Preparation of

Hazard, Vulnerability & Risk Analysis atlas and report for the state of Himachal Pradesh

Non-technical Summaries
(T7)

Prepared for

Disaster Management Cell, Department of Revenue
Government of Himachal Pradesh, Shimla

Prepared by

TARU Leading Edge Pvt. Ltd.
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Contents

Himachal situated in the heart of the western Himalaya, identified as "Dev Bhumi" and is believed to be the abode of Gods and Goddesses. The State has many stone as well as wood temples. The rich culture and traditions have made Himachal unique in in this part of Himalayan region. The shadowy valleys, rugged crags, glaciers and gigantic pines and roaring rivers and exquisite flora and fauna makes this sate unique.

Pre & Proto History

About 2 million years ago, humans lived in the foothills of Himachal Pradesh, viz in the Bangana valley of Kangra, Sirsa valley of Nalagarh and Markanda valley of Sirmaur. The foothills of the state were inhabited by during Indus valley civilization, which flourished between 2250 and 1750 B.C. People of Indus valley civilization pushed the original inhabitants of Ganga plains who were known as Kolorian people towards north. They moved to the hills of Himachal Pradesh where they could live peacefully and preserve their way of life.

In the Vedas they have been referred to as Dasas, Dasyus and Nishadas while in later works they have been called Kinnars, Nagas and Yakshas. The Kols or Mundas are believed to be the original migrants to the hills of present day Himachal.

The second phase of migrants came in the form of Mongoloid people known as Bhotas and Kiratas. Later on came the third and most important wave of migrants in the form of the Aryans who came from Central Asian plains. These laid the base of history and culture of Himachal Pradesh.

Post-Independence Period:

The history of present day Himachal Pradesh in the post-independence era has been outlined below:

- The Chief Commissioner's province of H.P. came into being on 15th April, 1948.
- H.P. became a part C state on 26th January, 1950 with the implementation of the Constitution of India.
- Bilaspur was merged with Himachal Pradesh on 1st July, 1954.
- Himachal Pradesh became Union Territory on 1st November, 1956.
- Kangra and most of the other hill areas of Punjab were merged with H.P. on 1st November, 1966 though its status remained that of a Union Territory.
- On 18th December, 1970 the State of Himachal Pradesh Act was passed by Parliament and the new state came into being on 25th January, 1971. Thus H.P. emerged as the eighteenth state of Indian Union.

Himachal Pradesh has come a long way since then. It has seen a number of full-fledged governments which have led the state towards economic self-reliance.

Administrative Sub-Divisions:

For the purpose of administration, Himachal Pradesh comprises 12 Districts, subdivided in 123 Tehsils, 56 subdivisions, 77 blocks with 20,690 villages and 59 towns. (Census of India, 2011)

Relief, Physiography & Geology

The soils of the State can broadly be divided into nine groups on the basis of their development and physico-chemical properties. These are: (i) alluvial soils, (ii) brown hill soils, (iii) brown earth, (iv) brown forests soils, (v) grey wooded or podzolic soils, (vi) grey brown podzolic soils, (vii) planosolic soils, (viii) humus and iron podzols (ix) alpine humus mountain skeletal soils. The soils found in the districts of Mandi, Kangra, Bilaspur, Una, Solan, Hamirpur and Sirmaur is generally brown, alluvial and grey brown podzolic, Kullu and Shimla have greywooded podzolic soils, while Kinnaur, Lahaul and Spiti and some parts of Chamba district have humus mountain skeletal soils.

Climate:

Himachal Pradesh can be divided into three regions: (i) The Shivalik ranges (the height from plain up to 915 m.); (ii) Colder Zone (the height is about 4,500 m.); and (iii) the Axis and Crystalline core of the whole system (the height above 4,500 m. but below 5,500 m.). The climatic conditions, therefore, vary from the semi- tropical to semi-artic. Physiographically, the state can be divided into five zones based on altitudes and moisture regime conditions.

These vary from wet humid sub-temperate situation to dry temperate alpine high lands. Besides the seasonal variations, the climate of Himachal Pradesh varies at different altitudes. The average rainfall is 1520 mm. (60 inches). The highest rainfall occurs in Kangra district followed by Shimla district.

Rivers and Lakes:

Himachal Pradesh has the privilege of snow-fed perennial rivers and rivulets flowing in most parts of the State. Yamuna, with its important tributaries of Tons, Pabbar and Giri in the east and Satluj, Beas, Ravi and Chenab in the west flow through various parts of the State. Some of the important natural lakes are Khajjiar, Ghadasasu Lamba Dal, Manimahesh, Mahakali in Chamba Distt.; Dal, Kareri in Kangra Distt.; Rewalsar, Kumarwah, Prashar in Mandi district; Bhrigu and Dashahr in Kullu Distt.; Chandratal and Surajtal in Lahaul & Spiti Distt.; Chandra Naun in Shimla district; and Renuka in Sirmaur Distt. The man-made lakes include Gobind Sagar in Bilaspur district; Pong lake in Kangra district; Pandoh lake in Mandi district; and Chamera lake in Chamba district.

Economy:

The economy of Himachal Pradesh has diversified from mostly agriculture and animal husbandry prior to 1970's to industry and services sectors and allied activities. The declining share of agriculture sector does not affect the importance of this sector in the State economy as the state economic growth still is being determined by the trend in agricultural production as it is the major contributor to the total domestic product and has overall impact on other sectors via input linkages, employment and trade etc.

Due to lack of irrigation facilities agricultural production to a large extent still depends on timely rainfall and weather conditions. Agriculture sector is undergoing transformation from mainly cereal crops to a mix of fruits and vegetables. The state has made significant progress in the development of Horticulture. The topographical variations and altitudinal differences coupled with fertile, deep and well drained soils favor the cultivation of temperate to sub-tropical fruits. The region is also suitable for cultivation of ancillary horticultural produce like flowers, mushroom, honey and hops.

The start has accorded high priority to tourism industry, which has emerged as a major sector in the development of economy of the state.

Agriculture:

Agriculture provides direct employment to about 69 per cent of the main working population, while agriculture and allied sectors accounts for only 22.1 per cent of the total State Domestic

Product. Out of the total geographical area of 55,673 sq. km (55.7 lakh hectare)., area of operational holding is about 9.79 lakh hectares owned by 9.14 lakh farmers. The marginal and small farmers possess 86.4 per cent of the total land holdings. The reported net sown area in the state is only 10.4 percent.

Horticulture

Nature has endowed Himachal Pradesh with a wide range of agro-climatic conditions, which have helped the farmers to cultivate a variety of temperate to sub-tropical fruits. The main fruits under cultivation are temperate fruits like apple, pear, peach, plum, apricot and strawberry as well as tropical fruits like citrus fruits like mango, litchi, guava.

The Horticulture Technology Mission for the integrated development of horticulture is being implemented since tenth five-year plan period. Under this scheme, four centers of excellence are being created in different Agro-Climatic Zones with common facilities like water harvesting, vermicomposting, greenhouses, organic farming and farm mechanization.

Roads:

Roads are the major means of communication in the predominantly hill State of Himachal Pradesh. Out of its 55,673 sq. km area, there are more than 36,700 villages out of which 16,807 are inhabited. These villages are scattered over slopes of numerous hill ranges and valleys.

Realising the importance of construction of roads for connecting production areas with market centres, Himachal Pradesh Government has decided to connect every panchayat with roads. When the Himachal Pradesh came into existence in 1948 there were 288 km. of roads. This and has increased to 33,171 km by 2010.

Hydro-power Generation:

The total identified hydroelectricity potential five perennial river basins in the State is about 23,230 M.W(large medium and small projects), which is one fourth of Indias total hydro-power potential. Presently out of this 6,480 M.W has already been harnessed by various agencies. Projects aggregating to 7,602 M.W are under execution. The strategy of development in the power sector includes expeditious actualization of the Hydro Electric Potential and introduction of power sector reforms to bring efficiency in the sectors.

The Government has embarked upon an accelerated Power Development Programme and moving towards becoming a "Power State" of the Country. All the census villages in the State have been electrified and now left out hamlets are being covered.

Industrial Growth:

Industrial development has been given big boost in the State. Pollution free environment, abundant availability of power and rapidly developing infrastructure, peaceful atmosphere, and responsive administration are some of the added attractions that the entrepreneurs get in Himachal Pradesh. 349 large and medium and about 33,284 small-scale industrial units have been set up in the State generating employment for about 2 lakh persons. The sector is contributing 17 per cent to the State Domestic Product and the annual turnover on this account is about ` 6,000 crore.

Information Technology:

The Government of Himachal Pradesh has developed an IT Vision-2010 in collaboration with NASSCOM to make Himachal Pradesh an IT destination. Under the IT policy, it has been decided to accord the status of industry to all IT projects including IT related services and educational institutions. As such, all the incentives available for industrial units are also being given to all IT units, and IT related services.

Bio-Technology:

Keeping in view the importance of bio-technology, special emphasis is being laid on exploiting the vast bio-technology potential available in the State. A separate Department of Bio-technology has been set up in the State and a bio-technology policy has been formulated. All bio-technological units are entitled for incentives which have been allowed for industrial units. The State Government proposes to set up Bio-technology Park in Solan District.

Irrigation and Water Supply:

The net irrigated are as of 2009 was about 1.08 lakh ha. Most of the irrigation is done through small channels locally called as *Kuhls*. These divert water from the local streams. Despite having three major dams, large scale irrigation is not possible due to hilly terrain downstream of the dams. Dispite hilly terrain, almost all villages have been provided with the facility of drinking water. Over 15,000 hand pumps have been installed in the State so far.

Forestry:

The estimated area under the control of the Forest department is about 37,033 sq. km. Out of this, 16,376 sq. km. area is not fit for tree growth comprising alpine pastures, area under permanent snow, etc. The recorded actual forest area is only 20,657 sq. km.

Efforts are being taken to bring maximum area under green cover by implementing States own projects, Government of India's projects and also through external aided projects. There are 2 National Parks and 32 wild life sanctuaries in the State. Total area under wild life sanctuaries is 5,562 sq.km and National Parks is 1440 sq. km and total area of Protected Area Network is 7002 sq. km.

Education:

Himachal Pradesh has emerged as the third best State in terms of over-all education development and performance. The state has been adjudged number one State in Primary Education and teacher-student ratio. Himachal Pradesh has witnessed literacy revolution and is second only to Kerala in terms of literacy.

The State has about 17,000 educational institutes, including three Universities, two Medical Colleges, one Engineering College in the Government Sector and a number of technical, professional and other educational institutions under private sector.

The literacy percentage of the State according to 2011 Census is 83.78. The State Governments emphasis now is to ensure qualitative improvement in the education besides need based expansion.

Tourism:

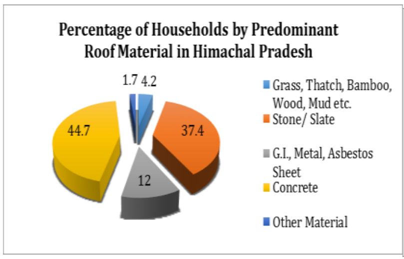
Tourism Industry in Himachal Pradesh has been given very high priority and the government has developed an infrastructure for its development which includes provision of public utility services, roads, communication network, airports, transport facilities, water supply and civic amenities, etc. In 2010, tourist arrivals in the State was 13.3 million (incl. 0.43 million foreign tourists).

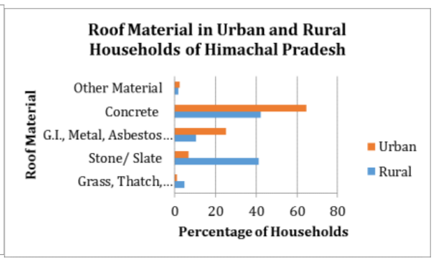
The State has a rich treasure of places of pilgrimage and of anthropological value. The State also has Hot-springs, historic forts, natural and man-made lakes, grass lands, cold deserts, which are sources interest for tourists.

The State Government is aiming at promoting sustainable tourism and encouraging private sector to develop tourism related infrastructure in the State while sensitive to the ecology and environment. The main thrust is on employment generation and promoting new concepts of tourism in the State.

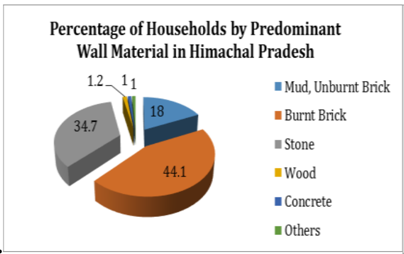
Buildings in Himachal Pradesh

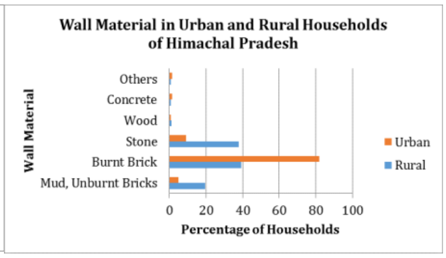
There are total 25,75,947 census houses in Himachal Pradesh. 23,15,172 census houses belongs to rural area while just 2,60,785 houses are located in urban area. As per the census 2011, total houses in Himachal Pradesh are over 2.5 million. 55.8 % of buildings are occupied for residential purpose and 7.5 % buildings are used for shop, office etc. 89% of census houses belongs to rural area while only 11% houses exist in urban areas. There are total 10,27,788 buildings in the state (TARU Analysis 2014). Census 2011 categorizes buildings on the basis of the different material used for wall, roof and floor. Most of the population belongs to rural area but rural houses lack of seismic safety measures due to poor construction practices. Concrete (47.4%)is the most predominant roof material followed by stone/slate (37.4%) and GI/ Metal/ Asbestos sheet (12%). There has been shift away from using asbestos to GI sheet in recent years due to long term durability. Concrete and GI sheet are mostly used as roof material in urban areas whereas in rural areas, concrete and stone/slate are predominant roof material.





Burnt brick (44.1%) and stone (34.7%) are the most common wall material in households of Himachal Pradesh followed by mud/unburnt brick (18%) and wood (1.2%). In urban households, burnt brick is the most common material for walls while rural households also use mud and stone along with burnt brick for the construction of walls.

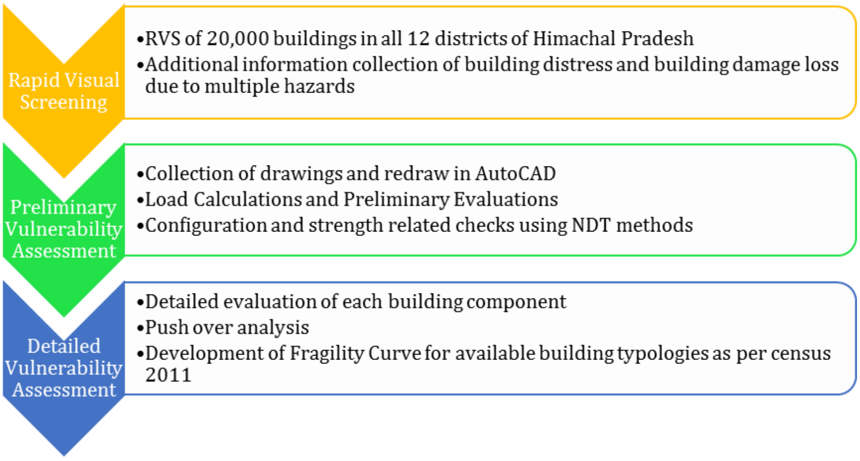


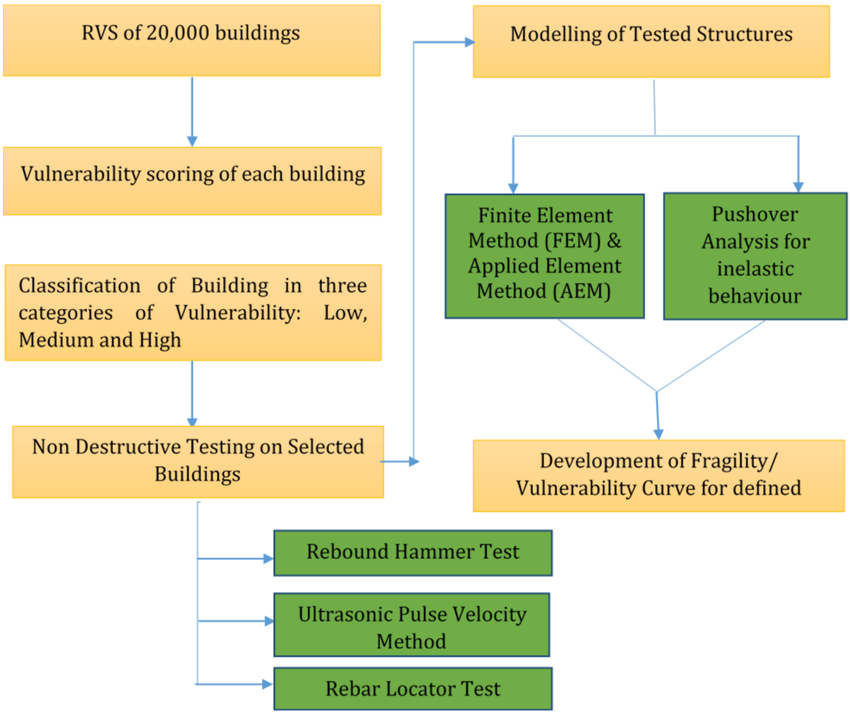


Methodology:

Building vulnerability assessment (BVA) is a three stage process. It includes rapid visual screening (RVS) of buildings, preliminary vulnerability assessment (PVA) and detailed vulnerability assessment (DVA). DVA was undertaken for selected structures. Rapid visual screening of 20,000 buildings were conducted to collect the information through visual observation. PVA involves the analysis of building data obtained from RVS and configuration and strength related checks. In DVA, AEM and FEM methods were used to study the seismic behaviour of structures.

