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Environmental Volatility in the Himalayan Cold Deserts

Rapid-Onset Disasters in the Himalayan Cold Deserts

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The cold deserts Himalayas have always been prone to frequent rapid-onset disasters such as snowstorms, avalanches, landslides and glacial lake outburst floods. With climatic volatility on the rise, the inhabitants have to face recurrent hazards, which cause tremendous damage to life and infrastructure. The region however, does not receive adequate research and policy attention. This report summarizes the findings of a study to assess the vulnerability of the region to rapid-onset disasters and to identify the contributing factors. It also deals with the environmental, economic and social consequences of such events and the existing and potential mitigation measures for a range of stakeholders.

Recent years have seen an unprecedented increase in natural disasters and their horrifying effects around the world (2001 Gujarat earthquake, 2005 Hurricane Katrina, 2004 Asian tsunami etc). Rapid-onset disasters come unannounced and cause extensive impact on human life and property (an average of six flood events occurred in India, which affected a reported 40,000 people). Due to their nature of onset, mitigation measures are mostly limited to relief and recovery, which are reactive in approach. However, nowadays, disaster management is making a paradigm shift from reactive approaches like relief and recovery, to more proactive approaches like prevention and reduction of disaster events, and preparedness.

The UN defines disaster as, "A serious disruption of the functioning of society, causing widespread human, material or environmental losses, which exceed the ability of affected society to cope using its own resources." The National Institute of Disaster Management (NIDM), India recognizes that frequent disasters lead to erosion of development gains and restricted options for the disaster victims.

Disasters can be categorized based on the nature of their onset. While some disasters may occur within seconds (earthquakes), minutes (tornadoes) or hours (flash floods), others may take months or years to manifest themselves (droughts). The former category comprises rapid-onset disasters and is characterized by the sudden and acute intensity of the impacts during a short period. The severity of rapid-onset disasters is usually quantified by the loss in terms of human lives and property for a particular disaster event. Owing to its nature of onset, rapid-onset disasters do not give people adequate time to mitigate the risk of an event occurring. Unlike in the case of slow-onset disasters, a flood or landslide event can occur suddenly, giving people little or no time to evacuate and mitigate the impacts.

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The fragility of the Himalayan region and its geo-tectonic characteristics as well as its extreme sensitivity to climate change have rendered it highly vulnerable to rapid-onset disasters of hydrologic, meteorologic and geologic nature. The remoteness and inaccessibility of the region make effective and timely response a challenge, and the incomplete understanding of its environmental dynamics makes preparedness and alert/early warning measures difficult as well. Till recent years, information on the occurrence of natural disasters in the region was rarely known to those outside, and even today information of events of extremely severe magnitude alone reaches the world beyond the ranges.

Pragya, an NGO working in the Himalayan region, has been working to draw attention to the environmental vulnerability and the escalating occurrence of natural hazards in the cold deserts of the Himalayas. During the period, 2006-2009, the organization has carried out an initiative in the region to map and document its vulnerability to environmental threats. The initiative involved the following:

1. A study to assess the vulnerability to disasters of 57 watersheds in Lahaul & Spiti, Kinnaur and Chamba districts, Himachal Pradesh and 25 watersheds in Leh and Kargil districts, Jammu & Kashmir. The study was essentially an attempt to understand the changing pattern of exposure to environmental threats in the cold deserts and how the perception to this threat has undergone a change over the years. Ground surveys involved Participatory Rural Appraisals (PRAs) blended with scientific field observations for a detailed analytical study.
2. A study to document the occurrence and impacts of major natural disasters and understand people's perception of threats due to impending disasters in the cold deserts region of India – the Western Himalayan districts of Leh (Jammu & Kashmir), Lahaul & Spiti and Kinnaur (Himachal Pradesh). This involved collection and perusal of all available data and reports on the region, as well as the eliciting community reports of disaster events in the area.

The key findings of the above-mentioned initiative have contributed to this paper.

VULNERABILITY OF COLD DESERTS TO RAPID-ONSET DISASTERS

Vulnerability of the cold desert region to environmental threats is increasing and the incidences of rapid-onset disasters of hydrologic/meteorological and mass movement nature have been on the rise with concomitant impacts on populations that inhabit the region.

Climate Change and Disaster Risk

The Pragya studies validated the relation between climate change and increase in disaster occurrence in the Himalayan cold desert region. Change in climate is found to have a concomitant change in the frequency of floods, droughts, avalanches and landslides (having a significant positive correlation) and similarly a threat to the livelihood and property of the people living in the region. Further, the relationship between altitude and climate change as well as disaster risk was explored.

Environmental Threat levels were found to be the highest at the very High Altitude belt (>3700 m) in cold deserts. Similar threat levels were observed in the Threshold Altitude belt for Himalayan cold deserts (2000-3000 m) with 50% of the watersheds facing moderate degrees of threat and another 50% facing high to very high degree of threat. Impact of climate change were found to be higher in the Highest Altitude belt (3700 m) where even small shifts in climatic parameters wreak havoc on the inhabitant communities; impacts are also high in the Medium Altitude belt (3000-3300 m), where high anthropogenic pressure threatens the equilibrium of the socio-ecological system.

Table 1. Disaster occurrence and threat perception in 82 watersheds in J&K and H.P.

District*	Threat perception*		
	Decrease in threat to life	Decrease in threat to property	Increase in threat to livelihood
Leh (25)	56% high	56% moderate, 28% significant	44% moderate, 28% high
Lahaul (18)	72% moderate, 33% high	77.8% moderate	77.8% moderate
Spiti (16)	69% very high	75% very high	69% very low
Kinnaur (13)	61.5% very high	84.6% high	69% very low
Chamba (10)	80% moderate	80% moderate	70% moderate

* The figures represent the number of watersheds surveyed

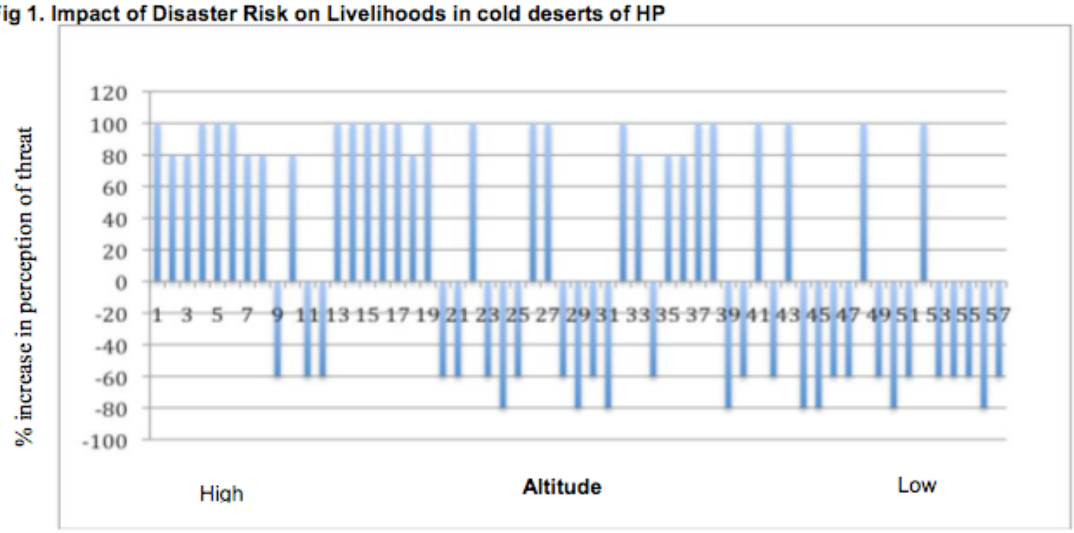
** The figures represent the percentage of watersheds surveyed

