afford.

Some of the farmers have adopted protective irrigation. Ujagar Singh from village Deedbagad in Sirmaur District of Himachal Pradesh had installed a gharat (water powered mill) in the early 1980s to grind grains (wheat, maize, jowar and millet, etc). His gharat has stopped working in the last few years as the stream which is used to power the turbine, is reduced to a trickle. According to Ujagarji, his land is shown as irrigated in the 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 the last decade.

There is historical evidence that rainfall is becoming less than normal. At some altitudes, we find that there have been several periods when rainfall has been low half of the time and excess rainfall 43% of the time. In some cases the excess rainfall has been due to cloud bursts. Thus in these areas, we have normal rainfall for only about 10% of the time. The “western disturbances” that bring rain to most parts of northern India seems to have modified its behavior such that when the monsoon winds cross the Pir Punjab range they result in erratic rainfall, humidity and moisture conditions.

HISTORICAL EVIDENCE: LESSER NORMALS!

Table 14: 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 w.r.t. Rainfall Normals		
			Normal	Excess	Low
Bilaspur (300-900m)	1256.7	37	18.92	40.54	40.54
Hamirpur (300-900)	1462.6	32	15.63	40.63	43.75
Una (300-600m)	1209.0	31	12.90	58.06	29.03
Mandi (900-1800m)	1564.6	45	13.33	42.22	44.44
Chamba (1800-4500m)	1355.1	35	5.71	37.14	57.14
Kangra (600-900m)	1852.3	39	5.13	30.77	64.10
Sirmour (300-900m)	1688.7	46	8.70	47.83	43.48

Shaded portions only depict clubbing of altitude classes to compare (these all are adjoining districts with large valley formations) as these are adjoining regions and lie over more or less in the same longitude!
Variance seen across the agro climatic regions

Peoples' perceptions of climate change

While studying peoples' perception of climate change, local farmers confirmed that their investments in cash crops and horticulture have increased and that this has increased their economic vulnerability because of the variations in weather conditions, which have become erratic. Besides, monoculture in horticulture and in agriculture have destroyed forest diversity and reduced productivity. They feel that the decrease in the biodiversity is because of the change in agricultural patterns. Some of them have opined that risks are higher now with mono-crops and getting back to the traditional system of multiple cropping may help them adapt to climate change.

They feel that the invasion of species like raja-grass and lantana has also affected biodiversity and reduced the fodder. As a result of which, they now have fewer cattle. Women say that it is harder to find firewood, as the lantana has taken over the shrub areas

The local people have observed that there is an increase in erratic precipitation and some years are particularly bad. For example, this press clipping shows that in 2010, 62 lives were lost and over 6000 houses and about 17000 km of roads were damaged.

They also observed that only a few decades ago, such episodes of high precipitation would take place once in two or three years but now it was more frequent. Some elders observed that the rainfall was spread more evenly, was gradual and prolonged which enabled better snowfall. But now with shorter bursts of more rain, the glaciers would melt faster and retreat faster. They spoke about how there used to be about two feet of snow in certain reaches, which is no longer there

Fog-like conditions are getting prolonged. For instance, in 2008 some of the plains did not see sunshine for more than 120 days. The abrupt changes in temperature patterns also disturb the sowing and harvesting cycle. Local people have testified to longer and more intense warmer periods and shorter winters. Many people say that the production of cereals have dropped down. One reason for this is the increasing instances of pest attack.

Table 15: People's perception of climate change

Rainfall	
Normal precipitation	10%
Increased erratic precipitation	90%
Duration of winter	
Decrease in duration of winter	75%
No change	12.50%
Increase in duration of winter	2.50%
Can't say	10%
Intensity of summer	
No change	7.50%
Increase in Temperature	85.00%
Can't say	7.50%
Production of cereal	
Decreased	77.50%
No change	10%
Increased	12.50%

Incidents and episodes of impacts of climate events on land based production systems

The following are compilation of quotes from news reports mainly from Himachal Pradesh, archived at Environics Trust alongwith remarks on climate vulnerability aspects of these episodes.