Pushover analysis was done on selected structures to study the inelastic behaviour of structures and fragility curves were developed for five predominant building typology i.e. brick masonry, stone masonry, rammed earth, RC frame and Hybrid & others.





Fragility Curves & Grade of Damage:

Fragility curves were developed for reclassified five predominant building typology. Fragility curve represents the expected level of damage of a building under different PGA values. The damage parameter (D) is classified as no damage ($D<0.2$), slight damage ($0.2<D<0.4$), moderate damage ($0.4<D<0.6$), heavy damage ($0.6<D<0.8$) and collapse ($D>0.8$). Classification of damage grade is shown in following table.

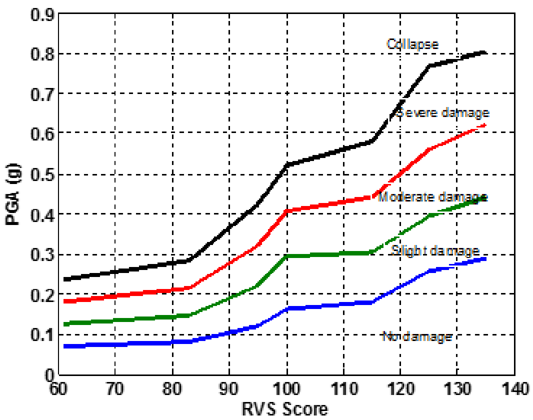
Grade of Damage	Description of Damage
Grade 1(D1)	Slight damage Fine cracks in plaster: fall of small pieces of plaster.
Grade 2 (D2)	Moderate damage Small cracks in plaster: fall off fairly large pieces of plaster: pan tiles slip off: cracks in chimneys parts of chimney fall down.

Grade 3 (D3)	Large and deep cracks in plaster: fall of chimneys.
Grade 4 (D4)	Gaps in walls: parts of buildings may collapse: separate parts of the buildings lose their cohesion: and inner walls collapse.
Grade 5 (D5)	Total collapse of the buildings.

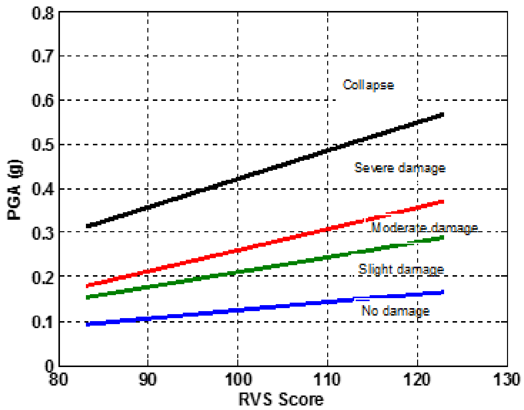
Type of Buildings as per IS 1893: 2002 is shown in following table.

Type of Structure (Buildings)	**Description**	**Building Typology in Vulnerability Assessment**
Type A	Building in field-stone, rural structures, unburnt-brick houses, clay houses.	Rammed Earth, Stone Masonry
Type B	Ordinary brick buildings, buildings of large block and prefabricated type, half-timbered structures, buildings in natural hewn stone.	Brick Masonry, Stone Masonry, Hybrid
Type C	Reinforced buildings, well built wooden structures.	RC Frame , Hybrid

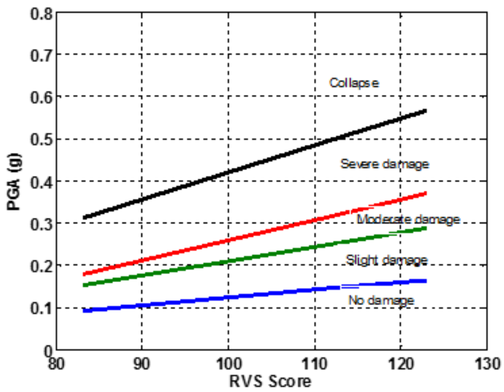
The PGA values with respect to RVS scores for damage categories are found out from fragility curves. The state of damage of all typology of buildings can be found out from fragility curve shown in the figure, if PGA value of the region and RVS score of building is known.



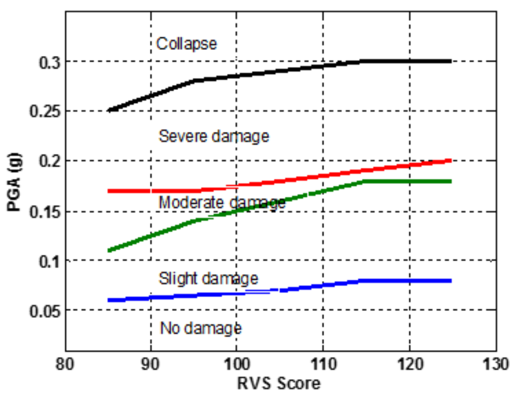
Reinforced concrete buildings



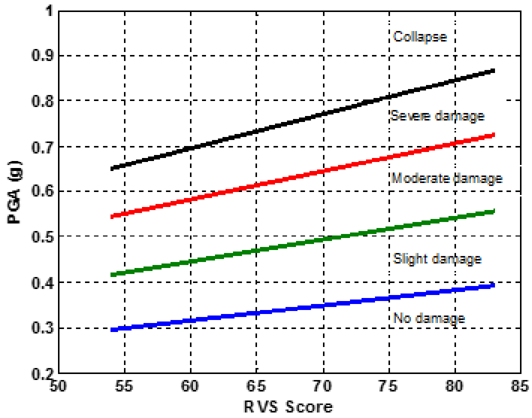
Brick masonry buildings



Stone masonry buildings



Rammed earth buildings

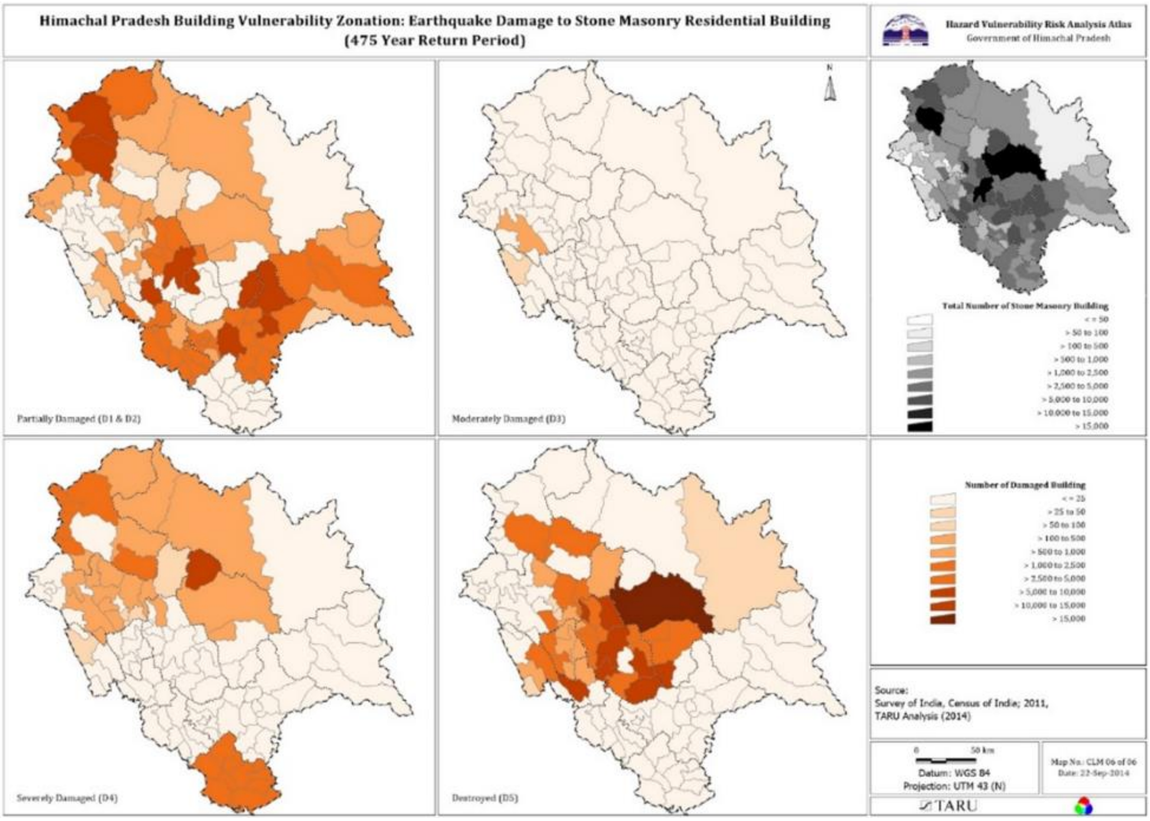


Hybrid buildings

Fragility curve shows that a building with low RVS score means highly vulnerable building will suffer more damage at low intensity of earthquake only (low PGA value). For RC frame structures, a building with RVS score of 70 will suffer D3 or higher category of damage due to earthquake capable of producing PGA value of more than 0.14g. Rammed earth buildings are more fragile than other building typology. Rammed earth and stone masonry buildings are expected to get severe damage or full collapse at low intensity of earthquake also. Hybrid buildings demonstrate better performance in earthquake and receive only partial damage.

Expected level of building damage has been calculated for entire residential and residential cum other use building stock of Himachal Pradesh at different return period of earthquake i.e. 100, 200, 475 and 2475 year return period. For 100 and 200 year return period earthquake, most of the buildings will suffer only D1 and D2 category of damage. Only buildings situated in Hamirpur, Mandi, Chamba and Una will show D4 and D5 category of damage under 200 year return period of earthquake which have the 22% probability to exceed in 50 years period. For 200 year return period of earthquake, moderate to heavy damage may occur in most of the districts except Kinnaur, Shimla, Sirmaur and Solan.

For 475 year return period earthquake, stone masonry buildings shows D4 category of damage mostly in Chamba, Kangra, Kullu and Sirmaur. D5 category of damage mostly occur in Kangra, Chamba, Madi, Hamirpur and Kullu.



Conclusions:

Building vulnerability assessment in the state of Himachal Pradesh shows that stone masonry and rammed earth building types are the most vulnerable one which may cause the huge loss of life in the state. In last two decades brick masonry and RC frame construction have been on rise but the quality of construction was not maintained which resulted into increasing vulnerability.

Traditional construction practices like Dhajji Dewari and Kath Khunni should be promoted as these structures have shown great capability to resist the lateral forces during strong earthquake also. Vulnerability and damage assessment of buildings represent the areas having concentration of risk at certain areas. Mitigation planning should be taken at tehsil and district level to improve the building condition.

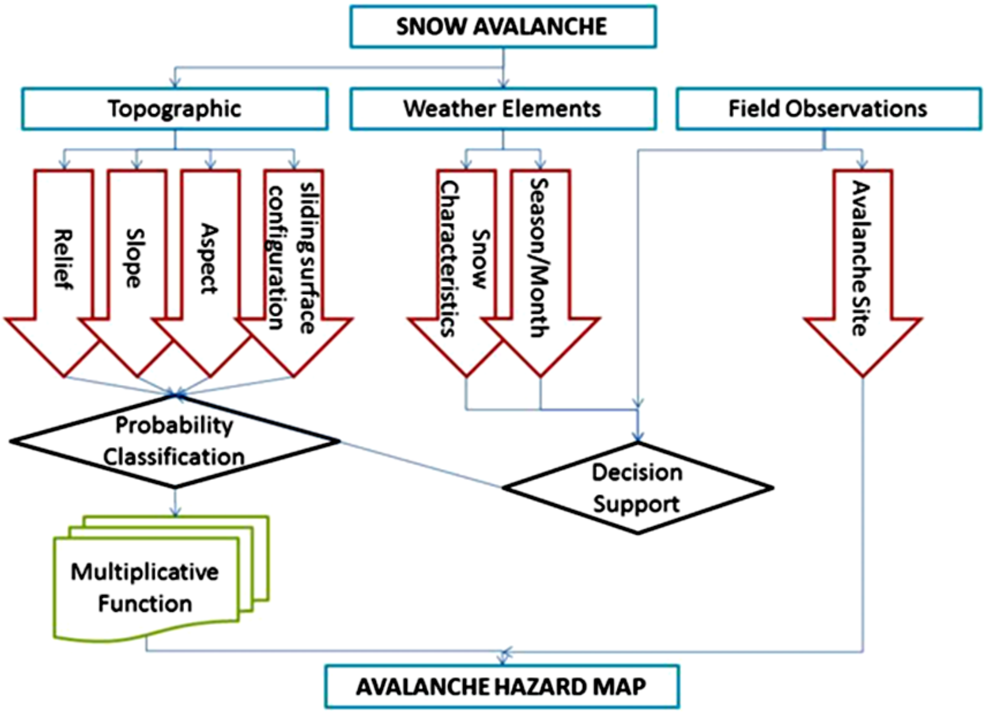
Avalanche Hazard Risk:

Avalanches occur when weight of accumulated snow on slopes exceeds cohesion within snowpack or between snowpack and ground. Such imbalance can take place when there is an increased snowfall or internal changes occur within existing snow cover or caused due to anthropogenic activities such as skiing. This relatively marginal force required to start the snow sliding is called an avalanche trigger.

There are two types of snow avalanches; avalanches which originate in cohesion-less snow and starts from one point and gathers more snow as it descends (so called snow-balling effect) are called the loose-snow avalanche; and avalanches which start when large area of cohesive snow begins to slide at the same time are called slab avalanches. Both types occur in wet and dry snow (Cox and Fulsaas, 2003).

Methodology:

Avalanche hazard risk mapping presented within this study was based on geographical factors that initiate snow-avalanches. In analyzing risk zones, the regional climatic factors were given equal importance. The methodology adopted within this study was coupled with the field-occurrence evidences of avalanche around the same time. While precise assessment was not possible in this case due to the lack of required time series data an effort was made to collate information from secondary sources to identify risk prone regions. The methodology is therefore appropriate for regional scale analysis, with an error margin of ± 5 percent. A detailed flow chart indicating the methodology is presented in below figure.



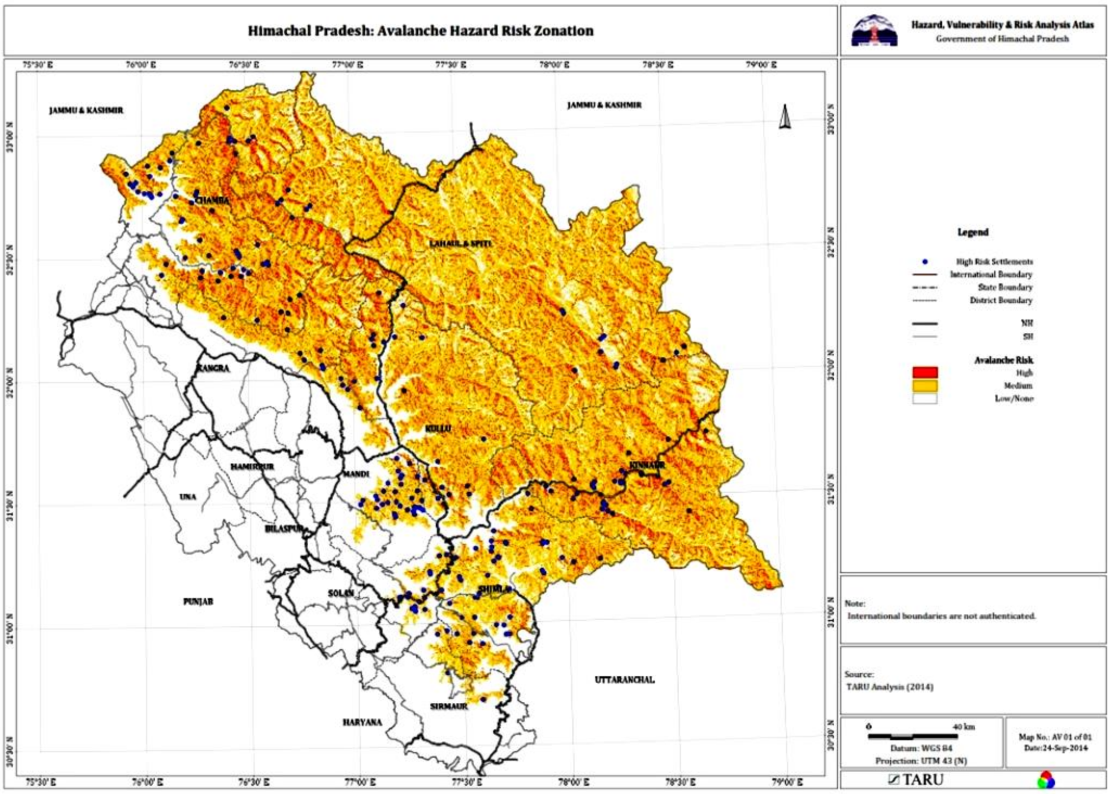
Data Sources:

Primary Data: The primary data for this study were collected through field visits including Beas, Chandrabhaga, Ravi, Yunam and Spiti Basins. In addition to field photographs, information collected from these visits included data on avalanche deposits and cones that survived through winter failures, terrain information and records of type of infrastructure/ settlements.

Secondary Data: Data on the type, snow characteristics, weather elements and historical avalanches locations are currently limited for the snow-fed Himalayas. Further, there is limited availability of cloud free satellite imageries especially for the winter seasons. In the absence of necessary base data, proxy methods were incorporated. In order to overcome this imageries from different years but from same months and location were collated to create composites to estimate and analyze. Cloud free Image Mosaic (Through WMS services of ArcGIS, QGis and GE):

1) Quick bird Imageries (Ranging from 2003-2010 at 0.6m resolution)
2) SPOT 4 and 5, Panchromatic (of 2011 and 2012 at 10m resolution)
3) Topographical sheet, 1:50,000, Survey of India.
4) Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER), 16 bit, version 2, (30 m resolution)
5) Shuttle Radar Terrain Mapper (SRTM, 2000) for elevation data (90 m resolution).
6) GLC-2000, processed from the SPOT Vegetation sensor.