Extent of climate change, measured through change in amount and incidences of snow and rainfall, number of winter days, change in temperature, scarcity of water resources, retreat of glaciers, show higher levels of climate change impacts in the high altitude band, gradually diminishing towards lower altitudes; disaster risk also follows a similar pattern. However, there are regional variations in the datasets. For example, in Lahaul and Spiti, disaster risk is higher in the High and Medium Altitude ranges due to avalanches, landslides and occurence of droughts, but in the neighbouring district of Kinnaur, disaster risks are higher in the lower altitudes due to incidences of cloudbursts, flashfloods and Glacial Lakes Outburst Floods (GLOFs).

Along with the information regarding the frequency and trend of disaster occurrence, the study also tried to bring out the perception of threat of the Himalayan communities. The PRAs and key-stakeholder interviews revealed the changing pattern of their perception of threat to life, livelihood and property. The above table (Table 1) also brings to light the fact that in all these areas, there has been an overall decrease in the perception of threat to life and property. For e.g. in the district of Lahaul, out of 18 villages surveyed, 72 percent believed that there has been a moderate reduction in the threat to life while 77.8 percent believed it to be moderate in case of threat to property. Similarly, in Kinnaur, 61.5 percent of the villages surveyed believed the life to be safer than before and 84.6 percent believed the decrease in the threat to property to be high. This seems evident, as over the years the rescue and relief operations have shown tremendous improvisation, incorporating more technology-oriented approach. In addition, various insurance schemes introduced by the authorities have significantly brought down the threat to property in the hazard prone areas.

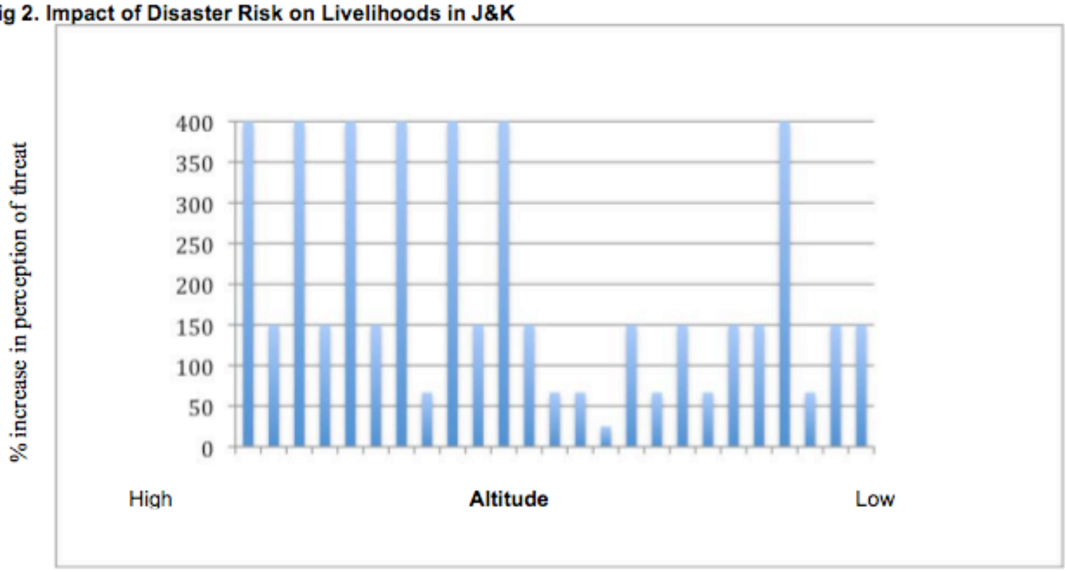
It is interesting to note that while the people believe their lives to be safer due to better communication, rescue measures and improved health facilities etc, majority of the villages surveyed were of the view that their livelihoods are exposed to a greater threat than before. This can be attributed to the change in climate and impacts of the concomitant disasters on livelihoods, and the frequent need for post-disaster reconstruction; it is also related to the fact that as the population in this region has increased, people have had no option but to move towards the otherwise perilous regions in search of livelihood. In addition, the changing climatic conditions has rendered this area ever more vulnerable to the environmental threats. Communities in isolated villages of higher altitudes perceived greater threat to their livelihoods. As fig. 1 shows, the perceived threat to livelihoods has increased over the year in Himachal Pradesh at altitudes above 3300 m, although threat levels are lower in the 2000-3000 m altitude.

Fig 1. Impact of Disaster Risk on Livelihoods in cold deserts of HP



Similar trends are seen in the cold desert region of Jammu & Kashmir. However, unlike Himachal Pradesh, where there were instances of people perceiving lesser threats due to improved market linkage, insurance and subsidy packages, government schemes etc, respondents belonging to Leh revealed a very high perception of threat to their livelihood due to increasing levels of the same. Over the year the level of uncertainties have increased, often described as four times the vulnerability, compared to the situation 20 years back.

Fig 2. Impact of Disaster Risk on Livelihoods in J&K



OCCURRENCES & IMPACTS OF HYDROLOGIC AND METEOROLOGIC DISASTERS IN COLD DESERTS

Every year disasters related to meteorological, hydrological and climate hazards cause significant loss of life and set back the developmental clock in such regions by years. The major types of hydrological and meteorological hazards that plague the cold desert regions are discussed as follows.

A. Floods and Flashfloods

Flash floods are defined as short duration floods with relatively high discharge[3]. They are extremely destructive, transporting huge amount of debris in the form of snow and rocks at a very high velocity. Every year they occur in this region causing massive destruction, rendering many communities homeless and disrupting livelihoods. These incidents are not new to the people in the Himalayas, who have been braving the unbending terrain since time immemorial. Presently however, in the wake of the changing climatic conditions, the hazards in the Himalayas have assumed a greater dimension. Various studies by the Intergovernmental Panel on Climate Change (IPCC) have suggested that as the impacts of global warming become more pronounced, there will be an overall increase in the precipitation pattern in the region[4]. This, together with the fact that the Himalayan people are not well equipped to face such kind of disasters, exacerbates the situation further.

Table 2. Flash flood incidents in the Himalayan region some columns of the table have gone missing

Date/ Period	Location	Reason	River	Direct cost (mill US $)	Dead	Displaced	Damages
1 Aug 2000	Kinnaur, Mandi, Shimla Districts of HP, India	Dam break from natural dams	Sutlej	625	41	611,000	20 bridges, Rampur water and sewerage scheme, 8 powerhouses, 722 houses, 12000 ha crops cattle lost, US $ 17 million worth of public utilities, 590 head of cattle.