Wheat and Cereal Crops

As per the National Wheat Research Centre's analysis a long dry spell in 2010 affected the wheat crop in the lower hills. Later, heavy rain accompanied hailstorm and high velocity winds flattened the remaining ripe wheat crop. The yield of the wheat that year fell by 20-30 percent due to hostile weather at the time of harvesting. However, as already mentioned, ginger production in HP rose to 21,267 tonnes in 2010-11 which is an increase of over 6000 tonnes from the previous year.

Fruit production

Longer dry seasons in the valley have created disturbances in the sowing and growth of different crops. If the trend continues, it will also severely affect the fruit crops The Himachal government claims that approximately 900 crores worth of fruit crops has been lost over the last three years. Kothgarh-Thanedar, one of the prominent apple growing belts in Shimla district, was severely impacted in 2011. Cherry, pear and peach was also affected. For instance, in 2009, over 30 % of the crops standing at the height of 4000-5500 ft. were damaged due to hailstorms. There has also been a reduction in the chilling period required for the fruit crops due to shorter winters. Thus there is now a search for shorter-chilling-period varieties of such fruit.

The higher reaches of Shimla, Kullu, Mandi, Chamba, Kinnaur and Lahaul and Spiti are ideal for cherry cultivation which flower in March-April. As per the horticulture department estimates, at least 10,000 farmers, most of them with small land holdings, grow cherries over an area of 374 hectares. Explaining the rationale for opting for cherry cultivation, Dogar, a farmer says the fruit requires less care than apple and fetches 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.' Many farmers in Shimla, Kullu, Chamba Kinnaur, and Mandi districts have gone in for growing Kiwi fruit which is an exotic fruit but does not have a wide market. Though Kiwi has high export potential it is not a staple of these areas. The only market for them is in the mega cities. Thus exotic species are coming in due to climate variability, and farmers have to be subsidized to the tune of Rs. 22,000 per hectare to sell their produce in faraway places like Delhi thereby increasing food miles.

Farmers in Himachal Pradesh are moving from cultivation of traditional crops like apples to growing the more exotic nectarine. Nectarine, an American species, 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. Other horticulture crops like cherry, kiwi, apricots, strawberry, olive, almonds and plums are also expected to replace vulnerable crops like apple which constituted more than 80 % of the horticultural produce of the area.

Another adaptation has been the introduction of some citrus fruits like orange, kino, malta etc. Oranges are grown in over 25,000 hectares of land in the State. 80 percent of such cultivation is done in Kangra valley. "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.

Sirmour in the temperate zone accounts for 90% of the estimated production of strawberries: in the state of Himachal Pradesh. Along with the Poanta,– Dhaula Kuan 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.

Vegetables

There has been an increase in vegetable cultivation area from 25,000 hectares to 50,000 hectares and the economy of the Kandaghat area of Himachal Pradesh depends on tomato, capsicum, brinjal and cauliflower. The drought like situation in 2011 has damaged over 60 percent of the crop.

Farmers in Shimla, Solan, Sirmour, Kullu, Una and Kangra are increasingly looking forward to growing vegetables like cabbage, cauliflower, peas, tomato etc. when they are off season in other areas. Taking advantage of different climate conditions, they grown these vegetables when they fetch a high price in the markets in the plains. For example cauliflower is grown from april to june. In fact the 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

Forest Fires

An increasing number of forest fires have been reported, perhaps due to a rise in average temperature, or the heat island effect because of the large construction activity relating to dams and other projects. The fires could also have erupted due to the long dry spell and unprecedented hot weather. In 2009, the meteorological office (HP) stated that the mean maximum and minimum was 1 to 4 degrees C above average. In that year, 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.

It is estimated that around 7900 hectares of forest land have been destroyed due to unprecedented fires. These fires impact the bio-diversity in the area. Himachal is home to 36% of the country's bird species. According to the Council for Science, Technology and Environment, there are 447 animal species in Himachal out of 1228 reported for the whole of India. Similarly, 77 species of mammals (snow leopard to Himalayan Tahr) are found here. The forests also support 3,120 species of flowering plants, including 187 species of medicinal plants.