Avalanche Probability Zones:



Conclusions:

Almost 1.2% area of Himachal Pradesh falls under category of high avalanche probability zone, whereas 14.5% area has moderate probability. Rest of the region (i.e. 84.3%) have low to nil snow avalanche probability. However, 99% of avalanches do not have adverse-affect and is a part of natural process of maintaining glacier mass balance and as a low-magnitude high frequency mass movement process.

The highly potential areas, identified in category 3 should be monitored at the time of winter snowfall, as these reach highways and infrastructure. The proven method of controlled sound and blast mechanism should be initiated to trigger avalanches to avoid hazard to life and structures during heavy snow events in the high probability zones.

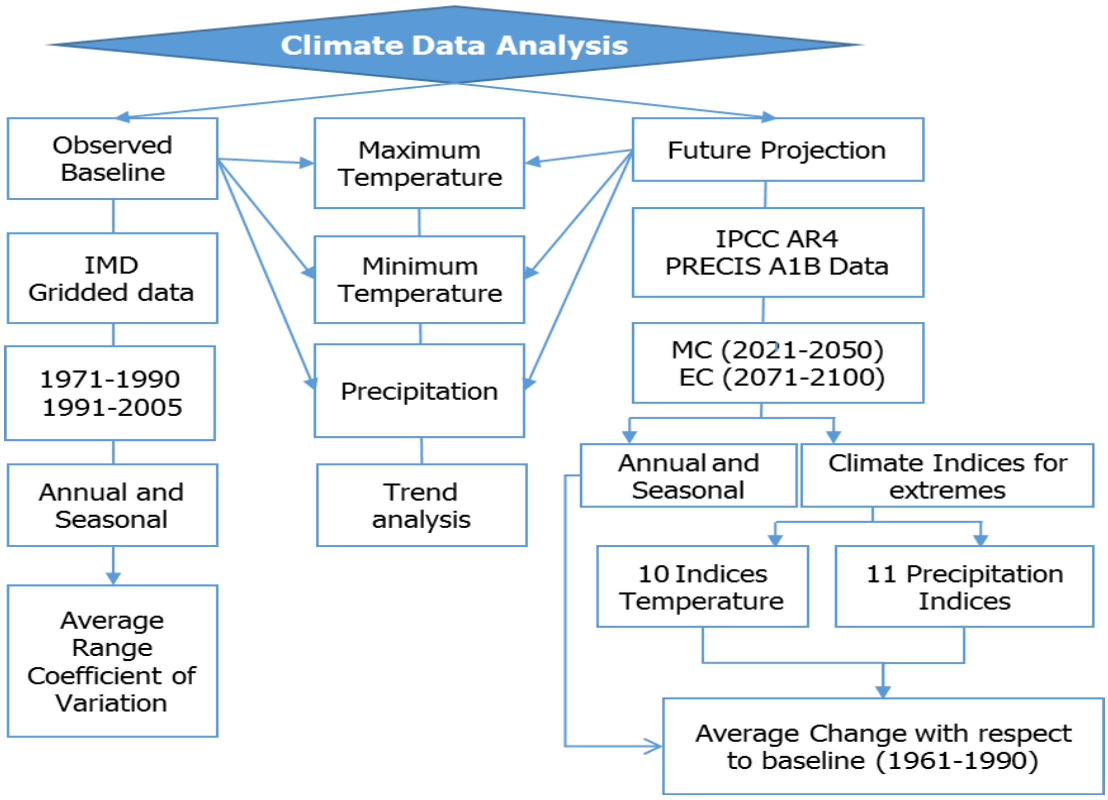
The study on snow avalanche hazard can be strengthened provided the following set of data and variables are made available:

1) Snowfall data/ meteorological conditions
2) Snow properties (snow structure and mechanics)
3) Analysis of avalanche path configuration and gradient at micro level.
4) Properties of snow rupture and run out zones in the probable areas.
5) Debris carrying capacity of snow avalanche, if any (for understanding damage potential).

Climate Change Hazard Risk:

Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically many decades or longer). Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. The long term trends in observed seasonal precipitation and temperature over Himachal Pradesh using IMD gridded rainfall and temperature at daily time scales has been performed to arrive at current baseline climatology for the state. IMD gridded data was used for Climate change hazard risk analysis.

Methodology:



Data Source:

The long term trends in observed seasonal precipitation and temperature over Himachal Pradesh using IMD gridded rainfall and temperature at daily time scales has been performed to arrive at current baseline climatology for the state.

1) IMD gridded rainfall at 0.5 degree spatial resolution for the time period 1971-2005 (35 years).This data set has been then analysed further for two periods-1971-1990 (20 years) and 1991-2005 (15 years).

2) IMD gridded maximum and minimum temperature at 1 degree spatial resolution for the time period 1969-2005 (37 years). This data set has been then analysed further for two periods-1971-1990(20 years) and 1991-2005(15 years).Two time periods have been analysed for comparison between them

Conclusions:

Observed Temperature and Precipitation:

Summary of the long term trends in observed seasonal precipitation and temperature over Himachal Pradesh using IMD gridded rainfall and temperature at daily time scales is:

Rainfall:

- Annual average rainfall for Himachal Pradesh from 1971-2005 (35 years) is1294.3 mm. The mean south-west monsoon (June, July, August and September) rainfall (802 mm) contributes 62% of annual rainfall. Contribution of pre-monsoon (March, April and May) rainfall and post-monsoon (October, November and December) rainfall in annual rainfall is 17.8% and 13.6% respectively.
- Annual average rainfall for the state show significant positive trend in period 1971-1990 while insignificant negative trend in 1991-2005.
- Maximum mean observed monsoon rainfall is observed in North Western districts of the state namely, Chamba, Kangra, Sirmaur and Hamirpur districts for both the periods (1971-1990 and 1991-2005). Lahul & Spiti receives the least rainfall.

Rainy days:

- Average number of rainy days in Himachal Pradesh during the south west monsoon is about 50 days for the period 1969-2005and varies from 25 days to 69 days. Average number of rainy days in the state during the post monsoon (winter) is about 7 days and varies from 3 days to 9 days
- Average number of rainy days (when daily rain >2.5 mm) in the state during the south west monsoon is about
- 43 days and varies from 17 days to 71 days for 1971-1990.
- 45 days and varies from 17 days to 78 days for 1991-2005.
- In monsoon months in period 1991-2005 light to rather heavy rainfall days ($0 < R \leq 64.4$ mm)have increased by 3 days on average compared to 1971-1990 while the extreme and heavy rainfall days show no change

Temperature:

- Annual average maximum and minimum temperature for Himachal Annual average maximum and minimum temperature for Himachal Pradesh from 1969-2005 is 25.2^{0}C and 13.0^{0}C respectively. Seasonal average maximum temperature is higher during monsoon season (30.0^{0}C) and ranges between 28.6^{0}C to 31.6^{0}C. Similarly seasonal average minimum temperature is lowest during winter period (4.4^{0}C) and ranges from 1.9^{0}C to 6.1^{0}C.

- Annual maximum temperature for Himachal Pradesh shows increase of about 0.410C in 1991-2005 while in 1971-1990 it shows no change. In pre monsoon season, state maximum temperature show decline of about 1.630C in 1971-1990 while increase of about 2.070C in 1991-2005.
- Annual minimum temperature for Himachal Pradesh shows increase of about 0.19^0C in 1991-2005 while in 1971-1990 it shows a much higher increase of about 3.6^0C. State shows much higher increase of minimum temperature in pre monsoon, monsoon and post monsoon seasons in 1991-2005 in comparison to 1971-1990

Climate Change Temperature and Precipitation:

PRECIS simulations for future indicate an all-round warming over Himachal Pradesh associated with increasing greenhouse gas concentrations.

- The mean minimum and maximum air temperature rise by mid-century is projected to be around 2.3°C and 1.9°C respectively. Change for the same towards end century is projected to be around 5.0°C and 4.6°C respectively. Increase in minimum temperature is projected to be marginally higher than the maximum temperature.
- Precipitation is projected to increase by about 15% and 28% towards mid-century and end Century respectively.

Climate Indices:

Climate extremes shows that minimum of maximum and minimum of minimum temperatures is consistently increasing in MC and EC compared to the BL, indicating significant warming up increasing over the Himachal Pradesh districts. Very wet and extremely wet day precipitation is projected to increase for all the districts in MC and EC compared to the BL implying that rainfall and its intensity would increase in the future.

- Percentage of warm days and warm nights is projected to increase while percentage of cool days and cool nights is projected to decrease for all the districts implying warming up.
- Kullu, Kinnaur and Mandi districts of Himachal Pradesh are expected to get the warmest in MC and EC compared to the BL, while for Lahul & Spiti temperature increase is expected to be the least compared to the other districts.
- Increase in precipitation in MC and EC is projected to be the maximum for Salon, Bilaspur, Hamirpur districts of Himachal Pradesh compared to the BL, while increase in extremely wet days (annual total rain when rainfall is greater than 99th percentile of baseline) is projected to be the maximum for Mandi, Hamirpur and Bilaspur districts.
- Increase in count of very heavy precipitation days is expected to be the maximum for Salon, Bilaspur and Kangra of Himachal Pradesh districts compared to the baseline
- 1 and 5 day extreme precipitation increase is projected to be the maximum for Shimla towards end century

Glacial Lake Outburst Flood (GLOF) Hazard Risk:

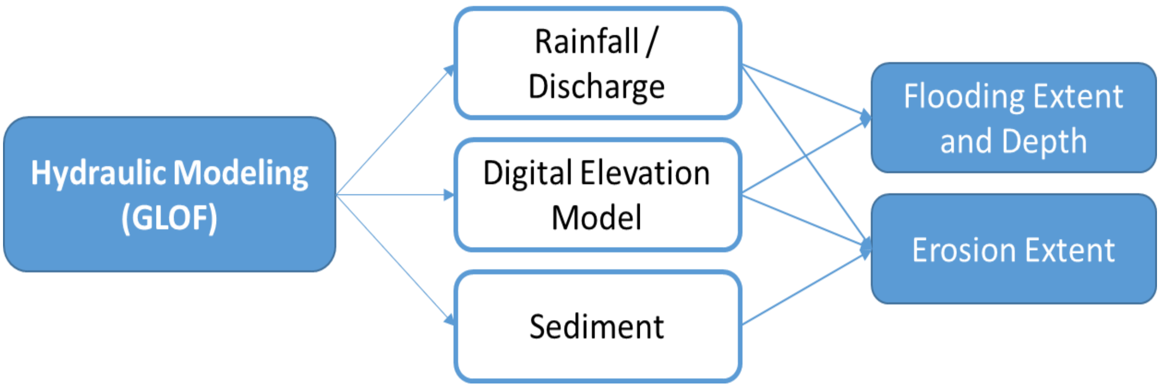
The glaciers are the frozen water reserves in the high altitude and are one of the most important natural resources in the Himachal Pradesh region. Melt water released by the glaciers serves as the perennial source for most of the Himalayan River systems. The streams originating from these glaciers are also the source of energy for hydroelectric power plants. Also stream provide irrigation to agricultural lands in the command areas especially during the summer period when it is most needed.

Natural dams of different size and origin exist in mountain areas all over the world (Costa and Schuster, 1988). In case of dam failure, these lake outbursts cause destructive floods downstream. Many of these lakes are found near the snouts of glaciers, with natural dams formed by loose moraine materials. The dam burst of lakes located within the glacial or periglacial area are called Glacial Lake Outburst Floods (GLOFs). GLOFs often have a highly destructive potential because a large amount of water is released within a short time, with a high capacity to erode loose valley sediments, potentially leading to a powerful flow with a long travel distance. The downstream fertile valley areas prone to such extremely low frequency (in scale of many decades/centuries) floods are often have large populations, valuable agricultural land. The risk of GLOF has increased with climate change.

Peak discharges are often some magnitudes higher than in the case of "normal" floods. The source area is usually far away from the area of impact and events occur at very long time intervals or as singularities, so that the population at risk is often not prepared for such events. Deficiencies in risk communication are often responsible that events evolve into disasters. A number of significant GLOFs resulting in fatalities and severe damage have occurred during the previous decades, particularly in the Himalayas. The Himachal Pradesh region holds 2,554 glaciers with the glacier area of 4160 sq.km and 229 lakes including 22 potential GLOF prone lakes.

Methodology:

The steps followed to model and analyses impact of GLOF is shown in the following figure.



GLOF Modeling:

The GLOF hazard assessments need to take into account possible interaction of processes or chain reactions as the implications can be complicated and far reaching. One of the many chain reactions that could take place in the Himalayas is that the outburst of a comparably small lake cascading in to a downstream lake/ lakes causing exceptionally large floods. The total discharge of such a chain event could be much larger than anticipated from analyzing individual lakes only. The triggering lake nay be apparently safe, but the outburst may be triggered by an landslide or avalanche. This is one of the reasons why smaller lakes can actually pose a large hazard.

CAESAR-Lisflood (Caesar Lisflood Landscape Evolution and Flow Model) model developed at University of Hull, UK was used for Glacial Lake Outburst for all eleven (11) lakes. Caesar Lisflood is a geomorphological / Landscape evolution model that combines the Lisflood-FP 2d hydrodynamic flow model (Bates et al, 2010) with the CAESAR geomorphic model to simulate erosion and deposition in river catchments and reaches over time scales from hours to 1000's of years.

Landscape evolution models (LEMs) simulate the geomorphic development of river basins over long time periods and large space scales (100s–1000s of years, 100s of km^2). The LISFLOOD-FP simplified 2D flow model addresses this issue of shorter term hydrodynamic effects (e.g. the passage of a flood wave). The LEM CAESAR and the hydrodynamic model LISFLOOD-FP were merged to create the new CAESAR-LISflood model, and it is tested through a series of preliminary runs to route flow in an LEM. The model is fast, computationally efficient and has a stronger physical basis. It allows hydrodynamic effects (tidal flows, lake filling, alluvial fans blocking valley floor) to be represented in an LEM.

Eleven susceptible glacial lakes falling in Ravi, Chenab and Sutlej basin in Himachal Pradesh were identified using expert knowledge, surveys and literatures. The surface area of the relevant lakes was computed and the lake volumes were estimated. The peak discharges of potential outburst events were estimated. Scenarios of outburst Hydrographs were then created based on the estimated peak discharge and the lake volume. Mapping of the characteristics of the flow path and the area inundation was conducted.

Data Source:

1) ASTER digital elevation model of horizontal resolution of the 30 m
2) Maximum Glacier volume
3) One day discharge for Glacier Lake Outburst routed as flow of single day is spread over complete 24 hrs to release lake complete volume.

Conclusions:

The present study illustrates that modelling of GLOFs remain a challenge. Given the present state of knowledge, it is not possible to predict exact time of occurrence or magnitude of risk posed by glacial lakes in Himachal Pradesh. The study took a step-wise approach to ensure that coverage to be as comprehensive as possible. At the same time, careful selection of most critical lakes were taken for study with the help of field experts of the region.

Inundation map of glacier lake outburst of selected 11 (eleven) lake shows vulnerable villages and area. It is evident from inundation maps that out of 11 (eleven) glacier lakes, some glacier lakes in each basin are more vulnerable. According to modelling output and inundation maps of Chenab Basin, area falling under vulnerable zone of Lake 8 and lake 7 are at utmost risk. In Ravi basin, area falling under vulnerable zone of Lake 5 and Lake 6 are at maximum threat. Volume and area wise, glacier lakes in Sutlej basin are not so vulnerable, when compared to glacier lakes of Chenab and Ravi basins. But number of villages falling within the inundated vulnerable zones are quite high in Sutlej basin.

Although the eleven lakes considered for study have been evaluated as relatively stable, the possibility for a GLOF occurring sometime in the near future cannot be dismissed, particularly in view of continued atmospheric warming and the associated increase in volume of glacial lakes. Furthermore, expansion of infrastructure in the vulnerable sectors downstream means that the actual risk associated with any individual event is increasing. As with earthquakes, the difficulty lies not in predicting that such an event is likely to take place. In the current situation, it is impossible with any certainty to predict where such an event will occur, and when. However, because such an event is possible, it is vital that steps be taken to mitigate against severe loss of life and property.