26 Jun 2005	Kinnaur, Shimla, Kulu, Mandi Districts of HP, India	Dam breaks from natural dams	Sutlej	200	-	4650	200 km roads, 10 bridges, 10 hanging bridges, 1 powerhouse, 22 houses
7 Jul 2005	Kinnaur, Shimla, Kulu, Mandi, Chamba, Bilaspur, Sirmour, Kangra Districts of HP, India	Cloudburst	Beas, Sutlej and their tributaries	140		8,73,900 affected (This includes incident No. 2)	47800 ha crops, 2024 houses 3049 head of cattle lost, 8962 ha land lost, 59,873 ha agriculture land covered by debris from landslides and siltation
29 Sept 1988	Kinnaur district of HP, India	Cloudburst and dam break from natural dam	Sutlej	-	-	32	2 km of road, bridge, orchard and 15 houses
31 Jul 1991	Lahaul & Spiti district of HP, India	Dm break from natural dams	Maling Nalla/ Spiti	-	-	-	Road section, bridge and farm lands
1950-1990	China	-	-	-	152,000	-	-
1950-1990	Nepal	-	-	-	400	-	Loss of infrastructure worth US$ 205 million
2005	Afghanistan	-	-	-	362	100,000	-

The flash floods in the Himalayan region occur due to many reasons and are of many types[5].

1. Intense Rainfall Flood (IRF)
2. Glacial Lake Outburst Flood (GLOF)
3. Landslide Dam Outburst Flood (LDOF)
4. Rapid Snow/Ice Melt Flood (RSMF)
5. Ice Dammed Lake Outburst Flood (IDLOF)

The Western disturbances from the Mediterranean cause a lot of precipitation in the form of snow, in the winter season. A consequent abnormal warming in the spring season, (a repercussion of climate change) leading to rapid snow melting can cause flash floods. Flash floods events can be triggered by many factors like heavy downpour due to cloud burst, failure of natural or man-made dams, sudden release of water from glacial lakes (in which case it is called as Glacial Lake Outburst Floods). Whatever be the reason, the outcome is unequivocally devastating for the downstream riparian. Since predicting the onset of any of these events is very difficult, therefore the prediction of flash floods becomes all the more difficult. The gravity of the situation can be adjudged by the figures shown in Table 2 above.

B. Glacial Lake Outburst Floods or GLOFs

Glacial Lake Outburst Floods take place when naturally dammed lakes in a glacier or the margins of a glacier drain out. "Glacier floods represent, in general, the highest and most far-reaching glacial risks with the highest potential of disaster and damage[7]." Studies suggest that the warming in the Himalayas has been much greater than the global average of 0.74^{o} C over the last 100 years. This enhanced warming has accelerated the ablation of the permafrost with many glaciers retreating at a rate as high as 20m per year[9]! When glaciers move, they deposit rocks and sediment in the form of ridges and along their course. These deposits are called moraines and can be of various types depending on their position – terminal (at the end or snout of a glacier), median (running along the centre of a glacier) or lateral (depositions along the sides of a glacier).

In the Himalayan region, accelerated glacial melt has caused the formation of glacial lakes behind open moraine ends. An increase in the level of these glacial lakes due to higher rates of melting can exert an excessive hydrostatic pressure on moraine dam walls, which puts them under constant threat of breaching suddenly due to some trigger events like earthquakes, avalanches, landslides etc. This can cause a rapid gush of water and debris to flow downward, which can be very dangerous considering that it is a sudden phenomenon, and has the potential to inflict huge damage downstream. GLOFs are not a new phenomenon, but there is evidence that the frequency of such events has increased over the past three decades. Moreover, satellite studies have shown a considerable decrease in the snow cover of many of glaciers indicating the disaster that looms large. India has about 2554 glaciers and 156 glacial lakes out of which 16 have been declared dangerous[10]. With increasing temperatures, the number and severity of GLOF incidents can only be expected to rise[11]. It is unfortunate, however, that they have not received adequate attention from policy makers leading to high vulnerability and very low preparedness level among the people affected which make the impact of any glacial lake outburst event even higher.

GLOFs can affect areas up to hundreds of kilometer downstream and the discharge can be as high as 15,000 m^3 per second! GLOF events have known to cause extensive damage to the life, property, forests, farms and infrastructure of the mountain areas. In one such instance, the nearly complete Namche Hydropower Plant (estimated cost of $ 1.5 million) was washed away in Nepal in 1985. About twelve such incidents have occurred in the Tibetan region since 1935 and almost every country of the Himalayan region has faced a glacial lake outburst event. In India, GLOFs have known to occur in regions of Ladakh and in some areas of Himachal Pradesh like Kinnaur, and Shimla. In 2005, the Parechu outburst flood in the Sutlej valley caused a considerable damage to the downstream riparian region.

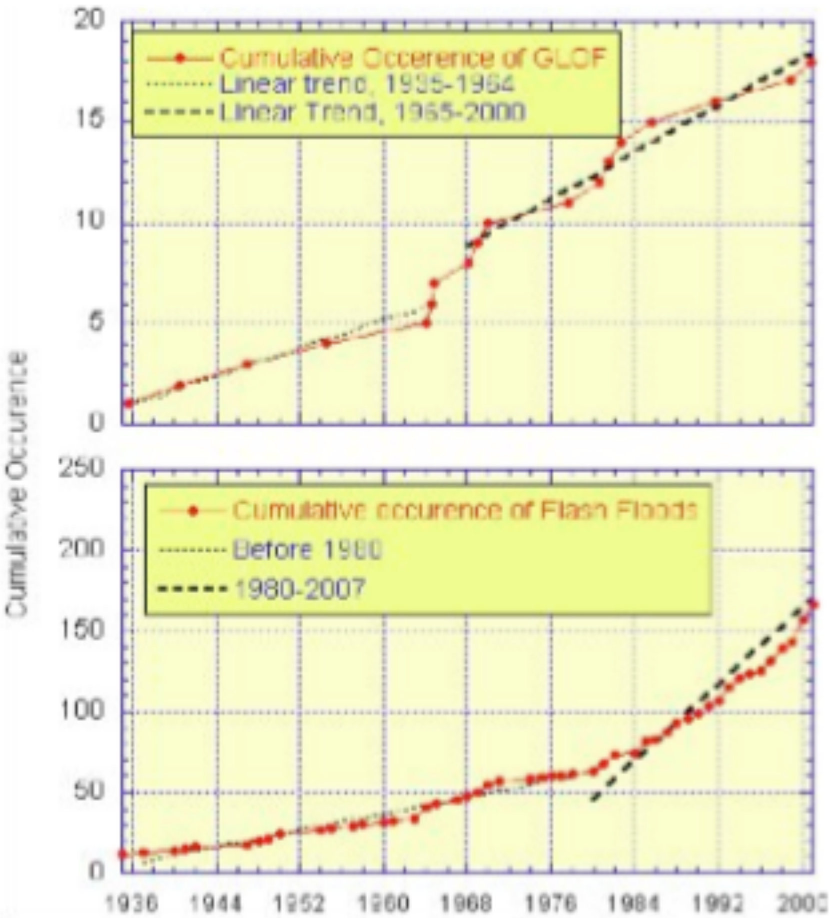


Fig 3. Incidence of GLOFs
Source: ICIMOD

C. *Snowstorms*

A snowstorm is when a large amount of snow falls from the sky as precipitation. Snowstorms happen when a mass of very cold air moves away from the polar regions. When it collides with a mass of warm air, the warm air rises quickly and the cold air cuts underneath it. This causes a huge cloudbank to form, leading to heavy snowfall. Snow will only fall from the cloud if the temperature of the air between the bottom of the cloud and the ground is below 4º C.