REDUCING RISKS DUE TO CLIMATE CHANGE

It is quite clear from the preceding chapters that marginalized communities in the Himalayas are highly depended on the natural resources that are sensitive to the changing climate, and therefore they are highly vulnerable to climate change. As in other eco-regions, the risks that marginalized communities face need to be specifically addressed and in the context of the Himalayas. Through dialogue with mountain communities, this study has identified the following adaptation measures for (a) reducing vulnerability to major impacts (b) increasing resilience in the face of environmental changes which affect livelihood and (c) improving the adaptive capacity of the society

A. Measures to Reduce Vulnerability.

Vulnerability is reduced by addressing the physical, social, economic, and environmental effects of critical climate change related impacts. These include crop insurance to minimize loss due to crop failure or climate events, early warning system to prevent loss of life in major events, prevention measures to reduce flash floods, and management of water resources.

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). The Agriculture Insurance Company of India, an Indian government-owned company, is the implementing agency. The premium is subsidized for small and marginal farmers. The scheme is compulsory for all the farmers who take agricultural loans from any financial institution. It is voluntary for all other farmers. The current dispensation incentivizes only those who take loans to buy external inputs and cultivate cash crops and sell their produce in the market. The scheme needs to be extended to all, particularly those who use less external inputs as in organic farming and multiple cropping particularly of subsistence crops. Such crop insurance can be of enormous help for communities completely dependent on sustainable agriculture but also face risks against climate variability and change. Appropriate agriculture extension services and support from a network of civil society organizations, can also ensure those farmers who suffer less due to better management and use of self-labour, do get compensated at the same rate as the others, thereby incentivizing appropriate climate resilient practices. While crop insurance will not increase the yield or profitability in a normal year, it will surely reduce the adverse impact of crop failure due to climate issues and incentivize climate resilient strategies.

2. Early warning system

Recent disasters in the Himalayan region like the earthquake in Sichuan, China; cyclone Nargis in Myanmar; the outbreak of the Koshi barrage embankment in Nepal; and the 2010 floods in Pakistan remind us of the devastating and catastrophic effects on the lives of people in this region.

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.

In a voluntary initiative APRSAF (Asia-Pacific Regional Space Agency Forum), five countries -- Japan, India, Thailand, Taiwan, and Korea -- are providing earth observation data to Sentinel Asia members during major disasters using locally mirrored servers not only via Internet but also using communications satellites. When a region in the Himalayas asks for support in an emergency, Sentinel Asia would be able to provide appropriate products to a regional knowledge centre in Nepal, which can then forward it to the concerned governments. There is an urgent need to have fully capacitated comprehensive disaster management units that have access to this satellite data and have the capacity to use it. The earth observation would facilitate the monitoring of an event as it unfolds and act as a early warning system to trigger prepared response plans.

3. Flash flood prevention

Normally flood prevention programmes involve building large-scale structures like building of embankments, dams, and levees. These have often proven to be disastrous, as when breach occurs, the impacts is many times more disastrous. Further in the case of the Himalayas, it is difficult to predict the exact location, magnitude, and extent of most flash floods. There are however many non-structural measures that can help to reduce the impact of floods, ranging from land use planning,, construction codes, and soil management. 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).
As Himalayan communities face such events on a regular basis, there is plethora of local solutions based on indigenous knowledge. These need to be integrated into broader plans. Further these plans should built on and incentivise individual households strategies and the latter should be recognized, promoted and improved upon. All these

are essential to create a robust community-based flash flood risk management plan. Such local plans are essential as external help can take several days to reach affected communities and locations. It is therefore essential that community's capacity to manage the risks from disaster by themselves is strengthened. These include post catastrophe recovery plans, alongwith awareness raising, public information of emergency plans, drills as well as tools like insurance. Further a decentralized peer to peer network needs to be established based on wi-fi and radio technology to help local groups to take and modify decisions based on unfolding scenarios. The advantage of such systems in non-disaster times is that it can be used for communications at low cost between groups of communities,

4. Managing water resources

The most important long term impact of climate change is the availability of water resources. Due to climate change(including glacial melt) and mismanaged development activities the flow of water into the natural storage systems is going down, resulting in a shortage in the lean path of the water cycles. Other impacts of climate change are flash floods, lakes outburst floods, heavy run-off induced landslides etc. All these impacts can be attenuated if we have a comprehensive framework integrating the water systems in cryosphere, biosphere and built environment of the entire river basin from the snow peak through the plains onto the deltas.