Sutlej basin - area affected by flooding and inundation caused due to Glacier Lake Outburst

- Three glacial lakes were considered of sizes, 0.07, 0.21 and 0.06 MCM respectively
- About 49 villages in flood risk zone of Lake 2
- About 51 villages in flood risk zone of Lake 4
- About 10 villages in flood risk zone of Lake 9

Chenab basin - area affected by flooding and inundation caused due to Glacier Lake Outburst

- Four glacial lakes were considered of sizes, 18.36, 44.21, 0.55 and 1.16 MCM respectively
- About 48 villages in flood risk zone of Lake 7
- About 71 villages in flood hazard region of Lake 8
- About 5 villages in flood risk zone of Lake 10
- About 7 villages in flood risk zone of Lake 11

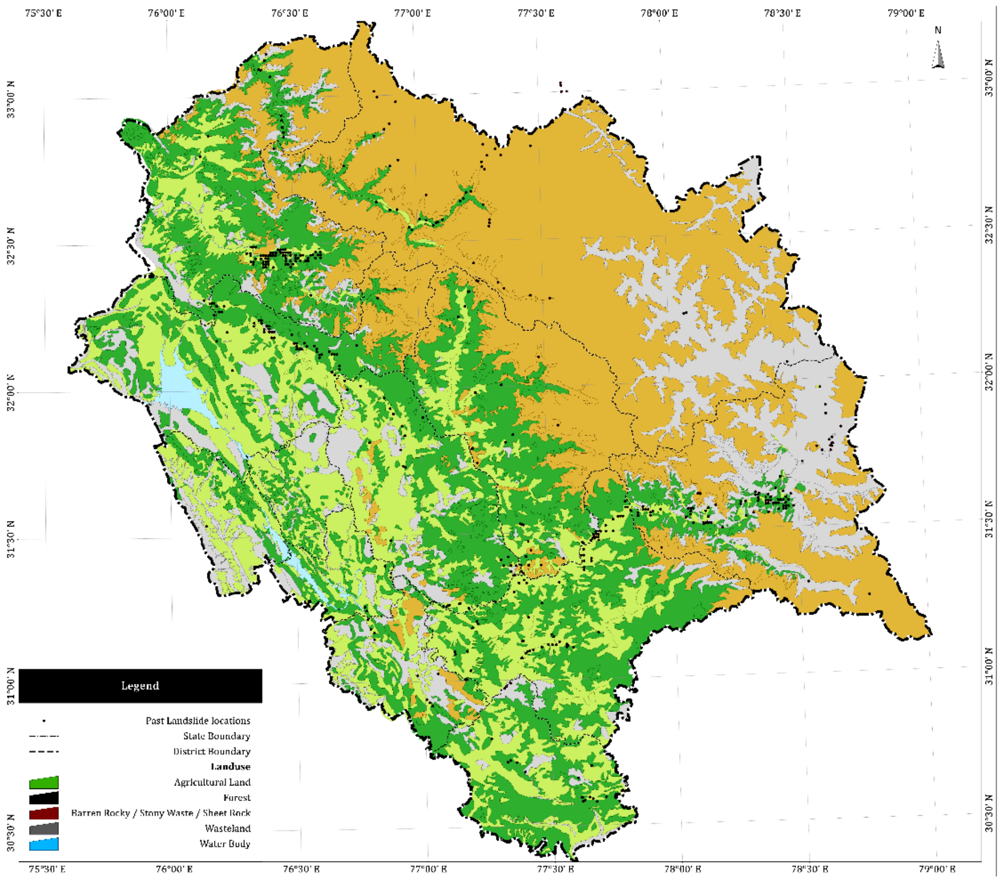
Ravi basin - area affected by flooding and inundation caused due to Glacier Lake Outburst

- Four glacial lakes were considered of sizes, 0.06 , .13, 0.28 and 0.88 MCM respectively
- About 39 villages in flood risk zone of Lake 1
- About 64 villages in flood risk zone of Lake 3
- About 59 villages in flood risk zone of Lake 5
- About 65 villages in flood risk zone of Lake 6

Landslide Hazard Risk:

The complex physiography, demography and developmental activities in this mountain state are exposed to hazards such as heavy snowfall, floods, landslides, land subsidence, removal of vegetation and soil erosion. According to one estimate about 58.36 % of the land in India is subjected to intense soil erosion and majority of which is located in the Himalayas. An estimation of the sedimentation rate of the major river systems of the area depicts the seriousness of the erosion.

Hilly areas of Himachal Pradesh is vulnerable to landslides geo-physical, meteorological and anthropogenic factors. Several devastating landslides have occurred in Himachal Pradesh over the past decade. The hydro-meteorological conditions and fragile structure of geological strata of Himachal Pradesh increase the possibility of landslides. Anthropogenic factors such as removal of vegetation cover, overloading of slopes by debris through constriction activities also contribute to landslide risks to a great extent. Anecdotal evidence indicates that the development activities like construction of roads, tunnels and excavation for hydro projects have further amplified the problem. Loss of life, damage to buildings, soil erosion, and loss of tree cover, damage to bridges, communication lines and hydropower infrastructure are some of the impacts the landslide and these risks tend to cause. The landslide risks cascade in to flood risks by damming of rivers and catastrophic failure of such dams after few days/months.



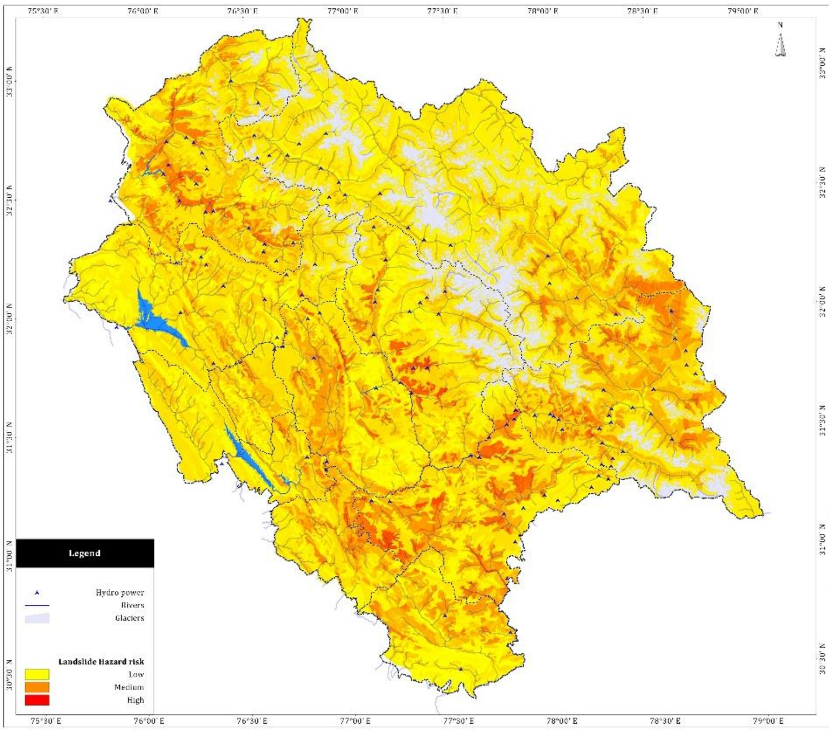
Methodology:

Landslide hazard of an area is determined by multiple factors. There are many techniques which have been applied to delineate the area into different landslide hazard zones. These techniques are broadly divided into direct and indirect methods. Direct method includes geomorphological mapping and Landslide distribution analysis whereas there are number of indirect ways for landslide Hazard zonation. Indirect methods include Index overlay, Fuzzy logic, Analytical Hierarchical process, multivariate technique, deterministic modelling etc. No one method is accepted universally for effective assessment of landslide hazards. In recent years, several attempts have been made to apply different methods of LHZ and to compare results in order to find the best suited model. The advanced multivariate techniques are proved to be effective in spatial prediction of landslides with high degree of accuracy.

For the present study, three approaches of Multi Criteria Analysis technique were used for landslide hazard and vulnerability mapping. Classified LULC layer, classified geology layer, classified soil layer, classified rainfall layer and classified slope layer were used for overlay analysis. Weights indicating measures of influence of different layers were quantified by three means: 1) BMPTC vulnerability assessment method 2) expert knowledge and 3) analytical hierarchical process.

Landslide Risk Assessment:

Landslide Risk analysis usually consider the potential damage due to landslides in any area. The elements at risk includes population, infrastructure, agriculture, critical facilities and so on. Major roadways, location of hydropower projects and settlements were the elements taken into consideration to analyze the risk associated with them. Simple overlay, thematic mapping, multi-criteria selection and visual interpretation techniques were also used to understand the risks associated with each element under different Hazard risk.



For Risk assessment the results obtained from AHP approach was used with different elements such as location of hydropower projects, major roadways, villages and major towns to analyze the risk associated with these elements.

Data Source

Digital maps of Himachal Pradesh with district boundaries were used for Digital maps of Himachal Pradesh with district boundaries were used for preparation of Flood hazard risk map and to perform Risk assessment. The table below gives the sources of the data

Layer Name	Sub-type	Source
Base Layers	Geological	GSI, HP State
	Soil	GSI, HP State
	Rainfall	IMD and IITM, 2009
	Land use Land cover	GLC 2000
	Population density map	CIESIN: 2010 and 2015
Remote Sensing Data	Slope	ASTER(30m)
Geological Hazard	Landslide	GSI, HP State, BMPTC, TARU

Conclusions

Hazard and Vulnerability mapping are the most vital steps to be conducted so as to tackle the adverse effects of the landslide risk. This exercise was carried out to delineate the areas under different hazard zones and further analyze the vulnerability to landslides in state of Himachal Pradesh. Comparison of both the results obtained from methodology as adopted in BMPTC Vulnerability atlas with incidences of past landslides recorded by GSI indicates that Hamirpur, Bilaspur and Una although falling under high to very high hazard area hardly having any incidences of landslides in the past. Similar results are observed in the case of revised methodology as well.

Past landslide location map was prepared using GSI Atlas No. 71. Most of the past landslides reported were along the roads/highways and along the pilgrimage routes as observed in NRSC Atlas. This clearly indicates that the slides are triggered mainly due to anthropogenic factors. This results calls for taking immediate measures to improve design of development activities considering the landslide risks. Road cuttings and other development activities should be carried keeping in consideration of the hazard profile to reduce present and emerging risks due to landslides. Such hazard zoning and vulnerability assessments may use as an integral part of the disaster management and development plans to provide guidance to government and regulatory authorities for better informed land use and physical planning process in hazard prone areas.

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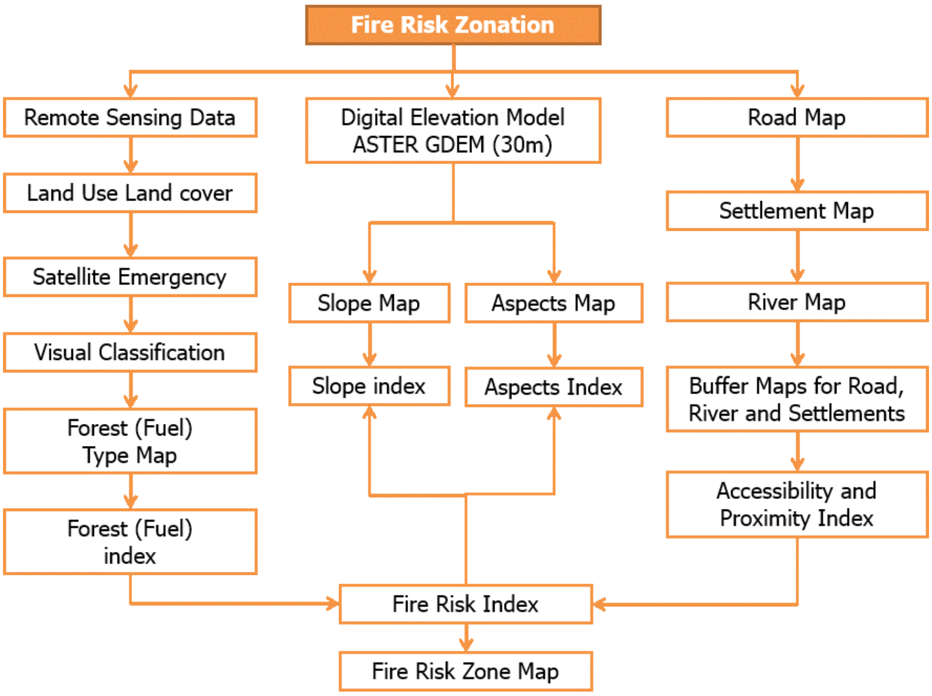
Forest Fire Hazard Risk:

The forests of Western Himalayas are more vulnerable to forest fires as compared to those in Eastern Himalayas due to drier climates and higher population densities. Frequency and intensity of forest fires has been increasing, especially since 1990's in Himalayan region. Forest fires are an annual phenomenon in state of Himachal Pradesh. This is a most frequent hazards. Fire season starts from mid-April, when there is no rain for months, forests become littered with dry senescent leaves and twigs, which could burst into flames or ignited by the slightest spark. In June 2007, forest fire destroyed 2,000 hectares of forest in Himachal Pradesh (SAARC-DM Center, 2007). Forest fires are mostly anthropogenic in nature in Himachal Pradesh and may occur due to the following reasons:

- Forest floor are often burnt by villagers to get a good growth of grass in the following season or for a good growth of mushrooms,
- Wild grass or undergrowth is burnt to search for animals,
- Firing by miscreants,
- Attempt to destroy stumps of illicit fallings.

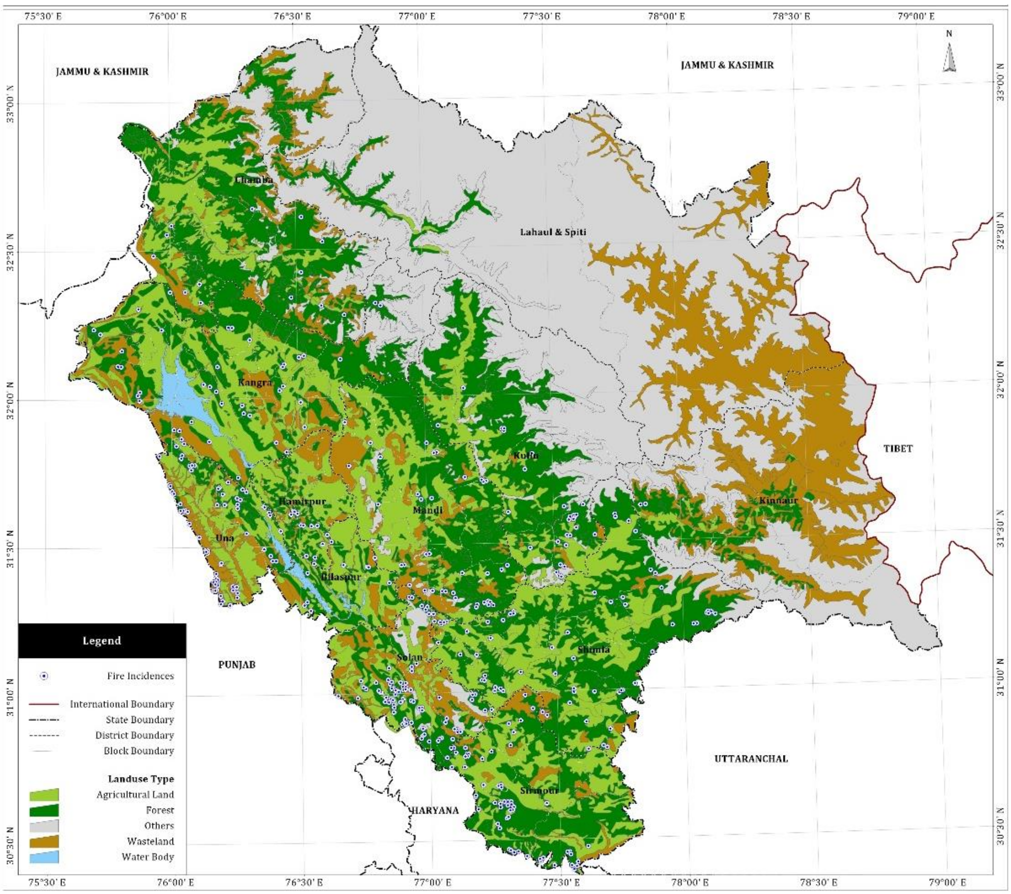
Methodology:

Following methodology was used for assessment.

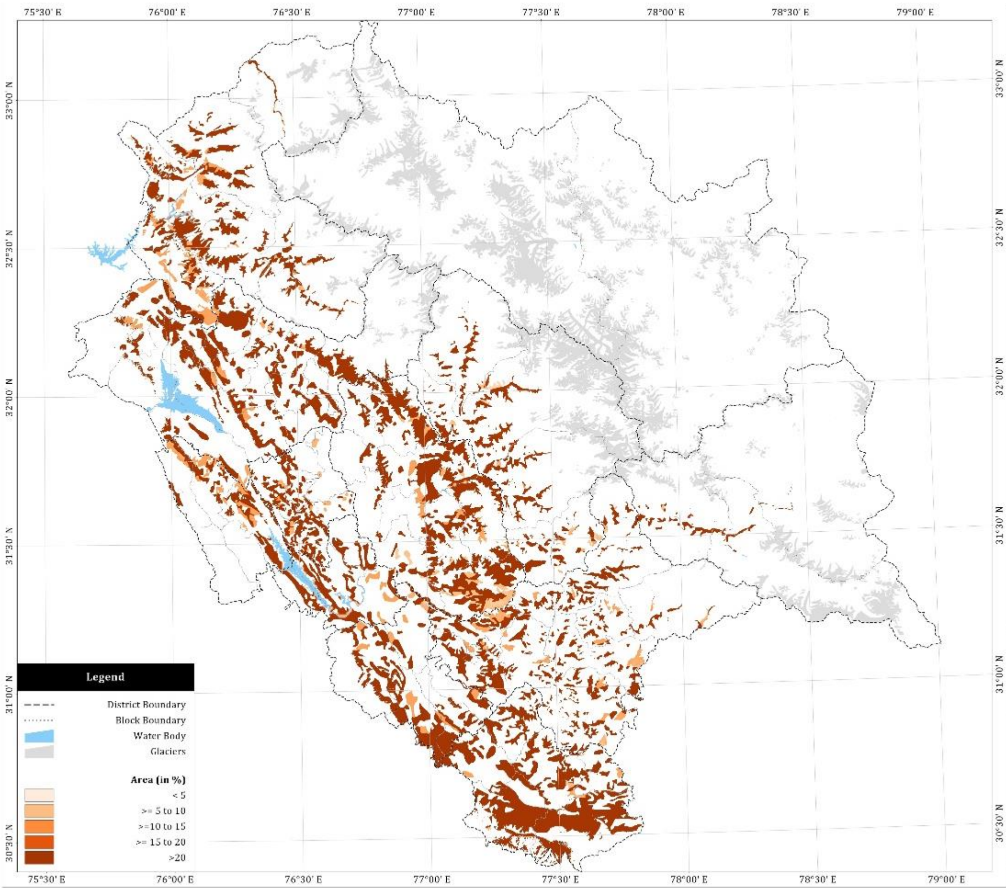


Forest Fire Risk Assessment

In this study, Saaty's (2000) Analytical Hierarchy Process (AHP) method was used for risk mapping and zonation. AHP is a multi-criteria decision making (MCDM) method in conjunction to rank and prioritize the causative factors of fire risk in the study area.