Large snowstorms could be quite dangerous – a 15 cm snowstorm will make some unplowed roads impassible, while a 30 cm snowstorm will cave the roofs of some homes and cause loss of power. Standing dead trees can also be brought down by the weight of snow, especially if it is wet or very dense. Even a few inches of dry snow can form drifts many feet high under windy conditions. Sub-zero temperatures, arctic conditions, and strong winds in mountainous regions pose additional threats. A blizzard is the worst kind of snowstorm, in which strong winds blow snow into snowdrifts (huge piles) that can bury people and possessions. Properly defined, it is a tempestuous, frigid snowstorm with blustery, piercing winds of 15m/s or more and a wind-chill factor as low as -30º C. Blizzards carry the risk of hypothermia, frostbite, suffocation, and being stranded. Transportation is difficult and dangerous during blizzards because air temperatures can be -12º C or lower, with visibility less than 150m. When there is so much snow that people and animals cannot tell the earth from the sky, it is known as a whiteout. In this disoriented state, humans and livestock can lose their way and freeze to death. Severe snowstorms in the winter of 1997-98 for instance affected more than a quarter million mobile pastorals in the Tibetan Plateau region and led to the death of more than 3 million heads of livestock with hundreds of families losing their cattle. In October 2008, four people went missing in an unusual early snowstorm in the higher reaches of Chamba hills in Himachal Pradesh. In another unfortunate case, six people died in Tibet snowstorm on October 30th, 2008 in Lhasa.

D. Impacts

As the effects of climate change and the concomitant glacial melt are beginning to show in the Himalayan region, the threats associated with natural hazards have increased manifold. In the face of augmented threats, communities that were earlier resilient are now finding it increasingly difficult to survive and adapt to the rapidly changing climate.

1. **Economic impacts:**

a. In case of GLOFs and flash floods, the massive flow of debris along with water causes extensive damage to life and property downstream. Most often, the downstream riparian are caught completely off guard thus elevating the damage.

b. Livelihoods are adversely affected as agricultural and horticultural fields are washed away. Damage to the livestock also adds to the misery of the people. Trade suffers due to closing down of the market routes.

c. The public infrastructure such as roads, railways, bridges, and communication system are damaged during such events, which not only adversely affects the livelihoods but also delay rescue operations. Other economic assets like hydropower projects also suffer since they need to be closed down for some time, leading to loss of revenue. For e.g. floods carry huge rocks and boulders along causing serious damage to the power project infrastructure.

d. Sometimes the spell of a snowstorm can be as high as 7-8 days with an intensity of 9-12 cms/hr. This causes a lot of damage to the pastoral communities, who are not able to graze their livestock if the snow cover lasts long. It has an adverse effect on their livelihood.

2. **Social impacts:**

a. Community assets like hospitals, schools, *panchayat ghars* (community halls) are washed away or may get severely damaged. This not only causes infrastructural damage but also adversely affects the relief operations. Similarly, destruction of schools adversely affects the education of the children.

b. The impact of such disasters is hardest on the most vulnerable groups of society comprising the women, differently abled and children.

c. A continuous threat can cause rural to urban migration that in turn has serious social, economic and cultural implications, both for the urban as well as the rural areas. While the men migrate to the urban areas in search of better livelihood options, it is left to the womenfolk to look after the family and run the household. As most of the urban agglomerations are devoid of basic amenities including water and sanitation, this can become a huge social menace for the country as a whole.

d. The day-to-day activities of the people in these areas are affected. For e.g. although a snowstorm has a localized effect it still causes huge disruption in the daily activities of the Himalayan people.

3. **Environmental impacts:** These kinds of events also inflict huge damage on the environment and the biodiversity of the area. For e.g. while an event like a flash flood or GLOF can turn fertile land to barren land, events like snowstorms can destroy trees and forests. Also, it seems quite evident that a continuous exposure to such threats can have adverse effects on the biodiversity of the region, which is already losing its ability to adapt under the wake rapidly changing climatic conditions.

MASS MOVEMENT

Mass movement describes a quantity of debris/land/snow or ice that slide down a mountainside under the force of gravity. It often gathers material that is underneath the snow pack like soil, rock etc. Such movement is generally along a well-defined surface confined to a limited portion of the slope. Some of the hazards related to this phenomenon are as follows:

A. Landslides

Landslides are defined as the mass movement of rock, debris or earth down a slope and include a broad range of motions whereby falling, sliding and flowing under the influence of gravity dislodges earth material. They often take place in conjunction with earthquakes, floods and volcanoes. Landslides are a part of the Himalaya environment because the slopes are weak and are made up of friable rocks. If the slopes were thickly forested, a major landslide would occur once in 20-30 years. With deforestation becoming the order of the day, minor landslides are occurring with increasing frequency[14].

The two regions in India most vulnerable to landslides are the Himalayas and the Western Ghats. The Himalayan mountain belt consists of tectonically unstable younger geological formations subjected to severe seismic activity. Compared to the Western Ghats, slides in the Himalayas are huge and massive and in most cases the overburden along with the underlying lithology is displaced during sliding, particularly due to the seismic factor. Landslides can be caused by poor ground conditions, geomorphic phenomena, and natural physical forces and quite often due to heavy spells of rainfall coupled with impeded drainage. Factors triggering landslide are heavy rainfall, increased pore pressure in the slope forming mass, increased weight of slope forming mass, removal of vegetation cover, weak rock and soil of the slope forming mass, steep slope, removal of support at the toe and ground vibration during earthquake.

Going by the geological clock, the Himalayas is a "young" mountain range, and is prone to natural disasters. Experts also say that they are one of the most erosion-prone ranges. Rainstorms and earthquakes make these mountains prone to frequent landslides and intense rainfall is the primary factor that triggers landslides. Prolonged downpours often reactivate old landslides. Large-scale deforestation (which loosens the soil) and faulty farming practices (extensive terrace farming) have also led to soil erosion, according to local people. The increase in human activities along the slopes has changed the existing land use pattern. The crop pattern has also changed with villagers growing less soil-binding crops such as rice instead of millets, the latter being more suited to this area. Local crops like millets and maize have taken a backseat while commercial and water intensive crops like paddy are grown, making the hills unstable.

Table 3. Types of landslides

S. No.	Types of landslides	Description
1.	Falls	Abrupt movement of materials that become detached form steep slopes or cliffs, moving by free-fall, bouncing and rolling.
2.	Flows	General term including many types of mass movement, such as creep, debris flow, debris avalanche, lahar and mudflow.