Glaciers, ice-fields, snow packs are important regulators of water storage and release spanning intra annual and multi-year cycles. Climate Change is expected to disturb the current patterns, making water flow and its impacts on floods more unpredictable. Thus the melt water process and glacial changes need to be monitored, researched and predicted in order to help reduce vulnerability.

The Himalayas also has around 665 sq km of **wetlands**, and about 8790 **glacial lakes** with a total area of 800 sq. km. Their role in regulating flow as well as triggering outburst floods, also needs to be studied. While they have the potential of acting as major water storage, the risk of outburst floods can reduced using appropriate technologies along the lines of the initiatives in the Andes in South America. The knowledge and practices of the local communities who have worked in these systems are essential to develop appropriate local system oriented solutions for wetland conservation, and water use. Downstream users need to reward upstream communities for maintaining such systems, in order to ensure its continuance and avoid adversarial use plans, as is the case with most big dam projects.

Watershed management

Soil moisture and sub-surface water play a vital role in water flow regulation. With the increased intensity of rainfall, watershed development will go a long way to moderate runoff. Improved land cover, water conservation practices, low tillage farming, thick leafy trees, bio-diverse forests, small gully plugs and check dams etc help water retention and increase soil moisture and sub-surface water. Further rain water harvesting systems, built structures such as ponds and tanks, which is an age-old practice in the region are designed to take in and reduce run-off. The problem is in modern structures like roads which could have been designed to enhance percolation, using appropriate technologies like permeable paver blocks, channeling, avenue plantations in swales etc.

Groundwater Aquifers

They provide much needed water for drinking and agriculture during dry spells and therefore many of the villages are situated near an active aquifer. There is very limited scientific knowledge about the groundwater aquifer systems in the Himalayan region. Detailed studies need to be conducted 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

In the past, India and China have constructed numerous dams in the Himalayan region. These have displaced communities and increased seismic and out-burst risks. Sedimentation has also decreased the storage in these dams, reducing their usefulness. However, if the natural lakes are used to harness and store glacial and snow melt-water at high altitudes, 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. It would also be useful to have small dams of less than 0.75 million cu.m embankment volume. The cost of such projects much lower and the water would be made available much closer to the communities. Though the evaporation loss in these small reservoirs is high due to the higher surface area to volume ratio, the humidity is spread across the region. In order to use them effectively there is a need of active community participation. Being small such structures permits a mechanism wherein the local community can have significant control over the maintenance and running of the reservoir and can allocate water to local farms and families.

B. Increasing Resilience

Resilience to climate change can be built up by promting a) better knowledge of ongoing changes, b) protection of the resource base and preservation of the diversity of crop and livelihood options c) developing diversity of livelihood and d) creating alternative livelihood opportunities is essential if these communities have to preserve their way of life.

1. Enhancing observational and monitoring network

Systematic collection of data and information about the Himalayan mountain system is critical for improved understanding of climate change and its impacts and therefore build community resilience around it. The key areas include glaciers and snow cover, snowmelt dynamics and river water flows, water basins and recharge locations, weather and climate trends, land degradation, land use change and energy systems. There is also need for information on critical biological systems like habitats (ecotones, wetlands, alpines, etc.) and species (native, endemic, and economically valuable, etc.), ecosystem structure and its diversity and resilience and ecosystem functions including carbon sequestration and water relations.

Data on global trends and well as regional and local trends on each of these areas need to be collated in order to inform adaptation strategies and appropriate development interventions for the benefit of mountain communities in the region.