Forest Fire Incidences:



Fire Risk Zones with District Level Statics

District wise Forest Fire Risk Zones (in Sq. Km.)							
District	**No Risk**	**Very Low**	**Low**	**Medium**	**High**	**Very High**	**Total Area (Sq. Km)**
Chamba	27	2,098	926	41	1,302	2,007	6,402
Bilaspur	87	25	214	27	561	247	1,162
Hamirpur	-	2	236	4	615	255	1,113
Kangra	208	872	959	27	2,045	1606	5,718
Kinnaur	10	4,444	1,446	9	56	502	6,468
Kullu	13	2,699	223	49	1,187	1324	5,495
Lahul & Spiti	56	12,702	823	5	72	188	13,845
Mandi	3	242	788	29	1,71	1,419	3,951
Shimla	-	469	826	13	1,658	2,147	5,113
Sirmaur	-	3	377	6	1,092	1,324	2,802
Solan	-	4	819	10	583	507	1,923
Una	44	57	505	14	720	194	1,534

Data Source:

The following datasets were used to access forest fire risk across the state.

- Road network (Open access database)
- Elevation data (ASTER GDEM 30 m)
- Land use and land cover (GLCF)
- River network and water bodies (Hydro sheds & Google Earth Pro)
- Historical fire events (MODIS Burned Area, Forest Survey of India)

Conclusions:

The results obtained through the analytical hierarchical process was quite useful in delineating potential "**fire risk**" zones at a block level. These maps and results can be used both as a strategic planning tool to address broad-scale fire hazard concerns and also as a tactical guide to help managers in designing effective fire control measures at local level.

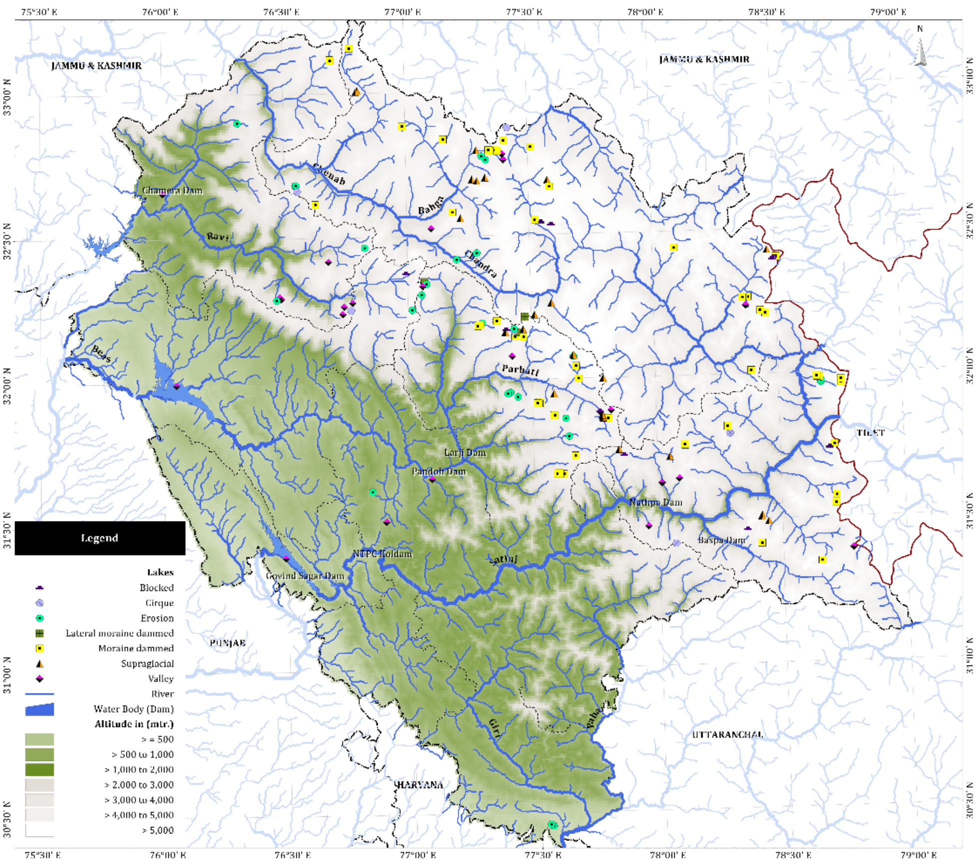
The results from the analysis demonstrate the fire potential and possible spread of fire events in the state of Himachal Pradesh. To manage growing forest fire frequency and associated fire hazards, as well as prioritize prescription efforts, it is essential to improve our understanding of the causative factors of fires. Forest fires in the mountainous regions are the result of several underlying factors. In this study, fire risk is quantified in coniferous forests and broad-leaved forests, as a function of topographic, vegetation, climatic, and socio-economic attributes. The criterion maps relating to topographic, biophysical, and socioeconomic predictors produced in this study can also be used to assess the susceptibility of any vegetation to fire and for determining future fire risks. In overall, this study demonstrates the potential of GIS technology and its viability in integrating objective as well as subjective data using fuzzy-AHP approach for assessing fire risk in the study area.

Flood in Himachal Pradesh:

The state of Himachal Pradesh has a complex physiography comprising hills and mountains with deep gorges that are cut by the majestic rivers. The altitude of the state ranges between less than 300 meters to more than 6000 meters. There are five main river catchments i.e. the Sutlej, the Beas, the Ravi, the Yamuna and the Chenab.

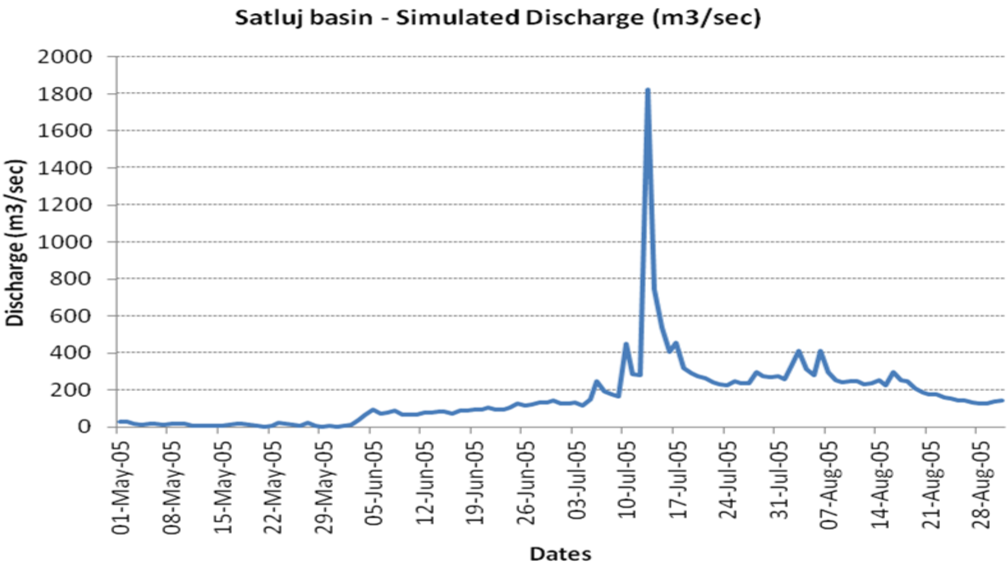
The occurrence of water related natural disasters- especially floods and flash floods- are common in most of the mountains states including Himachal Pradesh. The floods can be of various origins, but in a hilly area like Himachal they are the result intense and prolonged rainfall, the blocking of river channels by landslides or avalanches or the sudden breach or burst of artificial /natural lakes or cloudbursts in the catchment region. In Himachal, the riverine flooding is mostly associated with the rivers having snow fed origin because in summer the snowmelt coupled with heavy monsoon rain often triggers a flood. The Sutlej and Beas rivers face floods almost every year.

On the other hand, flashfloods are also common in the state. The flash floods are caused by extreme events that are sudden, severe and short lived. The duration of this phenomenon is short but can cause extensive damage. Flash flood is a sudden and often destructive surge of water down a narrow channel or sloping ground, usually caused by heavy rainfall/cloudbursts. The floods in the state occur is mainly during the months of June to September when the south west monsoon is in progress and snow is melting in the higher reaches.



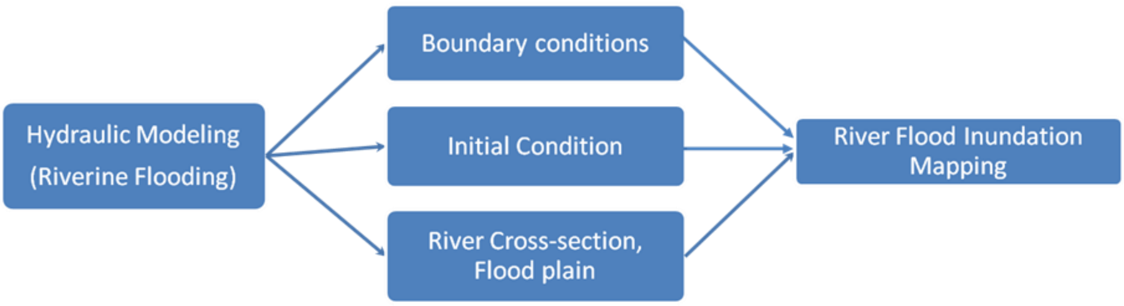
Data Source:

- Sutlej and Beas River cross-sections extracted using public domain ASTER digital elevation model.
- Sutlej river: Required boundary condition, flow / stage / rating curve at starting of river and at confluence of river - SWAT hydrological model simulated flow of Sutlej. This flow was enhanced by 50% to represent order of magnitude of June 2005 flood.
- Simulated flow used for modelling is shown in following figure.



Flood Hazard Risk Analysis for Himachal Pradesh:

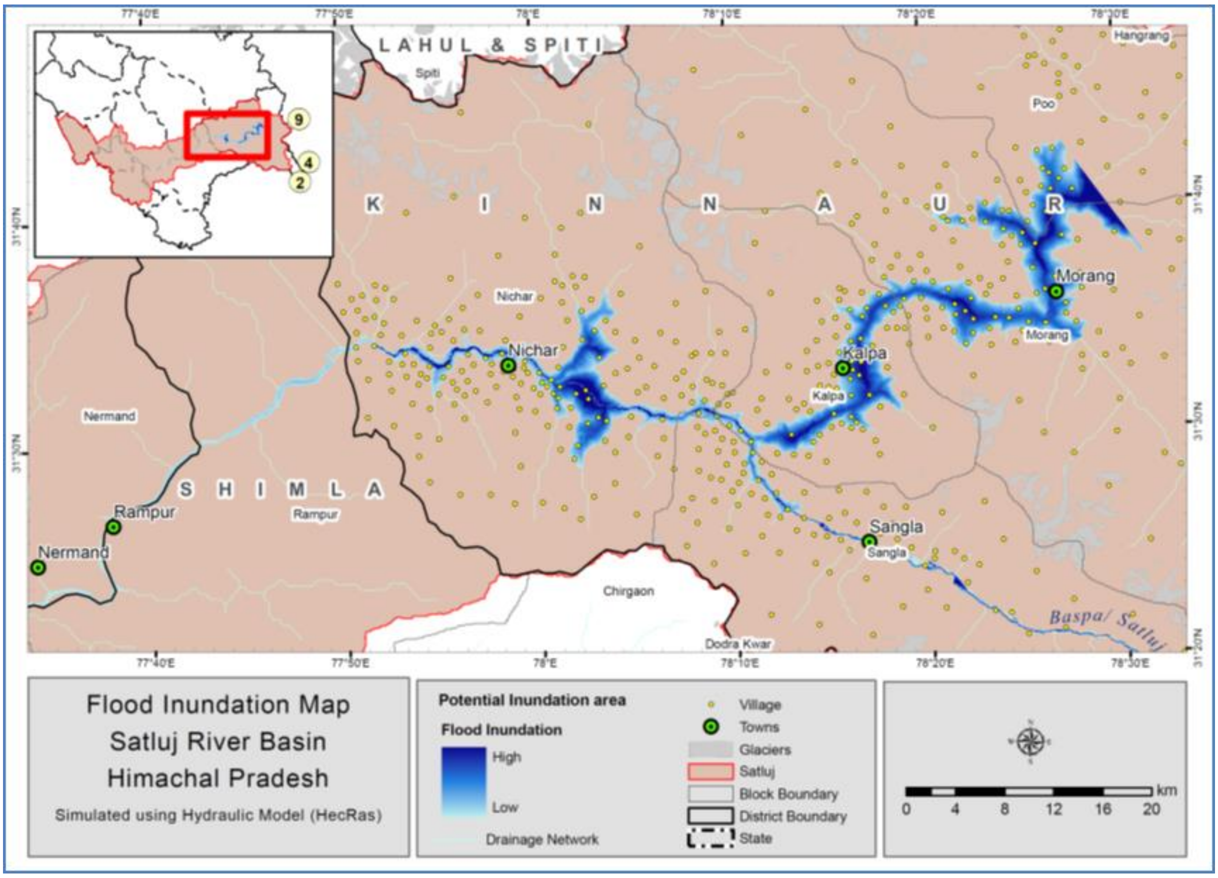
A methodology used for Flood Hazard Risk Analysis is presented below.



Flood Modeling:

A hydraulic model was used to analyze the implication of a flood passing through the river stretches. Flood inundation modeling was done for the identified stretches. HecRas Hydraulic model was used for simulating flood inundation on Sutlej and Beas River.

Hydrologic Engineering Centre – River Analysis System (HEC-RAS) is a one-dimensional steady and unsteady flow hydraulic model developed by the U.S. Army Corps of Engineers (HEC, 2002). The HEC-RAS hydraulic model takes the analysis further by studying the transformation of the flood events as they pass through the upstream to downstream of the river channel cross sections. These flood waves cause inundation when the carrying capacity of the channel is exceeded by the discharge. The output of the model provides the water surface profiles all along the river along with its temporal variation (change in flow depth during the flood period). Effect of storm surge has also been modeled using HECRAS. The model requires high quality of data on channel geometry and terrain to simulate the water surface profiles and inundation properly. It also needs data on the manmade interventions such as bridges, embankments, etc., so that their effect on the flow can also be simulated. Most of these data required for the modeling were not available and the quality of data obtained from other sources was poor.



Conclusions:

Riverine flooding or river floods is caused when a river reaches its flood stage. Water can rise and spill over the banks of the river. The amount of flooding is a function of the amount of precipitation in an area, the amount of time it takes for rainfall to accumulate, previous saturation of local soils, and the terrain around the river system.

Floods are natural phenomena, which can have severe economic, social and environmental consequences. An increased number of people and economic assets are located in riverine flood plain areas. The rising water level may be caused by heavy snowmelt or high-intensity rainfall creating soil saturation and high runoff either directly or in upstream catchment areas.

Locally, soil saturation after prolonged natural recharge may contribute to severity of the flooding. In Himachal Pradesh, flash flood due to cloud burst is common phenomena. Himachal Pradesh experiences riverine flooding of varied magnitude almost every year and

Sutlej and Beas are most vulnerable rivers. All the villages and property inside the flood plain and near close vicinity are in vulnerable zone

Background

Himachal Pradesh is a mountainous state with high diversity in rural livelihoods, largely depending on the altitudinal zones. The state is prone to various natural hazards including earthquakes, cloudbursts, avalanches and flash floods. The scale of these events range from a single slope (e.g. landslide, avalanche) or a valley as in case of hydro-meteorological hazards to regional scales as in case of earthquakes. From South to North, the state can be subdivided in to four zones namely:

1) Shiwaliks or Outer Himalayas (Subtropical Agro-ecological zone)
2) Inner Himalayas or Mid mountains (Sub-humid Agro-Ecological zone)
3) Alpine zone or Greater Himalayas (containing both temperate wet and temperate dry Agro-ecological zones)
4) Trans-Himalayan cold desert

The population is distributed quite unevenly across the state depending on natural resource endowment (determined by altitudinal zones, slope aspect and soil conditions). While the Great/Trans-Himalayan zones has sparse population due to inhospitable climatic conditions, the Shiwalik zone has the highest population densities. The rural population density generally depends on natural resource availability including cultivable land, grazing grounds, forests as well as irrigation. The altitudinal zone determines rainfall and temperature ranges, which in turn determines the type of potential crops that can be grown as well as type of rural livelihoods that can be supported.

Himachal Pradesh is inhabited by both case as well as tribal communities. While the lower altitudinal zones are mostly inhabited by various castes, the Trans and Great Himalayan zone is inhabited predominantly by the Tribal communities. Animal husbandry and transhumance is practiced by some of the communities who traverse through various zones over the seasons.

Socio- economic Profile

Himachal Pradesh had a total population of 6.8 million in 2011, with 90 percent residing in rural areas. The population density ranged from a minimum of 2 persons per sq.km in Lahaul & Spiti District (Trans-Himalayan cold desert Zone) to a maximum of 406 persons per sq.km in Hamirpur District bordering Plains of Punjab.

Agriculture based rural livelihoods range from mainly cereal based agriculture in the lower altitudes to predominantly horticulture in middle and higher altitudes. Animal husbandry is another major source of rural livelihood. Horticulture has become a cash crop due to suitable habitat as well as large markets in the neighbouring Indogangetic plains. Animal husbandry is practised by both farmers as well as transhumant communities.