3.	Creeps	Slow, steady down slope movement of soil or rock, often indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences.
4.	Debris flow	Rapid mass movement in which loose soils, rocks, and organic matter combine with entrained air and water to form slurry that then flows down slope, usually associated with steep gullies.
5.	Debris avalanche	A variety of very rapid to extremely rapid debris flow.
6.	Lahar	Mudflow or debris flow that originates on the slope of a volcano, usually triggered by heavy rainfall eroding volcanic deposits, sudden melting of snow and ice due to heat from volcanic vents, or the breakout of water from glaciers, crater lakes, or lakes dammed by volcanic eruptions.
7.	Mudflow	Rapidly flowing mass of wet material that contains at least 50 percent sand, silt, and clay-sized particles.
8.	Lateral spreads	These often occur on very gentle slopes and result in nearly horizontal movement of earth materials. Lateral spreads are caused by liquefaction, where saturated sediments (sands and silts) are transformed from a solid into a liquefied state, usually triggered by an earthquake.
9.	Slides	Many types of mass movement are included in the general term 'landslide'. The two major types of landslides are rotational slides and translational landslides.

Modified from Varnes 1978 cited in Landslides (www.saarc_sdmc.nic.in)

B. Avalanches

A snow avalanche is a rapid flow of snow down a slope typically occurring in mountainous terrain. It takes place in areas where there is a rapid accumulation of a huge mass of snow. The snow may begin to slide downhill at a very fast pace due to the increase in stress. This increase in stress can be due to many reasons – wind drifting, heavy snowfall in a short span of time, blasting, seismic activity or even thunder. In terms of frequency of occurrence, mass, energy and magnitude, snow avalanches account for a considerable proportion of the earth's contemporary mass movement activity. The upper tracts of the cold deserts remain under a perpetual cover of snow and it is here that thousands of avalanches occur involving the movement of thousands of tons of ice and vertical displacement of over 1500m. In the high mountain peaks of the world like Everest, Lhotse, and Nuptse, avalanches occur frequently and they provide a spectacle for the visitors. But these avalanches do not really affect human lives. It is the avalanches that occur near human settlements that are feared most, especially in the barren cold desert regions.

Snow cover on a slope tends to slide down the slope because of gravity. Conditions affecting stability include the gravitational force component of snow, and resisting forces, such as the frictional resistance of the slope or the anchoring effect of shrubs.

In general, avalanches are caused when this balance is lost and when the forces exceed the resistance. Avalanches are rarely observed closely since they normally occur during a short time period of one or two minutes[16]. Major causes of avalanches can be classified into fixed (prime factors) and variable factors (exciting factors), such as weather conditions and the weights of the snow cover, Avalanches occur when these factors are combined. The types and scale of avalanches can differ depending on the combination of these various factors and their scale. Major prime factors and exciting factors are shown in the following table.

Table 4. Major Causes of Snow Avalanches

<table>
<tr><th>Item</th><th>Description</th><th>Factor</th></tr>
<tr><td rowspan="2">Prime factors</td><td>Topographic factors</td><td>Inclination of slope
Shape of slope
Location (ridge line or toe of slope)
Orientation of slope</td></tr>
<tr><td>Vegetative factors</td><td>Vegetation cover and height of trees
Vegetation cover and its thickness</td></tr>
<tr><td rowspan="2">Exciting factor</td><td>Weather factors</td><td>Depth of snow cover
Depth of snowfall
Wind velocity
Atmospheric and snow temperatures</td></tr>
<tr><td>Other factors</td><td>Increase in weight of snow cover because of snow dropping from cornices or snow covers
Vibrations such as earthquake or the sound of gunfire</td></tr>
</table>

Several cases of avalanches have been reported in the past. Kalpa, the old headquarters of Kinnaur district, Himachal Pradesh, was under a constant threat of avalanches in winter and this was one of the reasons for shifting the headquarters to Reckong Peo. In 1838, Tunda village in Ladakh was completely destroyed by an avalanche, leaving 16 people dead. In recent memory, avalanches wrecked havoc in the Pin Valley of Spiti, India, in 1978. In 1998, heavy snowfall in Ladakh, North India, in October, trapped herders and livestock, many of whom subsequently died of cold and starvation. A desperate relief operation was mounted to provide shelter and animal fodder.

C. Earthquakes

Being a young-fold mountain range, the Himalayas are undergoing continuous seismological activities. Earthquakes in this region are not only a big threat themselves, but also trigger some other devastating events like landslides, avalanches and sometimes cause glacial lakes to burst resulting in GLOFs. While seismic activities caused by the tectonic movements of plates have long been a subject of research, it has often brought tremendous miseries to the people of the Himalayas. Unlike most other environmental hazards, earthquakes are not regional in occurrence with almost the whole Himalayan chain being affected by them. Although the damage caused by earthquakes in the cold desert region has been relatively low (owing to less habitation), this region has seen some severe quakes in the past five decades.

1. *Kinnaur Earthquake* (1975): An earthquake of magnitude 7.8 on the Richter scale occurred in the regions of Kinnaur, Lahaul and Spiti. It not only resulted in the loss to life and property but also triggered off 2 massive landsides, one in Malling in the Spiti valley and the other one blocking the Parechu river near Sudmo. This disrupted communication and transport channels for several days.
2. *Dharchula Earthquake* (1980) affected parts of inner dry valleys of Pithoragarh district. It was measured at 8 on the Richter scale.
3. *Uttarkashi Earthquake* (1991) caused massive loss of life and property in the regions of Uttarkashi, Kinnaur and Chamoli districts. The magnitude of this earthquake was 7.9 on the Richter scale.According to National Institute of Disaster Management (NIDM), India, the Himalayan and sub-Himalayan region are one of the most vulnerable regions to earthquakes. From 1897 to 1993, the Western Himalayan region has witnessed 25 earthquakes of a magnitude 5.0-5.9, seven of 6.0-6.9 and one measuring more than 8 on the Richter scale with a return period of 2.5 to 3 years.

D. Impacts of Landslide, Avalanches & Earthquakes

In hilly terrains of India, these events strike life and property almost perennially. These disasters, year after year, bring untold misery to human settlements apart from causing devastating damages to transportation and communication network. They negatively impact the environment of the hilly regions and also have harsh socio- economic consequences. The effects on vegetation and wildlife are mostly negative; in some cases, they are catastrophic. Various environmental, social and economic impacts of such events are listed as follows:

1. Environmental:

a. Mass movement events of all kinds have the impact of bringing down large quantities of sediments, which can affect habitats lying lower. Frequently, they cause devastating floods by blocking block the narrow gorges and forming landslide dams.

b. These events tend to change landform and river/stream bed conditions, as snow/mud slides tend to scour the mountainside, particularly when being accompanied by rock fragments. Large amounts of debris are carried by avalanches, which are left in freshly scoured gullies when the snow melts, to be washed away to rivers and stream by the snowmelt waters. This also affects water availability, quantity and quality.

c. Biodiversity is adversely affected as well. Trees wherever they grow may be broken at about breast height due to the excessive force of the on-rushing snow. Young saplings are the most prone to damage by avalanche as they offer the least resistance to the mass of on-rushing snow[19].

d. Earthquakes can be a big environmental hazard as they can set off a series of catastrophic events such as landslides and avalanches which, in turn, are a big environmental menace.