The earth observation data is important as large areas are inaccessible. 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 being continuously improved and converged, this making comparison and exchange easier.

To enhance meteorological observations over the western Himalayas, 26 surface observatories and two 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 western Himalayas is carried out through a combination of various products viz., regional/ meso-scale 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. 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.

2. Seed Management

The varying precipitation and temperature patterns in the region have been increasingly moving outside the tolerance range for the hybrid and green revolution seeds currently used the farmers. These seeds, purchased from the market are specifically bred for uniformity, better response to fertilisers and specific environments. Thus crop loss in addition to the cost of the seed and the other inputs required is high in bad years. This makes the farmer very vulnerable to climate change. Post 1980s, farmers in Himalayas, as in other places, had moved away from the practice of using their own seed and purchased hybrid and HYV seeds from the market. Their knowledge base on seed saving, breeding and non-chemical farming practices was also diminishing. Fortunately many of the diverse varieties of seeds of cereals, millets, pulses, vegetables, fruits, flowers etc are still available in remote areas where penetration of green revolution was not complete. Fortunately also for the region, the green revolution did not take effect till 1980, and did not permeate the entire Himalayan belt. Some of the germ plasm may have been preserved in research institutions, new varieties can be developed only through laboratory research and the resultant seeds may not be virile and adaptable to changing conditions. Traditional varieties on the other hand are more virile and can develop into resilient varieties through in situ propagation and simple techniques. For this farmers will have to go back to producing seed and exchanging them with their neighbors and families.

It would be critical at this point to create seed banks of local indigenous varieties to save them from extinction

3. Crop Diversification

Farmers in the hills are known to grow a variety of crops necessary for survival in isolated settlements in a highly variable and uncertain biophysical environment. There are high 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. However, as the local economy has moved from subsistence to market, staple food crops have been replaced cash crops and from multipurpose agro-forestry trees to fruit plantation mainly apple orchards. This has been incentivized by the subsidised supply of staple food grains by the government.

Meanwhile farmers have reported increasing pest attack. Higher prices of fertilizers and pesticides have increased farmers vulnerable to even a small variation in crop yields. As mentioned in the previous chapter, some farmers have diversified into other crops like Nectarine, and out-of-season vegetables. While the horticulturist can look forward to revitalizing the other non-timber forest produce, the agriculturist is planning multi-crops, and inter cropping and therefore increase their resilience. The question therefore is-- will the official policies and scheme of incentives and subsidies promote resilience and provide incentives for producing and using indigenous seeds? Will it support growing native varieties of staple and local foods and multi cropping for the agriculturists? And finally will it allow for policies which would fairly value to the gatherers of non-timber forest produce and medicinal plants? Instead of paying for adaptation, would the government opt for an economy of diverse traditional practices as a means for building resilience to 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 manifold. 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. 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.

The same holds true for mountain tourism, which, despite its enormous potential within the region remains largely underdeveloped, Models of tourism which benefit the local population in the form of sustainable and non-exploitive employment and supply of services and local products are particularly wanting. 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

The capacities of the communities to adapt to climate change needs to be enhanced by enabling decision making through better data and information. Supportive systems like crop insurance,

finance and community based institutions need to be enhanced.
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). Collective action enhances social networks which can serve to reduce economic vulnerability of the community. It provides a framework from which to discern and solve problems, contributes to individual and collective empowerment. This in turn can strengthen links with local government and facilitate quicker action in times of disaster and natural hazards. If social networks are strengthened, they will ensure replication and scaling of such activities.

While ascertaining the view of the communities during this study, they expressed the need to strengthen social networks and develop institutions which would foster communication and collective action among isolated community groups.
Several research reports have also supported this view. There are already many instances of organizations facilitating the formation of a voluntary collective of locals people (SHGs, cooperatives etc.) to pursue shared interest. For example 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 to impact of climate change on agricultural production. In a similar case, an NGO helped create a women collective which specializes in jam and honey production in their 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.

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