The working population is about 43 percent of the state’s population. The agriculture contributes about 20% of state’s domestic product, but about two-thirds of the workers are engaged in primary sector. The secondary and tertiary sectors contribute nearly 80% of the State domestic product, while employing about 30% of the workers.

Himachal Pradesh has one of the high literacy rates (7+ years) among the northern Indian states (82.8%). It is the fifth most literate state in India and it is one of the main factors determining the vulnerability of the population.

Districts	Population (2011)	% of State Pop.	% Rural to District Pop.	Area km²	Density (persons/ sq.km)	Sex ratio
Bilaspur	3,82,056	6%	93%	1,167	327	981
Chamba	5,18,844	8%	93%	6,528	80	989
Hamirpur	4,54,293	7%	93%	1,118	406	1,096
Kangra	15,07,223	22%	94%	5,739	263	1,013
Kinnaur	84,298	1%	100%	6,401	13	818
Kullu	4,37,474	6%	91%	5,503	79	950
Lahaul & Spiti	31,528	0%	100%	13,833	2	916
Mandi	9,99,518	15%	94%	3,951	253	1,012
Shimla	8,13,384	12%	75%	5,131	159	916
Sirmaur	5,30,164	8%	89%	2,825	188	915
Solan	5,76,670	8%	82%	1,936	298	884
Una	5,21,057	8%	91%	1,549	338	977
HP Total	**68,56,509**	**100%**	**90%**	**55,673**	**123**	**974**
Source: Census of India 2011.						

The proportion of workers across different sectors in the state is presented in the following Table.

Workers across sectors Himachal Pradesh					
Total	Total workers	Cultivators	Agricultural labourers	Household industry workers	Other workers
Persons	29,92,461	65.3	3.1	1.8	29.8
Males	16,86,658	49.5	3.3	2	45.2
Females	13,05,803	85.8	2.9	1.4	9.8
Source: Census of India 2011					

SOCIO-ECONOMIC VULNERABILITY ASSESSMENT

The Socio-economic Vulnerability Assessment (VA) is aimed to quantify the vulnerability across different income groups under conditions of disasters. It provides inputs to disaster mitigation strategies. Social Vulnerability is the possibility of impacts on assets as well as their livelihoods and social relations. Social vulnerability is the complex outcome of the human, asset and livelihood impacts.

APPROACH

The most common framework for social vulnerability uses three broad sets of parameters Physical (location, housing and infrastructure), Social (community, networks), and psychological status (ability to cope with loss) of households (Anderson & Woodrow, 1989). This approach is inadequate to capture the range of factors that result in differential vulnerability to multiple types of hazards.

The Sustainable Rural Livelihoods (SRL) approach provides a framework for analysis of household capabilities and vulnerabilities from a holistic perspective. Livelihoods depend on the capabilities, assets (both materials and social resources) and livelihoods as well as well-being. The ability of a household to cope with and recover from stresses and shocks (e.g. natural hazards) and maintain or enhance its assets base, determines the extent of its vulnerability. The SRL framework defines five capital assets namely: Natural, Social, Human, Physical and Financial. This framework has been developed in response to DFID's commitment to promoting sustainable rural livelihoods and has been used by researchers and planners to develop poverty eradication strategies. SRL framework can also be used as a framework for defining and assessing vulnerability. It recognizes that household vulnerability arises from the lack of these five capitals to deal with shocks and stresses.

Household level interviews were conducted to capture status of these five capitals and indicators were developed to assess the vulnerability across these sets of capitals. A composite Socio-economic vulnerability index was also developed to summarise the vulnerability across five capitals. Since the livelihood context households are quite different in rural and urban areas, separate sets of indicators were used. In rural areas, natural capital is important since a significant proportion of households depend on natural resources, while in urban areas, physical capital (e.g. lifeline services) are well developed and direct linkage of livelihoods to natural capital is weak.

Village Classification

Since rural economy is largely based on primary sector, type of agriculture practiced and crops determine the vulnerability of household incomes. Also, in mountainous environment, distance from road network from the settlement is one of the major determining factor in access to markets as well as lifeline services. These two parameters were used to classify the villages across the state. The brief statistics of villages across different classes is provided:

Categorization of Villages of Himachal Pradesh based on Altitude Range and Minimum Road Distance				
Altitude Range	Minimum Road distance			
	<5km	5-10 Km	>10Km	Total
< 1000	1,756	4,980	681	7,417
1000 - 1500	1,003	1,781	492	3,276
1500 - 2500	736	1,812	869	3,417
2500 - 3250		212	105	317
3250 - 4250		103	42	145
> 4250		12		12
Total	3,495	8,900	2,189	14,584

Source: TARU Analysis, 2013

Categorization of Sample Villages based on Altitude Range and Minimum Road Distance				
Altitude Range	**Minimum Road distance**			
	<5km	**5-10 Km**	**>10Km**	**Total**
< 1000	21%	76%	3%	210
1000 - 1500	28%	65%	7%	75
1500 - 2500	21%	62%	17%	105
2500 - 3250	0%	76%	24%	17
3250 - 4250	0%	67%	33%	6
> 4250	0%	100%	0%	2
Total	21%	71%	8%	415

Source: TARU Analysis, 2013

A total of 6,668 household samples were used for the vulnerability study covering 71 Development blocks of the state, except Pangi block, which could not be covered. Approximately 80-100 samples from each CD block for deriving the Socio-economic vulnerability indices.

Methodology

Questionnaire based Household interviews as well as village profiles were used for the survey. The households were chosen based on land holding classes as well as caste/tribal groups. The village profiles provided information on distribution of different land holding calluses as well as communities. The questionnaires covered basic information about the households as well as indicators for assessing status of five capitals. The data was used to develop five Vulnerability indices (Natural, Human, physical, Financial and Social). A composite index was derived from averaging the five indices

Human Capital:

Human Capital is defined as factors that enable households or individuals to pursue livelihood activities. These include factors such as skills, knowledge, labour available at household level, education level etc. Each of these helps in attaining a secure livelihood. The Human Capital Index is one of the indicators to identify the level of vulnerability of a household. This index is based on three indicators- the highest education level in the household, dependency ratio and presence of members with disability or terminal illness. Equal weightage was given for each of the sub-indicators.

Natural Capital:

Himachal Pradesh has mountainous topography exhibits a wide diversity in endowment of natural resources. People are dependent on natural resources for both income as well as consumptive use. These natural resources include land, water sources, forests, timber, NTFP/ MFP, fuel wood and fodder sources etc. Natural capital includes the stock of natural resources and important for deriving or supporting basic needs (land, fuel wood, fodder, non-timber forest products). Access to NTFP, fuel wood and fodder were used as direct indicators, while land ownership was derived by a multiplying land ownership with a factor indicating relative per hectare income across blocks. Equal weightage was given to these four sub-indicators.

Physical Capital:

Physical capital is one of the most important indicators because the households depend on the physical infrastructure for meeting basic needs (e.g. water supplies) as well as to improve efficiency. Physical Capital includes the private as well as public infrastructure and services, which are essential for wellbeing of households. These include access to water supply and sanitation, housing, health services, road connectivity, communication, production equipment or tools and goods etc. For assessing vulnerability of households following sub-indicators are used. Equal weightage was given for all the eight indicators.

1) Type of house (*kucha/semi pucca/ pucca*),
2) Access to piped water supply
3) Drainage (sanitation),
4) Distance to public distribution system
5) Distance to primary health centres,
6) Distance to road
7) Location of the dwelling (steep hill/flood prone area/landslide prone area/near a garbage dump/industrial area),
8) Ownership of telephones/mobile phones.

Financial Capital:

The Financial capital includes amount of incomes as well as earning member to non-earning member ratio. This may include income, disposable assets, savings, production, job security etc. The financial capital was assessed by per capita household income and working to non-working members ratio. Equal weightage was given to both the indicators.

Social Capital:

Social Capital includes social relationships and institutions from where households gain social security at the time of need, stress or shock. Often in an event of disaster, it people rely on their networks, groups or institutions for support and for coping with the stress. However, in the absence of such networks, groups or poor ties, a person or a household may become vulnerable. To identify vulnerability based on social capital membership of any social group and participation in the group is used. Equal weightage was given for two indicators. A total of seven types of social groups were considered. A brief scoring scheme for analysing the indices are presented in the following Table Rural Vulnerability Index Scoring Scheme.

Composite Socio-economic Vulnerability index:

The Rural Composite SEVI has been worked out by averaging the five indices. This index only provides a condensed information, but may not be used for designing interventions.

Aggregation:

The vulnerability indices of five capitals were calculated at household level and aggregated to block level. The reporting is done on poor (lowest 20 percentile) middle (20-80 percentiles upper (top 20 percentile) quintiles based on per capita incomes. This method assumes that the sample households represent characteristics of the block population. The vulnerability scores are scaled between 0 and 10, where 0 is the least vulnerable and 10 is the most vulnerable. The Rural Composite SEVI is the equally weighted score of five capitals.

Scoring system and map presentation:

The scoring for the individual index for each capital in a scale of 0-10. Blocks having score 0 are the least vulnerable and 10 are the most vulnerable. The maps are presented with Green-Yellow-Red palette using a pie diagram for each block. The proportion of households in five groups (With vulnerability scores of 0-2, 2-4, 4-6, 6-8 and 8-10) Dark green represents lowest vulnerability while Dark red represents highest vulnerability and yellow colour showing intermediate values. The maps for Low income (First), Middle income (Second to Fourth) and High income (Fifth) quintiles as well as whole block level samples are presented separately in each map plate.

Rural Vulnerability Index Scoring scheme		
Index	**Indicators**	**Scores**
Natural	NTFP	Reported Time spent per week: >17.5 hours =10; 14-17.5=8; 10.5-14=6; 7-10.5=4; 3.5-7=2; Nil-3.5 hours=0
	Fuel wood	
	Fodder	
	Land ownership	Equivalent land= Land owned X Land multiplier based on relative incomes across blocks. Landless-<0.5=10; 0.5-1=8; 1-1.5=6;1.5-2=4; 2-2.5=2; >2=0
Physical	Drainage	No drains=10; Open drains=7.5; Partially covered drains=5; Covered drains =0
	PHC	Above 5 kms=10; 3-5 km=6;1-3 km=4;<1 km=2; In the villlage =0
	PDS	No access=10; >3 km=5;1-3 km 2.5; <1 km=0
	Road	> 2 km =10; 1-2 km=5; 0.5-1km=2; < 0.5 km =0
	Dwelling location	Steep hill, Landslide/Flood prone=10;Industrial pollution, Near garbage ground=5, Plains, None =0
	House type	Kuccha=10;Semipucca=5; Pucca=0
	PWS	Piped water supply =10; All others=0
	Mobile phone	Yes=0; No=0
Financial	Per capita annual income (in '000 Rs.)	<9=10; 9-13.6=8;13.6-18=6; 18-25=4,25-35=2; >35=0
	Ratio of Nonworking to Working members	>2=10; 1-2=8;0.75-1=6; 0.5-0.75=4; 0.25-5=2; <0.25=0
Human	Highest education levels in HH	Illiterate=10; Primary=8; Secondary=6; Higher Secondary=4; Graduate=2; Post-Graduate=1; Professional =0
	Dependency ratio	>6=10; 3-6=7.5; 2-3=5;1-2=2.5;<1=0
	Disabled/ terminally ill members	2 or more 10; 1=5; None=0
Social	Social	Membership and participation in seven groups Score of 1 each for membership and participation in each group

Urbanisation in Himachal Pradesh:

The Himachal Pradesh is regarded as one of the least urbanized state in the country with only 10.04 percent of the population living in towns and cities. The total urban population of Himachal Pradesh was 6,88,704 in 2011. Shimla is the highest urbanized district within the state where 25 percent of the district population is urban (Census of India 2011). The towns have expanded from the small villages/market places to large settlements. As per Census 2011, there were 59 towns as compared to 36 in 1971.

Administration:

Shimla is the only city with a Municipal Corporation. The towns in the state are governed as per three new Municipal Acts- HP Municipal Corporation Act 1994, Municipal Act 1994 and HP Municipal Services Act 1994. The Municipalities are responsible for activities of infrastructure building & improvement, maintaining public streets, bridges, town halls, embankments, drains, drinking water and sanitation, tanks and water courses, solid waste management, maintenance of schools, hospitals and public institutions.

Demography:

The proportion of district urban population as well as the proportion of district urban population to the state's urban population is presented in the following Table.

Districts	Population (2011 Census)	Urban Population (2011)	% Urban to District population	% urban to total urban population
Chamba	5,18,844	6,528	1%	1%
Kangra	15,07,223	86,359	6%	13%
Lahaul and Spiti	31,528	0	0%	0%
Kullu	4,37,474	41,258	9%	6%
Mandi	9,99,518	62,624	6%	10%
Hamirpur	4,54,293	31,413	7%	5%
Una	5,21,057	44,917	9%	7%
Bilaspur	3,82,056	25,126	7%	4%
Solan	5,76,670	1,02,078	18%	15%
Sirmaur	5,30,164	57,238	11%	9%
Shimla	8,13,384	2,01,500	25%	31%
Kinnaur	84,298	0%	0%	0%
HP state	**68,56,509**	**6,59,041**	**10%**	**100%**
Source: Census of India 2011				

The Shimla, Solan, Kangra and Mandi districts with more than 10% urban population to district population, account for more than two thirds of the state's urban population. The percentage of urban population has grown from 6.99 percent in 1971 to 10.04 percent in 2011. The number of urban literates stands at 571,133 (55 percent male and 45 percent female). Urban literacy rate is 91.1 percent (93.42 percent among male and 88.37 among female). The sex ratio of urban Himachal Pradesh is 853 way below the sex ratio of the State (972). Poor sex ratio in urban areas is a concern. Lahaul and Spiti district does not have any urban population although Reckong Peo is being considered as an urban area. Average household size is 4.6.

Economy:

The urban centres are not growing at par with urban centres of neighbouring States of Punjab and Haryana. Total working population in urban areas is 270,038 of which the highest working population is in Shimla Town. Total number of main workers in urban areas is 240,392. In urban areas, tourism and trade are growing sectors. The total number of tourists visiting HP was 15,089,406 (Indian and foreigners) in 2011 (State Abstract of HP, 2013).

Per capita income is `47,106. About one third of the population was found to be Below Poverty Line (BPL): rural-35 percent rural and 7.6 percent urban (HP Fact Sheet- UNICEF, 2009). The number of families in the BPL category is now 24 percent, showing a reduction when compared to the 2009 data (State Abstract of HP, Economics and Statistics Dept, 2013).

Infrastructure:

There are 53 hospitals in the State, 10 dispensaries, 76 CHCs, 472 PHCs with a total 9,702 beds. Approximately 99 percent of the houses in urban areas are pucca however, their location on risk-prone areas such as steep hills etc. make them vulnerable if they are impacted by any natural disasters.

Most of the urban areas, especially located on ridges and upper slopes face drinking water shortages. Drinking water availability has been decreasing because of rapid urbanisation over the last two decades. To address issues around drinking water, the Drinking water Scheme of the Irrigation and Public Health department is working on water supply facilities and their operations and maintenance in 49 towns. Almost 96 percent of the urban areas have tap water supply. Sewerage facilities are inadequate. 98 percent of households have electricity. About 10 percent of the urban population has access to internet. Total length of Municipal roads is 750.84 km.

Socio-Economic Vulnerability and Risk Assessment:

A total of 726 urban households across 12 cities (0.55% of the urban population) were interviewed. The questionnaire covered age distribution, income sources, housing, access to basic services and different aspects of vulnerability. Sustainable Rural Livelihood framework was used to analyse the data.

Four capitals were used for assessing the urban household vulnerability. They include Human, Physical, Financial and Social capitals. Natural capital was not taken in to consideration since the livelihoods and well-being in urban areas are not directly linked with natural capital.

Human capital:

The Human Capital Index (HCI) is one of the indicators to identify the level of vulnerability of a household. This index is based on three indicators- the highest education level in the household, dependency ratio and presence of members with disability or terminal illness. Equal weightage was given for each of the sub-indicators.

Physical Capital:

Physical capital is one of the most important indicators in urban areas since the households depend on the physical infrastructure for meeting basic needs as well as to use to increase productive time. Physical Capital includes the private as well as public infrastructure and services, which are essential for wellbeing of households. These include access to water supply and sanitation, housing, communication. For assessing vulnerability of households following sub-indicators are used:

1) Access to piped water supply

2) Access to toilets

3) Type of the house

4) Age of the building

5) Location of the dwelling (steep hill/flood prone area/landslide prone area/near a garbage dump/industrial area),

6) Ownership of telephones/mobile phones.

In urban areas, road connectivity and other basic services are fairly well developed, therefore road access and drainage were not considered. Since significant proportion of the old city areas have buildings of various vintages, the age of the house was also considered. Equal weightage was given for all the six indicators.

Financial capital:

Financial capital includes amount of incomes as well as earning member to non-earning member ratio. The financial capital was assessed by per capita household income and working to non-working members ratio. Equal weightage was given to both the indicators

Social Capital:

Social Capital includes social relationships and institutions from where households gain social security at the time of need, stress or shock. Often in an event of disaster, people rely on their networks, groups or institutions for support and for coping with the stress. In the absence of such networks and groups or poor ties, households may become vulnerable. To identify vulnerability based on social capital, membership of any social group and participation in the group is used. Equal weightage was given for two indicators. A total of seven types of social groups were considered.