2. Economic & Social

a. The negative economic effects of mass movement and geologic disaster events include the cost to repair structures, loss of property value, disruption of transportation routes, medical costs in the event of injury, and indirect costs such as lost timber and lost fish stocks. Huge sums have to be spent on debris removal. Geotechnical studies and engineering projects to assess and stabilize potentially dangerous sites are also very costly.

b. The sudden nature of landslides can cause lot of damage to the unprepared people. It leads to tremendous loss of life and bring a lot of misery to the people in these regions. Also, it adversely affects the livelihoods for days together as it takes a lot of time to remove the debris form the inundated land.

c. In case of an earthquake the people suffer immense trauma, both physical and mental, as they live in constant fear of aftershocks.

MITIGATION MEASURES

When disaster events occur in the cold desert regions of the Himalayas, relief and recovery operators can be hampered due to factors like remoteness, the lack of adequate communication facilities and poor connectivity. Harsh climatic conditions and poor infrastructure can compound problems in the event of a disaster. Thus, it is necessary that capacity building be done at the level of community and district officials so that emergency operations are not delayed, exacerbating the impacts of an event. Community preparedness and training coupled with assistance from the district level officials can significantly contribute in mitigating disaster impacts in a localized manner. Early warning systems have a limited role to play in such situations and being in a constant state of preparedness is an appropriate mitigation measure for communities' areas vulnerable to risk. In a rapid-onset disaster, the emergency phase (relief or isolation phase)[21] is of utmost impost importance because relief and assistance during this phase determines the magnitude of the impact on local communities.

A. Measures for Floods, GLOFs and Snowstorms

Many international agencies such as the International Centre for Integrated Mountain Development (ICIMOD) and United Nations Development Programme (UNDP) have taken initiative and started projects related to awareness, mitigation measures and capacity building for such disasters. Other organizations such as Office for Foreign Disaster Assistance (OFDA) of United States Assistance for International Development (USAID), the World Meteorological Organization (WMO), United Nations Environmental Programme (UNEP) and United Nations Educational, Scientific and Cultural Organization (UNESCO) have also been instrumental in providing funds and necessary platforms for capacity building.

Mitigation measures being implemented at present include:

1. *Network for wireless connectivity*: Such a network has been set up in the hazard prone areas. This helps in generating early warnings, and communicating in times of emergency. The Indian Army has set up a wireless station at Kalpa and the Indo-Tibetan Border Police (ITBP) has one in Reckong Peo, both situated in Kinnaur district of Himachal Pradesh.
2. *Advanced water level monitoring system*: The ITBP has a visual monitoring of water level at various outposts. In addition, advanced monitoring stations have also been set up to assess any increase in the water levels of the Parechu, Sutlej and Spiti rivers. The Snow and Hydrology Division of the Central Water Commission established a telemetry relay station at Sumdo, and a similar station was set up at Khaab and Dubling villages to serve prior warning for the protection of the Naptha-Jhakri Hydropower Project[22].
3. *Community led initiatives*: Although few in number, some community led initiatives are also making a significant contribution in developing awareness and disaster preparedness. Some community representatives along with certain NGOs are working to integrate experience and local knowledge to apply in disaster management. These include activities like building bridges, planning alternative routes, disseminating early warnings etc. However, due to the challenges posed by the terrain, communities are still largely dependent on the administration.
4. *Administrative measures*: These have been largely in the form of providing infrastructural support by building dams, embankments, contour trenches and check walls, repairing roads. The concerted efforts of the administration were exemplified in the 2005 floods when helicopters were provided for rescue operations and thereafter various helipads have been constructed in the area. It has also played a vital role in rehabilitation measures. For e.g. Leo village at Pooh Block, Kinnaur was provided alternative housing facilities post the 2005 floods. In addition, to ensure a year round access to the markets, the travel and transport of the agricultural products has been subsidized on the roads and bridges damaged by such events. Similarly, the districts of Lahaul & Spiti have properly

functional District Disaster Management Agencies with a 24X7 phone in facility for adequate grievance redressal.

5. *Military and paramilitary force*: Usually involved in rescue operations, the army and the paramilitary forces like the Sashastra Seema Bal (SSB), ITBP, Border Roads Organization (BRO) etc generally help in re-establishing the communication channels, roads and temporary bridges, medical services etc.

Overview of some projects on GLOFs

- The Regional GLOF Risk Reduction Project: Supported by European Commission Humanitarian Organization (ECHO) and UNDP's Bureau of Crisis Prevention and Recovery (BCPR). The project aims to "build the capacity and the knowledge of the communities living in the various flood basins and to strengthen the administrative structure to effectively reduce the impacts of flash floods and GLOFs". The specific areas covered are India, Bhutan, Pakistan and Nepal.

- UNEP-ICIMOD Partnership to study GLOFs in Nepal and Bhutan: The project has prepared an inventory of Nepal and Bhutan's glaciers and glacial lakes and highlighted those where GLOF events are likely occur and cause serious damage to life and property. It suggests that 20 Nepalese and 24 Bhutanese glacial lakes were potentially dangerous. The project is also providing advice on methods of recognizing potential dangers and immediate threats, and on developing early warning systems, to the Governments of the two countries. It is helping to strengthen the capability of their national institutions to address the GLOFs issue.

More importantly, these organizations have realized that in order to achieve a long-term solution, the structural measures (like dams and reservoirs, embankments, natural detention basins, channel and drainage improvement) need to be suitably integrated with the non-structural ones (flood-fighting, relief and restoration efforts). The socio-economic aspects of such kind of disasters tend to be higher due to the lack of preparedness of the people. Since, in such a scenario a mere technological intervention would not suffice, therefore these organizations aim at creating awareness, capacity building and strengthening the non-structural and community-based approaches.

Source: www.managingclimaterisk.org

Gaps & Potential Measures

Due to their peculiar nature and confinement to the Himalayan terrain, these hazards have not yet received adequate attention of the policy makers**.** There has been a lack of concerted mitigation strategies thus leading to crisis management when the disaster actually strikes. The agencies have also failed to recognize the fact that the areas susceptible to these hazards are usually prone to other threats such as landslides, avalanches and cloudbursts that are closely related to each other. This requires demarcation of such areas as **multi hazard risk prone regions** and devising of strategies accordingly, rather than following the current approach of crisis management for isolated events. Some significant challenges requiring immediate attention are:

1. For the State:

a. One of the biggest challenges over the years has been the failure to recognize these events as proper natural hazards rather than just chance events. For e.g. flash floods are still not recognized as a distinct calamity rather considered just a form of riverine floods. This approach has limited the development of necessary technology required to cope up with such events. A paradigm shift in the policy framework is required. For e.g. framing a separate policy for the flash floods rather than treating them as riverine floods. Taking a cue from China's flood management policy, which has a lot of instruments relating to flash flood management, India could work towards developing one of its own.

b. Poor resource base and poor access to communication channels hinder community participation in developmental activities and subsequent capacity building. In order to carry out rescue and relief effort effectively and efficiently, transportation and communication infrastructure needs to be strengthened. Appropriate mechanisms need to be devised to ensure information dissemination to the community, which could include organizing awareness campaigns and providing first response trainings.

c. A thrust should be laid on developing the ability to rapidly evacuate hazardous area. Evacuation planning needs to take account of the low infrastructural base of the region as well as the fact that roads, bridges and railways are among the first causality in such incidents. For events such as earthquakes, it is very important to train local communities by means of drills etc, in the correct way to protect themselves in case of any such event. Considering the fact that most of the earthquake related deaths are due to the inability to timely evacuate the area, such measures become imperative.

d. Store houses for food grains and fodder in each block would ensure food security and relief at times of disasters. At present, in some regions of the Sutlej valley, people store food grains and fodder with their relatives or friends in relatively drier places. A centralized system for the same would be more accessible and therefore highly beneficial for the people. A build-up is necessary for emergency relief measures (alternate arrangement of food and water supply, para-medical team, temporary shelter, alternate communication link).

e. Infrastructure development programmes continue in such areas without accounting for the possible hazards. For e.g. in spite of realizing the risks in a particular area, the administration continues construction activities giving people the wrong impression that such areas are indeed safe. It is necessary to incorporate a calculated risk of such events while planning any major infrastructural project.

f. Political lethargy in implementation of mitigation efforts could have grievous costs. In 1975, the Ministry of Water Resources and Central Water Commission circulated a draft bill for flood plain zoning regulations for state governments to enforce. However, the Government of Himachal Pradesh has clearly refused to enact the bill and Rajasthan and Manipur are the only two states in India that have passed the bill (steps for enforcement are still pending)[24]. It is necessary to devise policies to discourage habitation of the hazard prone area, and the resettlement and relocation of affected populations to less hazard prone areas.

g. In addition, country-to-country learning by means of effective dialogues between the countries of the Hindu Kush Himalaya (HKH) region has been lacking despite the transboundary nature of such events. Floods are the main natural disaster aggravating poverty in the Himalayas. Technical advances in flood forecasting and management offer an opportunity for regional cooperation in disaster management. Regional cooperation in transboundary disaster risk management should become a political agenda.

h. Disaster preparedness and risk reduction should be seen as an integral part of water resource management. Integrated water resource management (IWRM) should include further climate change scenarios and be scaled up from watersheds to river basins. IWRM is a political process and researchers should engage constructively with the relevant stakeholders in the public sector, private sector, and civil society. Water allocation for ecosystems and livelihoods deserves particular attention. Water storage, based on local practices should be developed in the region to deal with the problem of too much water during monsoons and too little during the dry season.

2. **Crosscutting challenges**:

a. Information gap between the policy makers, research institutions and communities, and lack of coordination in mitigation efforts between all stakeholders. The nature of the Himalayan ecosystem is such that any disaster management policy cannot be framed and implemented without adequate engagement of the people.

b. Indigenous and traditional knowledge must be integrated into mainstream developmental activities. At the same time, notwithstanding the aspect of community involvement, it is also imperative to incorporate the appropriate technological component and strike a fine balance between the two.

c. Clear demarcation of duties in the policy structure with transparency and accounting systems. A clearly specified role of the NGOs, *Panchayats* and state level authorities.

3. **For researchers and civil society:**

d. In case of flood events, there is a lack of a general understanding about the physical dimensions and properties of GLOFs as well as their life cycle, which makes predicting a GLOF event almost as difficult as predicting an earthquake.

e. There is a lack of proper early warning systems and mathematical models for predictions of such events. Although R&D activities have been carried out, most of these models are either still in test phase or are not suitable enough to be used in their present form. Research has to focus on development of integrated models to predict flood onset, determining flood routes, performing vulnerability analysis and risk classification to identify hazard prone areas, mitigation and response measures, and evacuation routes.

f. There is also a serious lack of trained professionals and institutional capacity for hazard mapping, vulnerability assessment, and disaster forecasting.

g. Although introduced as a supplementary course in schools, disaster management training as a system is still poorly developed in the educational system. In universities, this component is completely lacking. Training of schoolteachers and health workers is also crucial to create a trained workforce, which can be mobilized in the event of a disaster.

h. Since many NGOs and other self help groups also lend a hand in the aftermath of disasters, it is crucial to coordinate with them in case of such disasters. Local organizations with community volunteers should be developed in the form of emergency response team.

4. For local communities:

i. The communities lack the preparedness to cope with such disasters, tending to see disaster events as a natural phenomenon over which they have no control. Proper training regarding pre-event (mitigation and preparedness) and post-event (relief and recovery) is necessary for communities to understand that the effects of any disaster can be minimized by proper measures. Since they are the first ones to respond to the disasters, an appropriate capacity building can reduce the damage caused. Capacity building should include inputs on rescue and search, evacuation and other related issues such as first aid, information and communication, as well as gender sensitivity.

j. Information and technology does not percolate from the laboratories to the local stakeholders, thus diluting the coping capacity of affected people. It is necessary to generate awareness amongst the communities about the exact causes and consequences of such events. These could include radio and television broadcasts, adult education and erecting permanent signboards indicating danger.

k. A change in the community mindset is required from the current dependence on the government as the agency that holds sole responsibility for relief work in the wake of disaster events. This poses a big challenge as any effective disaster management plan require a full-scale community participation.

l. A multi-stakeholder disaster reduction strategy must be developed by increasing community awareness. Resource mapping by including the local communities can make policies more region specific and appropriate.

B. Measures for Landslides and Avalanches and Earthquakes

The Government of India has several initiatives and programmes to address mass movement and geo-tectonic disasters in the country:

1. An important initiative with regard to landslide mitigation in India has been the inception of the *'National Core Group for Landslide Mitigation'* constituted by the Ministry of Home Affairs in 2004 for drawing up a strategy and action plan for mitigating the impact of landslides, provide advise and guidance to State Governments on various aspects of landslide mitigation, monitor the activities relating to landslide mitigation including landslide hazard zonation and to evolve early warning systems and protocols for landslide risk reduction. Geological Survey of India (GSI) has been declared the nodal agency responsible for coordinating/undertaking geological studies, landslides hazard zonation, monitoring landslides/ avalanches, studying the factors responsible and suggesting precautionary and preventive measures.

2. *Settlement policy*, which discourages permanent settlements in high-risk zones and diversion of stream channels in upper slopes, especially above settlements. The policy also demands that adequate provisions must be made to ensure drainage of storm water away from high sloping terrain. Contour bunding or terracing adopted for seasonal cultivation or initiation of plantations in slopes of >16° above settlements are required to have sufficient provision for drainage. These measures discourage the increase in drivers of landslides and avalanches.

3. *Snow and Avalanche Study Establishment (SASE)* was set up in 1969 near Manali to combat the hazards of snow and avalanches not only to help the Armed Forces to fight and live in the mountains but also to accelerate the pace of socio-economic growth of the inaccessible snowbound hill regions. SASE was initially assigned the task of studying snow and avalanche problems along certain mountain highways in snowbound belt of Indian Himalayas.