Sample Coverage:

A total of 781 urban household samples selected from 12 largest towns in the State covering a population of 4207 (about 0.5% of state urban population). In each city, low, middle, mixed and upper income dominated areas were identified on maps and samples were chosen from two areas from each group. The survey team also consulted representatives of Municipal Corporation, Councils, Nagar *Panchayats*, and held group discussions with the communities for urban town profiling. The total number of households covered in each selected town is as follows:

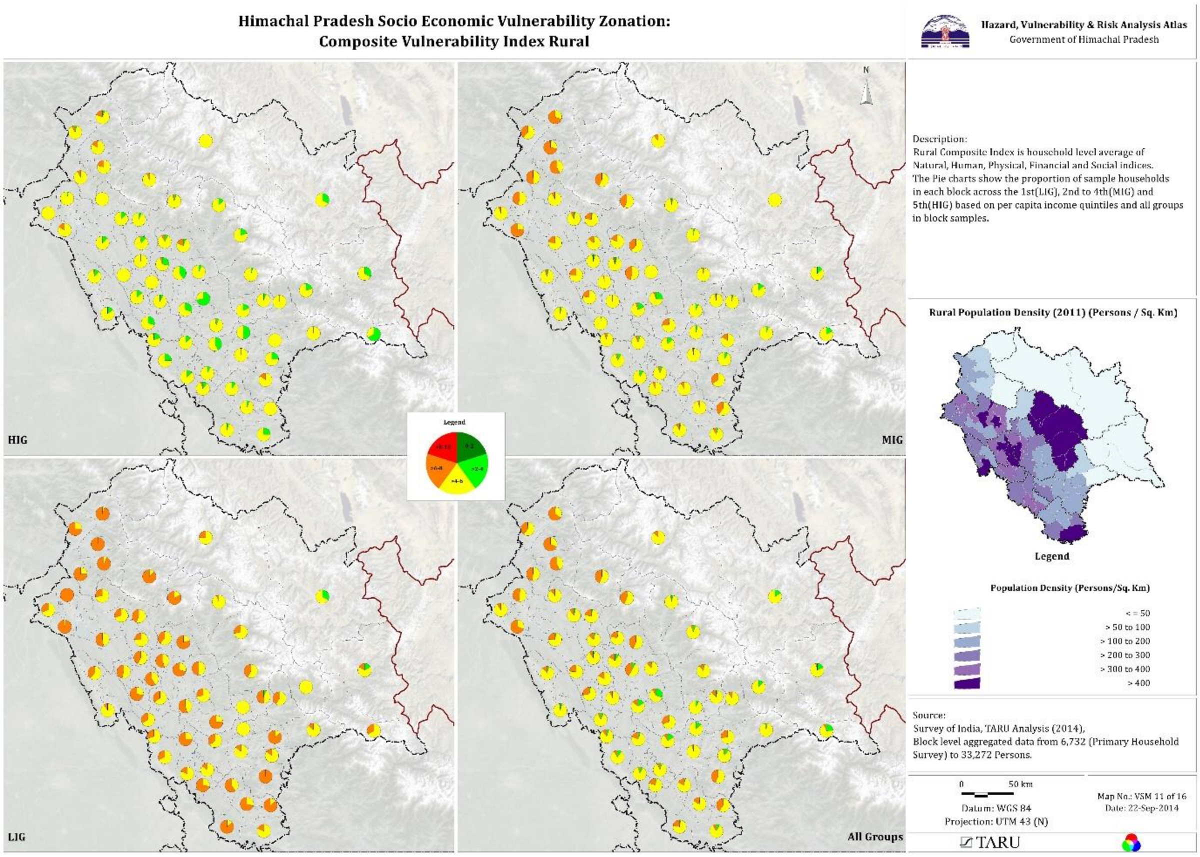
Town-wise urban sample covered in Himachal Pradesh			
District	**Town**	**No. of Households**	**Population Covered**
Bilaspur	Bilaspur	36	198
Chamba	Chamba	53	290
Hamirpur	Hamirpur	43	233
Kangra	Dharamshala	45	240
Kinnaur	Reckong peo	17	96
Kullu	Kullu	50	277
	Manali	16	107
Lahul & Spiti	Keylong	17	85
Mandi	Mandi	66	358
Shimla	Shimla	262	1340
Sirmaur	Nahan	56	323
Solan	Solan	80	439
Una	Una	40	221
Grand Total		**781**	**4,207**
Source: Primary Data, TARU Analysis			

Aggregation:

The vulnerability of each of the five capitals were analysed at household level and aggregated to town level. The reporting is done on poor (lowest 20 percentile) middle (20-80 percentiles upper (top 20 percentile) quintiles based on per capita incomes. This method assumes that the sample households represent characteristics of the city population. The Urban Composite Socio economic vulnerability index is the equally weighted score of five capitals.

Index scoring system and map presentation:

The scoring for the individual index for each capital in a scale of 0-10. The index score of 0 is for the least vulnerable and 10 the most vulnerable. The maps are presented with Green-Yellow-Red palette using a pie diagram for each town. The proportion of households in five vulnerability score groups are shown (with vulnerability scores of 0-2, 2-4, 4-6, 6-8 and 8-10). Dark green represents lowest vulnerability while Dark red represents highest vulnerability and yellow colour showing intermediate values. The maps for bottom (first), mid (2nd to fourth quintile) and top (highest) quintile as well as whole own level samples are presented separately in each plate. Composite Risk Index is presented in map.



Urban Vulnerability Index Scoring Scheme		
Index	**Indicators**	**Scores**
Physical	Building age (years)	>40=10; 30-40=6;20-30=4;10-20=2; <10=0
	House type	Kuccha=10;Semipucca=5; Pucca=0
	Dwelling location	Steep hill, Landslide/Flood prone=10;Industrial pollution, Near garbage ground=5, Plains, None =0
	Water Supply Source	River Stream=10; Tanker supply=8; Open Well=6; Hand Pump=4; Stand-post=2; Piped water supply-Pvt connection=0
	Access to toilets	None=10; Community toilet/Shared toilet=5; Household toilet=0
	Mobile phone	Yes=0; No=0

Urban Vulnerability Index Scoring Scheme		
Index	**Indicators**	**Scores**
Financial	Per capita annual income (in '000 Rs.)	<9=10; 9-13.6=8; 13.6-18=6; 18-25=4, 25-35=2; >35=0
	Nonworking to working members	ratio. >2=10; 1-2=8;0.75-1=6; 0.5-0.75=4; 0.25-5=2; <0.25=0
Human	Highest education levels in HH	Illiterate=10; Primary=8; Secondary=6; Higher Secondary=4; Graduate=2; Post-Graduate=1; Professional =0
	Dependency ratio	>6=10; 3-6=7.5; 2-3=5;1-2=2.5;<1=0
	Disabled/ terminally ill members	2 or more 10; 1=5; None=0
Social	Social	Membership and participation in seven groups Score of 1 each for membership and participation in each group

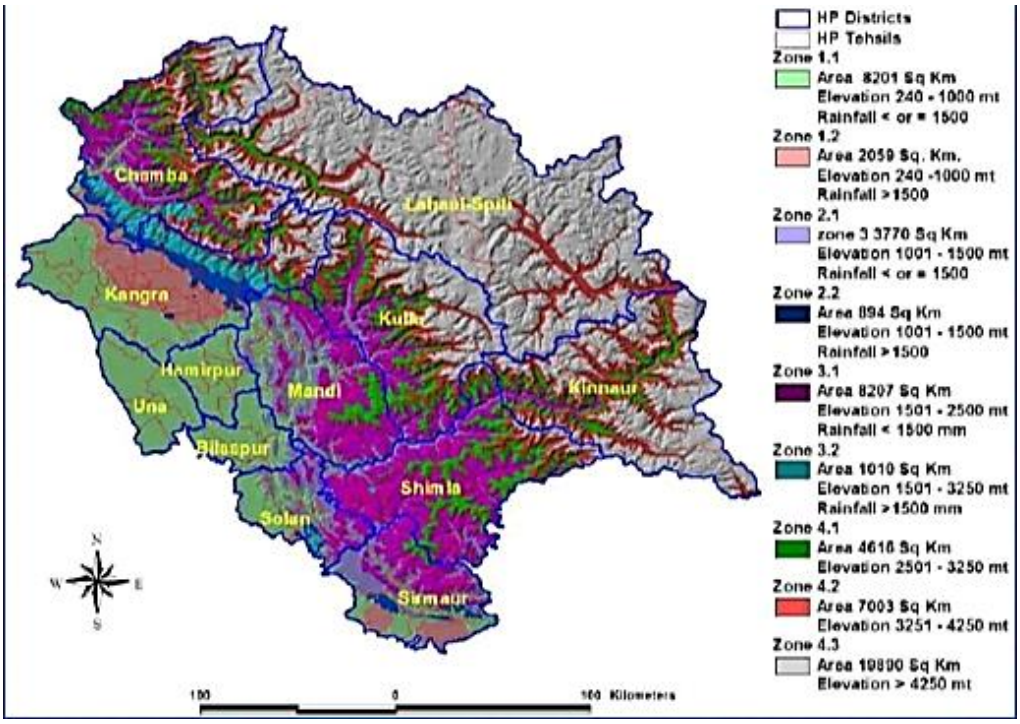
The Himachal Pradesh state has diverse geophysical set up with altitude ranging from less than 240 m in the southwestern region to more than 6,600 m beyond Great Himalayan region bordering China. The climate ranges from tropical in the lower attitudes to cold desert climate in the Trans Himalayan region.

The western and north-western part gets the highest annual rainfall of more than 2220 mm (facing Dhauladhar Range) while the eastern cold desert region gets the lowest annual precipitation, mostly as snow (<400 mm).

The maximum rainfall is contributed by monsoon about (80%) in the western region. The rainfall pattern shows high variability across years and location across the state. In any year, one or the more districts face drought as indicated by last decade's rainfall pattern.

As per the new classification of Himachal Pradesh Agricultural University, Palampur, (HP), the state has been divided in to eight agro-climatic zones. This zonation is mainly based on rainfall pattern and altitudinal ranges. Nearly half the state lies in cold desert zone with low population densities.

Agro-Ecological Zones of Himahcal Pradesh



Source: http://weathershimla.nic.in/fieldObsPDF/Agro%20Climatic%20zones.pdf

The Area, altitude and annual rainfall ranges of each zone is presented in the following Table 1.

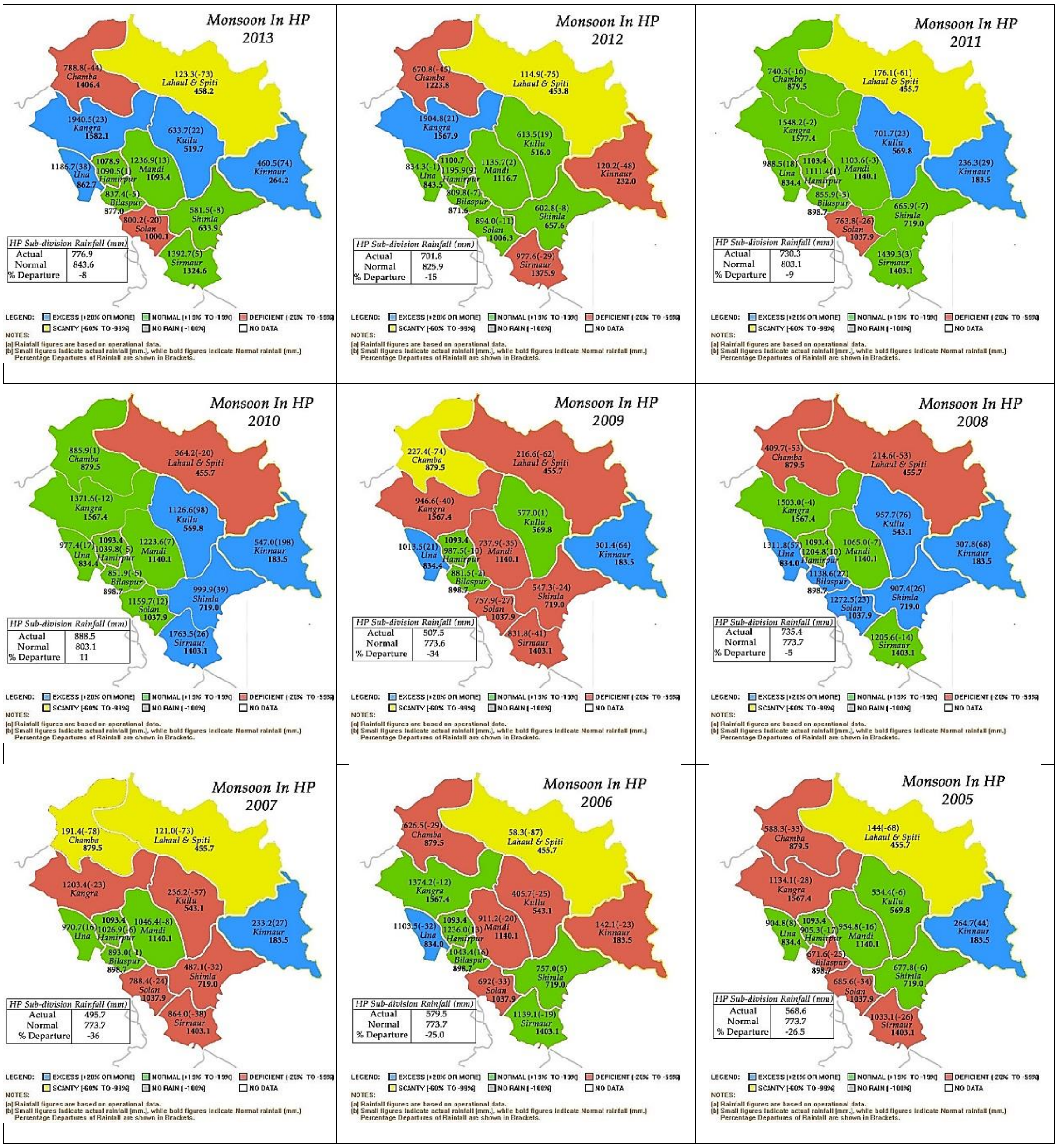
Table 1: Area, Altitude and Annual Rainfall Ranges

ZONE	AREA (SQ.KM)	% AREA OF THE STATE	ALTITUDE (M.AMSL)	ANNUAL RAINFALL (MM)
ZONE 1.1	201	0.4	240 - 1000	<1500
ZONE 1.2	2,059	4.3	240 -1000	>1500
ZONE 2.1	3,770	7.9	1000-1500	<=1500
ZONE 2.2	894	1.9	1001-1500	>1500
ZONE 3.1	8,207	17.2	1501-2500	<1500
ZONE 3.2	1,010	2.1	2501-3250	>1500
ZONE 4.1	4,616	9.7	2501-3250	<700
ZONE 4.2	7003	14.7	3251-4250	<700
ZONE 4.3	19,890	41.7	>4250	<700

Source: http://weathershimla.nic.in/fieldObsPDF/Agro%20Climatic%20zones.pdf

During most of the years, one or other district of HP faces drought like conditions, especially during monsoons. Last nine year data on monsoon precipitation pattern is presented in the following Figure 2.

Figure 2: Monsoon Precipitation Pattern



Source: http://weathershimla.nic.in/Monsoon/main.html

The 2009 drought that affected 6 out of 12 districts in the state, was one of the worst droughts during the last decade. The monsoon rains accounts for nearly 35% to 80% of the annual rainfall in the state.

Maize, Wheat and Rice are main cereal crops while Apple, Potato and vegetables are the main horticultural crops. As per Land use statistics, only 12 percent of the geographical area is classified as “Net sown area”, while about 39% of the land area is classified as “Other uncultivated/Fallow land”. Only high value horticultural crops including fruits and vegetables can provide sustainable farm incomes. In high altitude districts of Kinnaur and Lahaul& Spiti, cultivable land is less than 2%. The cultivable land is low in the state due to topographical, altitudinal and soil erosion constraints.

The land holding statistics show that nearly 9.68 lakh hectares of land is owned by the farmers. This land includes farming land, plantations and fallow lands as well as some of the waste lands. With about 5 million rural population and nearly 1 million households, most of the rural households have land, but the size of the holdings and agricultural returns is an issue in this state.

Himachal Pradesh agriculture is traditionally cereal crop based and over last few decades the area under horticulture is increasing in areas suitable for fruits like apple and a variety of vegetables.

The main objectives of this study were to delineate spatial variability of drought risk and to assess vulnerability of crops to natural disasters. Given the spatial diversity in the soil types, altitude, aspect and rainfall pattern, the secondary Block/Tehsil level crop data was used to capture the vulnerability of crops.