4. The government of India has issued *Guidelines for Earthquake Management* to minimize the impacts, loss of lives and damage to property.

5. The Ministry of Earth Sciences, (MoES), is coordinating with the India Meteorological Department (IMD), the Geological Survey of India (GSI), the Bureau of Indian Standards (BIS) and the Earthquake Risk Evaluation Center (EREC) for the development of scientific *Seismic Zonation Maps*.

The most important triggering mechanism for mass movements is heavy precipitation which infiltrates and increases pore pressure, causing an overburden. When this happens in steep slopes, the safety factor of the slope material gets considerably reduced causing it to move down. The natural way of preventing this situation is by reducing infiltration and allowing excess water to move down without hindrance. As such, the first and foremost mitigation measure is **drainage correction**. This involves maintenance of natural drainage channels both micro and macro in vulnerable slopes. The universal use of contour bounding for all types of terrain without consideration of the slope, overburden thickness and texture or drainage set-up needs to be controlled especially in the plateau edge regions. Leaving aside the 'critical zones' with settlements could be avoided altogether and which could be preferably used for permanent vegetation, the 'highly unstable zones' generally lie in the upper regions, which are occupied by highly degraded vegetation. These areas warrant immediate afforestation measures with suitable plant species. The afforestation programme should be properly planned so the little slope modification is done in the process. Bounding of any sort using boulders etc. has to be avoided. The selection of suitable plant species should be such that can withstand the existing stress conditions in this terrain.

Seabuckthorn, a widely distributed shrub in the cold deserts of Ladakh brings many environmental benefits, including soil and water conservation, desertification control and land reclamation in fragile cold desert ecosystem. Seabuckthorn plantations being resistant to the drying effects and physical injuries caused by the wind can serve as windbreaks to prevent wind erosion in open areas. The unique characteristics of seabuckthorn in improving the fragile ecosystem and socio-economic upliftment of the rural cold desert region are receiving attention from environmentalists and the Government. The Indian Council of Agricultural Research has recommended a concept note on seabuckthorn under the National Agricultural Innovation Project scheme24. Of late this shrub has caught enough research attention and its potential in disaster management in the cold deserts can be explored.

Good practice:
The *IMJA* Disaster Risk Reduction Project, Nepal is a fine example of disaster risk reduction. With financial assistance from the World Bank, the Department of Hydrology and Meteorology, Nepal signed a contract with MeteorComm and its partner British Columbia Hydro International Ltd. (BCHIL) to get a GLOF Early Warning System established downstream of the Tsho Rolpa Glacier Lake in Nepal. The sensing system is capable of generating a warning and transmitting it downstream. Similarly, the Intermediate Technology Group, Nepal, has introduced a community based disaster management system. It comprises of a community managed, flood early warning system along the Rapti River in Chitwan district. Although in a test phase, the technology can be replicated elsewhere if found effective for timely flood warning generation. Such kind of innovations can go a long way and set necessary precedents for appropriate disaster risk reduction strategies that can, in turn, save thousands of lives.

Gaps & Potential Measures

In the past the focus has been on post-disaster response only, which is no longer adequate and effective in dealing with disasters, therefore a shift is occurring in the region, as well as worldwide, from response to prevention, preparedness and mitigation of disasters. Collecting and developing more data and technology alone, will also not be sufficient to improve peoples' lives. Policy makers and practitioners need to better understand local contexts and needs for improved disaster risk reduction activities.

1. For policy makers and researchers:

a. The relationship between climate change and the Himalayan cryosphere, although confirmed by scientists generally, is not understood sufficiently to derive detailed policy responses. While in-depth studies of glaciers, snow pack, and permafrost have been carried out in some areas, they have been scattered widely in space and time. No detailed investigations of snow and ice processes or their relevance to climate have taken place in most areas of the Himalayan and other high ranges. Baseline studies are lacking for most areas, particularly for those higher than 4,000m, and there has been little long-term monitoring of climatic variables, perennial snow and ice, runoff, and hydrology in the extraordinary heterogeneity of mountain topography[28]. Before effective responses can be made, much work has to be carried out to identify and predict the possible impacts of climate change filtered through such diverse contexts. The immense diversity within the region should be recognized: diversity of climates and topo-climates, hydrology and ecology, and, above all, in human cultures and activities.

b. Credible, up-to-date scientific knowledge is essential for the development of climate policy. It is essential to develop high science with government agencies and academia for application of standardized methodologies for year-round observation.

c. Along with scientific and technical criteria, participatory methods, or civic science, need to be developed to assess and monitor climate and environmental changes based on local perceptions, practices, and use. This would enable local communities to play key roles in determining adaptation practices to reinforce resilience based on local information and knowledge. A school science programme can be developed in local communities in the Himalayan mountain region.

d. Preparation of seismotectonic/seismic zonation maps which can prove useful in the zoning of the hazardous areas and planning effective mitigation strategies.

e. Local climate change is influenced greatly by features of the Himalayas that are not well represented in global models because of their coarse resolution. Regional Climate Models (RCMs), with a higher resolution than global ones, need to be constructed for different 'hotspots' and run for shorter periods (20 years or so). The inter connectivity of Himalayan environmental change, the Asian monsoon, and local and global climate warming need careful study. The results of RCMs have to be downscaled and applied to impact assessments, in particular for watersheds or sub-catchments.

f. Integrated research programmes in the Himalayan region have to consider the interlinkages between the six spheres (lithosphere, cryosphere, hydrosphere, atmosphere, biosphere, and anthrosphere).

g. Mountain specificities and vulnerability to environmental change are also important. The vulnerability of humans and ecosystems to the impacts of climate change should be identified through integrated research and partnerships.

2. For community:

a. The main challenge is the lack of relevant knowledge in the region concerning key policy areas and strategies to improve the adaptive capacities of communities at risk. The complex regional differentiation magnifies the significance of two major problems: the widespread absence of basic scientific investigations into cryogenic processes and limited knowledge of the human cultures and ongoing developments in them. This leads to the theme of 'uncertainty on a Himalayan scale', referring more to problems of limited knowledge than inherent physical and social uncertainties. In particular, there has been little engagement with local populations so far to learn from their knowledge and experience in adapting to unique and changeable environments and to address their concerns and needs[29].

b. The best approach to vulnerability and uncertainty in regard to climate change is 'bottom-up' community- led adaptation built on local knowledge, innovation, and practices. The focus should be on empowering communities to monitor and take action to adapt to a changing climate based on their own decision-making processes and participatory technology development with support from outside.

c. Priority should be given to the most vulnerable groups such as women, the poor, and people living in fragile habitats such as along riversides and on steep slopes.

d. National adaptation plans of action (NAPAs) are currently being prepared by regional countries under the initiative of the UN Framework Convention on Climate Change. They are expected to identify sectors most vulnerable to climate change and to prioritize activities for adaptation measures in those sectors. NAPAs need to pay more attention to certain sectors such as water, agriculture, health, disaster reduction, and forestry, as well as the most vulnerable groups such as children, women, and other disadvantaged groups.