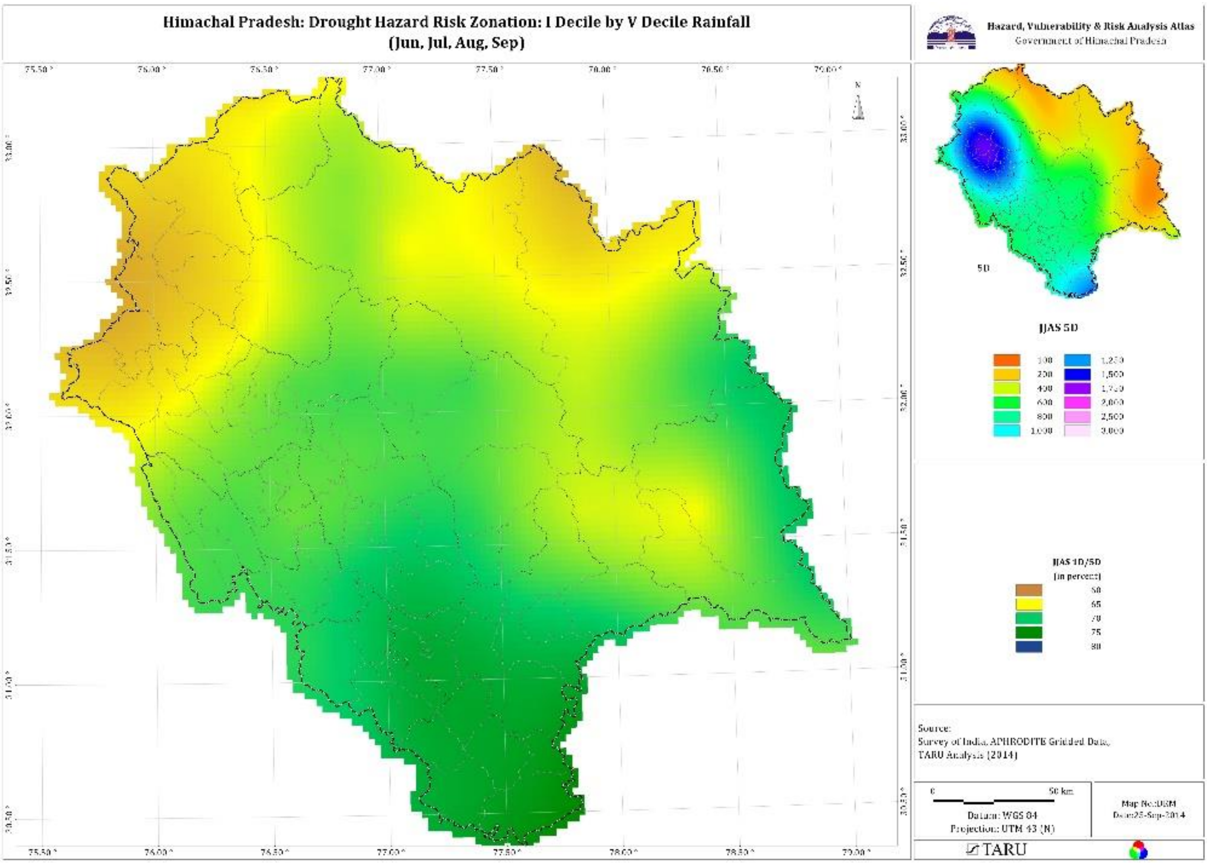
Methodology:

Himachal Pradesh has limited availability of continuous time series data on daily precipitation. Also, there are several gaps in available data and at least 30 years of continuous data is required for any drought analysis. Also, the rain gauges are located in select places, with limited coverage in the less populated areas. While tools and methods like Palmer drought index, Standard precipitation indices are available, these methods are difficult to use in data scarce and complex mountainous environments.

Drought Risk:

As sufficient rainfall gauges are not available to capture the spatial pattern of data, Aphrodite precipitation dataset covering 1951-2007 period was used for analysis. This data is available at 0.25 degree resolution with daily rainfall. This data has interpolated the rainfall data from available stations to derive daily rainfall over the period.

The rainfall data was analysed to get annual, monthly and seasonal deciles for each grid point and the results were interpolated as surfaces by krigging. The deciles method provides an easy way to understand the ratio to compare once in a decade’s lowest rainfall (1st Decile) with the median (Fifth Decile) rainfall. Lower this ratio (shown as percentage 1D/5D), the drought risk is higher. The 1D/5d Map is presented in the figure.



Agricultural vulnerability Assessment:

The cereal crop data is available at Tehsil level, but the horticultural data is available at Block level. The past decade's data on cropped area, production and yield were collected from Agricultural department and from National database on district-wise area, production and yield from 1998-2009.

Horticulture data was available at Block level from 2004-2012 period from Horticultural department and it was used to analyse changes in area, yields and production. Since there is considerable increase in area under most fruits, 2013 data on area under different fruit crops was used to estimate losses under different deciles. Changes in yields across years was used to estimate vulnerability.

The crop vulnerability from droughts alone cannot be estimated without detailed data on soils, local meteorology, aspect and slope and crop cultivars. Therefore, the tehsil/block level crop area and production time series was used to estimate the crop vulnerability. This method can be improved if the time series data at block/Tehsil is systematically collected and collated.

Crop losses estimations were done for rice, wheat, Barley, Maize, Rape& Mustard crops. Among horticulture crops, Potato, Apple, Mango and All nuts. For each crop, the First decile to fourth decile losses are presented as maps in the accompanying atlas. Financial losses were also estimated at block/Tehsil level based on average prices of 2013. The results are presented in the maps. The once in cereal 10 year crop losses can be as high a 25% compared to the median crop value. The Maize and wheat shows the highest losses among all the six crops.

Conclusions

Nearly half the state has less than 1,200 mm of annual median rainfall. Given the high slopes, and highly permeable soils, the moisture retention is likely to be low and regular and frequent rainfall is required for water demanding crops. Almost all parts of the state except region around Shimla faces medium to high risks. Parts of Chamba, Kangra as well as Lahaul & Spiti show lowest First decile/Fifth decile rainfall ratios indicating highest risk of droughts. In high drought risk zones, the once in 10 year drought may be nearly two third of the median monsoon rainfall, such droughts can cause severe distress to the rainfed agriculture.

Once in a decade horticultural losses can be as high as 50% compared to the median values. These results in indicate the need for irrigation, pest control as well as mitigating impacts of risks like hailstorm etc. As the state is promoting horticulture on horticulture on a large scale, extension activities will require further focus.

The decile based methods for assessing the drought risk as well as crop vulnerability are simple and can be improved with systematic collection of data. Strengthening data collection system is necessary to build reliable time series data.

The Himachal state was one of the earliest states to establish agro-industries. Himachal Pradesh has a long history of industries. One of the first brewery in India was set up in 1855 in Solan, due to availability of excellent quality of mineral water. The industrial development on large scale happened only since last two decades.

Year	No of units setup			Employment generated			Investment (rs. In lacs)		
	SSI	MLI	TOTAL	SSI	MLI	TOTAL	SSI	MLI	TOTAL
UPTO 02-03	30,176	196	30,372	129,871	29,823	159,694	70,977	237,806	308,783
2003-04	663	15	678	3,769	762	4,531	3,708	3,494	7,202
2004-05	913	35	948	6,412	3,473	9,885	8,891	30,287	39,178
2005-06	914	64	978	6,611	4,606	11,217	12,217	50,159	62,377
2006-07	952	46	998	10,665	4,568	15,233	45,273	61,526	106,799
2007-08	842	19	861	11,302	1,923	13,225	70,637	48,264	118,901
2008-09	909	46	955	10,939	4,225	15,164	73,795	114,103	187,899
2009-10	1,032	23	1,055	10,011	2,703	12,714	75,320	134,382	209,702
2010-11	963	27	990	10,002	3,740	13,742	96,539	211,834	308,373
2011-12	856	16	872	7,732	2,981	10,713	61,909	187,929	249,838
2012-13	798	7	805	9,298	339	9,637	96,332	21,169	117,501
TOTAL	**39,018**	**494**	**39,512**	**216,612**	**59,143**	**275,755**	**615,600**	**1,100,953**	**1,716,553**

Himachal is known for abundant hydroelectricity potential, diverse horticultural products and also has minerals like limestone suitable for industries. Hilly region provides diverse ecosystems suitable for horticulture. It was the first state initiative to produce and market bottled apple juice in the country. Being a hill state, it faces access constraints and higher risks of natural disasters. The climatic and geo-physical reduces the reliability of the road network while uneven distribution of resources limit the advancement of mineral based industries. Other problems faced by the state were non-availability of infrastructure and communication facilities, shortage of capital and lack of modern skills.

Most of the industries are located in the Shiwalik zone in the districts of Solan, Una and Sirmaur districts, which have better road access to markets in plains ans also face less natural hazards compared to the mountainous region. There is no dedicated department for addressing industrial safety and health in the state. These data are handled by Department of Labour and Employment (DoLE). As a result incident report and impact data is not available.

This study is aimed at collecting and collating secondary data on environmental and industrial hazards. There are eight Major Accident Hazard industries in the state as per the state DoLE. Due to lack of sufficient secondary data on disasters, a rapid primary study was done to understand the incidence of disasters and their impacts on industry. This survey provided synoptic data on incidences of disasters, but most industries did not provide sufficient financial data to estimate losses due to variety of concerns to share the data.

Employment:

The industry sector provides employment for 2.91 lakh persons in the state as of 2012 (GoHP 2013), while the industry department shows that the total number of industrial workers was 2.75 lakhs. Baddi-Barwala-Nalagarh belt of Solan district, located near the border of Punjab is the largest industrial zone in the state.

More than half of the factories and nearly two thirds of the industrial workers are based in the Solan district. Specific to industrial belts are Baddi-Barotiwala-Nalagarh(BBN), Mehatpur, Kala-Amb and Paonta Sahib.

Industry group-wise number of large and medium factories and workers in Manufacturing sector of Himachal Pradesh (2004-2005)					
Ind. code	**Industry description**	**Factories**	**% of factories**	**Workers**	**% of workers**
15	Food prods. & beverages	97	15%	2,694	8%
16	Tobacco products	10	2%	634	2%
17-18	Textiles	44	7%	10,909	32%
19	Leather & leather prods	12	2%	688	2%
20 & 36	Wood & wood prods.	14	2%	137	0%
21-22	Paper & paper prods.	48	7%	1,263	4%
24	Chemicals & chemical prods.	101	15%	3,694	11%
25	Rubber & plastic prods.	50	8%	541	2%
26	Other non-metallic mineral prods.	33	5%	2,716	8%
27-28	Basic metals & fabricated metal, excl. machinery & equip.	55	8%	2,213	7%
29-30	Machinery & equip. and accounting & computing machines. n.e.c	78	12%	3,184	9%
31-32	Electric machinery, communication & apparatus n.e.c	59	9%	2,790	8%
33	Medical, precision & optical instruments	21	3%	1,259	4%
34-35	Transport & equipment	16	2%	543	2%
99	others	16	2%	487	1%
TOTAL		654	100%	33,752	100%
Source: India stat Website: N.E.C: Not Elsewhere Classified					

Classification based on pollution potential:

Based on pollution potential, the industries classified by Ministry of Environment & Forests, Govt. of India. As per this classification, "Red" represents highly polluting industries, 'Orange' represents moderately polluting industries and 'Green' represents marginally polluting units. There is no systematic classification done based on hazard potential or vulnerability except for 8 Major Accident hazard Industries identified.

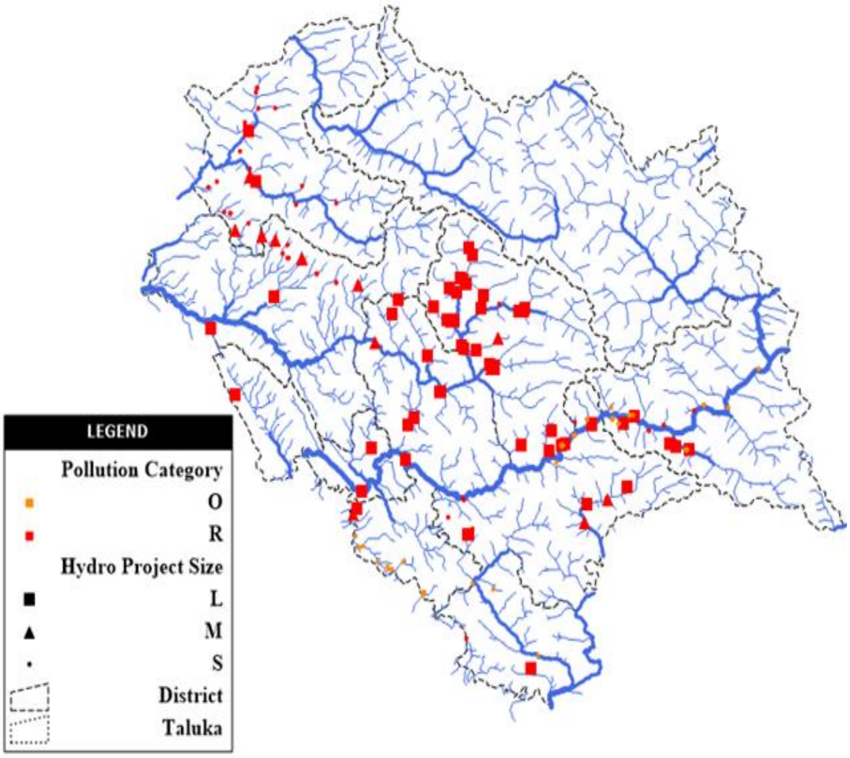
As per Department of labor and welfare, there are only 8 MAH industries in the state. The list of these are provided in the Annexure The following map shows the location of these industries and 5 km and 10 km buffer areas of these industries.

Estimated area and population(2011) in buffer zones of MAH Industries				
Km>	Estimated Population 2011		Estimated area (sq. km)	
	5 km	10 km	5 km	10 km
BILASPUR	-	9,219	1.5	48.9
HAMIRPUR	-	18,052	1.8	52.5
KULLU	11,208	32,005	53.4	185.4
MANDI	5,599	20,534	24.5	126.3
SIRMAUR	44,231	1,02,747	176.5	497.7
SOLAN	37,499	70,523	107.3	289.5
UNA	8,591	47,578	74.8	199.0
Grand Total	1,04,846	2,95,563	439.7	1399.4
Source: AGSAC, Deptt of Labour& Employment, TARU Analysis				

Hydroelectric Projects:

Himachal Pradesh has considerable hydroelectricity potential and over last two decades several private and government funded hydel projects have been commissioned in the state. The state has about 23,000 MW of hydel power potential in five perennial river basins (Satluj, Beas, Ravi, Chenab and Yamuna). Earthquakes, Flash floods, GLOFs are major risks to the hydroelectric projects in the state.

The Hydroelectric projects are categorized as Red category due to potential landslides risks from construction and tunneling activities as well as increased sediment load in the rivers from dumping of debris. There are about 196 hydroelectricity related project sites (dams, power houses and downstream discharge sites), out of which 132 sites are categorized under Red class. Rest are other downstream facilities classified as Orange. The following map presents the hydroelectricity related sites in the state.



Primary study results:

The primary study of industries did not provide major disaster events based on recollection. Out of the 143 industries contacted, only 40 respondents could recall any event casing impacts on their industries. In most cases the direct risk of flood damage is lower, but road access gets affected by the floods and torrential rains. A significant number of industries located in Shiwalik zone and this region has short streams clogged with sediments, and flash flood risks are high to orographic extreme rain events.

Events reported by the Industry respondents				
Type of event	**No of respondent reporting events**	**% of Respondent reporting events**	**Reported Work days lost**	**Average work days lost/year/industry***
Cold wave/snowstorm	3	2%	75	0.03
Drought	5	3%	185	0.06
Earthquake	3	2%		0.00
Floods	9	6%	134	0.05
Hailstorm	3	2%	0	0.00
Landslide/Roadblock	7	5%	12	0.00
Torrential rain/cloudburst	10	7%	98	0.03
Total	40	28%	504	0.18

Source: TARU Analysis 2014; * considering all sampled industries and 20 year recall period Sample size 143 respondents.

Since drought affects the agro industries and Himachal faces recurrent droughts, the raw material shortage from droughts is an issue for agro industries. None of the respondents recollected any other disasters chemical disasters. Minor industrial fires are reported from time, but unless formal mechanisms for recording these events are implemented it is not possible to collect the time series information at state and district level.

Industrial fatalities and Casualties:

The secondary data on fatality from industrial disasters from the Directorate of Labor and Employment for three years is presented in the following table. With over 3 lakh persons engaged in Industry sector, the fatality figures are about 4 persons/Lakh persons/year and casualty figures are of the order of 12 persons/lakh persons/year

Year	No. Of fatal accidents	No. Of persons died in fatal accidents	No. Of non-fatal accidents	No. Of persons injured in non-fatal accidents	Total no. Of accidents	Total no. Of persons died & injured
2008	6	6	5	5	11	11
2009	10	19	9	32	19	51
2010	3	11	3	5	6	16

Environmental Impacts:

The population located neighboring regions can be impacted by any disaster occurring in the large industries. These may be due to loss of livelihoods from disasters like earthquakes, or direct impacts of air pollution or water pollution. An estimate was done using GIS methods to estimate the potential population directly or indirectly impacted by the large industries. The results are presented in the following Table;

Estimated area and population at different distances						
District	Area buffer (m.)			Estimated Popln (2011) at		
	1 KM	**2.5 KM**	**5 KM**	**1 KM**	**2.5 KM**	**5 KM**
Bilaspur	21	100	286	12,466	34,835	97,648
Chamba	16	82	286	5,938	9,250	35,635
Hamirpur			15			3,295
Kangra	32	146	492	13,053	49,772	1,58,672
Kinnaur	31	139	394	4,990	17,024	21,890
Kullu	131	463	1051	29,688	56,567	1,22,464
Mandi	40	190	499	15,824	78,593	1,31,730
Shimla	48	194	545	17,487	45,817	84,158
Sirmaur	65	259	615	31,701	58,603	99,169
Solan	269	585	699	1,07,810	1,48,083	1,33,120
Una	54	227	516	26,105	84,566	1,68,706
Grand total	705	2386	5398	**2,65,062**	**5,83,110**	**10,56,487**
Source: AGiSAC, TARU analysis note: indicative estimates only based on buffers.						

A total of about 10 lakh population are located within a buffer area of the large industries and part of its population may be affected in worst case scenarios. The 1 km radius is a more probable population that can be affected by major industrial disasters. We have not accounted for upstream and downstream locations in this exercise. More detailed primary studies may be necessary and also modelling of disaster impacts.

TARU

TARU Leading Edge Pvt. Ltd.
D 406, 4th Floor, Ganesh Meridian,
Opp. Gujarat High Court, S. G. Highway,
Ahmedabad (Gujarat) – 380060 India.

Phone: +91-79-40052401, 40052402
Fax: +91-79-40052400
www.taru.co.in