ASSESSMENT OF SOCIO-ECONOMIC AND LIVELIHOOD VULNERABILITIES AND THE DISASTER RISKS: A STUDY OF LANDSLIDE AFFECTED AREAS OF NORTH AND WEST SIKKIM

Major Project Thesis

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DECLARATION

This is to certify that the work embodied in this thesis "ASSESSMENT OF SOCIO-ECONOMIC AND LIVELIHOOD VULNERABILITIES AND THE DISASTER RISKS: A STUDY OF LANDSLIDE AFFECTED AREAS OF NORTH AND WEST SIKKIM." is an original work carried out by me and has not been submitted anywhere else for the award of any degree.

I certify that all sources of information and data are fully acknowledged in the project thesis.

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Date:
18th May, 2015

CERTIFICATE

This is to certify that SHREYA TRIVEDI has carried out his major project in partial fulfilment of the requirement for the degree of Master in of Environment Studies and Resource Management on the topic "ASSESSMENT OF SOCIO-ECONOMIC AND LIVELIHOOD VULNERABILITIES AND THE DISASTER RISKS: A STUDY OF LANDSLIDE AFFECTED AREAS OF NORTH AND WEST SIKKIM" during January 2015 to May 2015. The project was carried out at THE ENERGY AND RESOURCES INSTITUTE, NEW DELHI.

To the best of our knowledge the thesis embodies the original work of the candidate.

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Table of Contents:

Acknowledgement:.....3
Title of the Report.....5
List of Abbreviations:.....5
List of tables:.....6
List of figures:.....7
Abstract:.....8
1. Introduction:.....9
2. Background and Rationale:.....10
2.1 Socio-economic and climatic vulnerabilities studied in various sectors:.....11
2.1.1 Agriculture:.....13
2.2.2 Water:.....15
2.2.3 Energy:.....16
2.2.4 Health Implications:.....17
2.2.5 Urban/Rural Habitats:.....18
2.2.6 Livelihood:.....18
3. Details of study area:.....20
3.1 General description of the study area:.....20
3.2 Climatic characteristics of the study area:.....21
3.3 Database for study area:.....22
4. Qualitative methods for vulnerability assessment.....24
4.1 Introduction:.....24
4.2 Basic understanding of the framework: Pressure and Release Model (PAR)) 27
4.3: Identification of Vulnerability drivers:.....29
4.4 Application of PAR in North and West Sikkim:.....30
4.5 GIS Application for Landslide Hazard probability Mapping.....36
5. Results:.....39
5.1 PAR in North Sikkim:.....39
5.2 PAR in West Sikkim:.....42
5.3 Landslide Probability mapping using weighted overlay analysis:.....46
5.4 Mitigation Strategies:.....62
6. Conclusions and Discussions:.....63
7. REFERENCES:.....65
8. ANNEXURE(S):.....68

Title of the Report

Assessment of socio-economic and livelihood vulnerabilities and the disaster risks: A study of landslide affected areas of North and West Sikkim

List of Abbreviations:

HEPs: Hydroelectric Projects

PAR: Pressure and Release Model

GIS: Geographic Information System

BIS: Bureau of Indian Standards

DRR: Disaster Risk Reduction

AMSL: Above mean sea level

KIIs: Key Informant Interviews

FGDs: Focus Group Discussions

GPU: Gram Panchayat Unit

DEM: Digital Elevation Model

SAPCC: State Action Plan on Climate Change

List of tables:

Table 1: Temperature trends by elevation zone for the period 1977-2000 (°C/year) 12
Table 2: PAR model applied in West Sikkim 32
Table 3: PAR model applied to North Sikkim 35
Table 4: Scores/Weight allotted to the criteria of slope 48
Table 5: Scores/Weight alloted to the criteria of road netwroks: 50
Table 6: Scores/Weight alloted to the criteria of Tunnel Buffer 50
Table 7: Scores/Weight alloted to the criteria of Rainfall intensity: 52
Table 8: Scores/Weight allotted to the criteria of Geology 53
Table 9: Scores/Weight alloted to the criteria of Lineament/fault Buffer 55
Table 10: Total and Percentage of area under different vulnerability levels in North Sikkim: 58
Table 11: Total and Percentage of area under different vulnerability levels in West Sikkim: 58
Table 12: Percentage of area under very high vulnerability zones in North and West Sikkim: 60

List of figures:

Figure 1 Climate Trends reported by two weather stations of Sikkim, Gangtok and Tadong. 13
Figure 2: DEM of Teesta Basin: Extracted North and West districts of Sikkim 23
Figure 3: Pressure and Release Model (PAR). 29
Figure 4: Methodology adopted for Literature Review and Field study 30
Figure 5: Flow diagram showing methodology involved in Landslide Mapping 39
Figure 6: PAR application in North Sikkim for identifying root causes 41
Figure 7: PAR application in West Sikkim for identifying root causes 46
Figure 8: Slope Map of North Sikkim 48
Figure 9: Slope map of West Sikkim 48
Figure 10: Road Map of North Sikkim 49
Figure 11: Road Map of West Sikkim 49
Figure 12: Tunnel Buffer map of North Sikkim 50
Figure 13: Rainfall Map of North Sikkim 51
Figure 14: Rainfall map of West Sikkim 51
Figure 15: Geology (Rock Type) Map of North Sikkim 52
Figure 16: Geology map of West Sikkim 53
Figure 17: Lineament/Fault Buffer map of North Sikkim 54
Figure 18: Lineaments/Faults buffer map of West Sikkim 54
Figure 19: Landslide Potential Map of North Sikkim 56
Figure 20: Landslide Potential Map of West Sikkim 57
Figure 21: Percentage of area under different levels of Vulnerability 58
Figure 22: Land-use map of West Sikkim with very high vulnerability zones 59
Figure 23: Land-use map of North Sikkim with very high vulnerability zones 59
Figure 24: Percentage of area under very high vulnerability zones in North and West Sikkim 60
Figure 25: Snow covered agricultural fields in Thanggu, North Sikkim 73
Figure 26: Agricultural fields (potato cultivation) in Uttarey, West Sikkim 69
Figure 27: Cardamom Cultivation in West Sikkim 69
Figure 28: Apiculture in West Sikkim 70
Figure 29: Wine Making in West Sikkim 70
Figure 30: Fish (Trout) Cultivation in Uttarey, West Sikkim 71
Figure 31: Fisheries in West Sikkim 72
Figure 32: Handicrafts in Lachen, North Sikkim 72
Figure 33: Stonewall fencing and stacked yak dung at Dokpa (Yak herders) house in Gurudongmar, North Sikkim 73
Figure 34: Dokpa shearing a sheep 73
Figure 35: Lachen, Present: The sprawl 74
Figure 36: Dzumsa, the traditional institution in North Sikkim 75
Figure 37: Landslides in Sikkim 75

Abstract:

The report is based upon the qualitative assessment of socio-economic and bio-physical vulnerabilities in the upper Teesta basin with the main focus upon North and West Sikkim. In order to assess the vulnerabilities in the study areas, it is important to understand the perception of the people and the problems and issues faced by them either due to climatic variability or non-climatic (politico-ecological) reasons. At the same time, it is very important to study the adaptive capacities of the people as well as the active local institutes playing an important role in increasing the resilience among the people. This study was motivated by the vulnerability assessment studies for mountain communities conducted by ICIMOD in Hindukush-Himalayan Region. The report emphasizes upon the study of livelihood vulnerabilities carried out for West and North Sikkim where the Pressure and Release Model(PAR) is tested for assessing the socio-economic, political and climatic related vulnerabilities impacting livelihoods. This method helped in identifying how livelihood options such as Agriculture, Fisheries and Sheep herding become vulnerable due to various social, governance and climatic drivers and how this vulnerability progresses to become a disaster when a natural hazard mainly landslides occurs. In North Sikkim, PAR framework is tested for assessing the same impact on livelihoods in the presence of landslides. This model yielded two different results for the same study conducted in two districts of Sikkim. It was found that vulnerable livelihoods become more prone to risks during a landslide event in West Sikkim while in North Sikkim, the same study showed that how newly emerged livelihood patterns remain less vulnerable and increase landslide probability in the surrounding areas. ArcGIS is used for preparing maps for locating areas which are landslide prone in North and West Sikkim. In this case, the triggering forces for landslides are taken to be the natural causes and hydroelectric power plants in proximity to the North Sikkim. This helps in studying the deeply rooted causes of landslides apart from the direct natural causes.

In the end, the report also gives the brief idea about the adaption measures which should be undertaken in order to reduce the landslide incidents.

Keywords: *Livelihood vulnerability · Vulnerability assessment · Pressure and Release Model · Landslide mapping · Adaptation strategies*

1. Introduction:

SIKKIM is the least populous and the second smallest state in India. Despite its small area, it is geographically diverse due to its location in the Himalayas, with a high variation in elevation ranging from 300 to 8598 m. Mt. Khangchendzonga, the world's third highest peak, is the guardian deity of the state. It is not only the highest but also the steepest landscape in the country, since the width of the Himalayas across its entire length is narrowest here. In terms of country-level vulnerability to climate change, India ranks high globally. Within India, Sikkim shows high resilience compared to other states. The relative climate change vulnerability rank of Sikkim amongst the mountain ecosystems in the Eastern Himalayas was found to be 51 out of 89 (S. Tambe, July 2011). The study mainly concerns with the vulnerability assessment being carried out in upper Teesta basin. The study area selected for socio-economic and livelihood vulnerability assessment are North and West district of Sikkim. The study mainly started with the identification of issues and impacts of climatic and non-climatic changes on the social, cultural and economic life of the people. The report mainly talks about the differential vulnerabilities across various livelihoods in West Sikkim as well as identification of socio-economic root causes responsible for converting a natural hazard like landslide into a disaster in North Sikkim.

2. Background and Rationale:

Vulnerability can be defined in various ways. Many scholars and researchers have tried to understand this concept of vulnerability and have come up with the following definitions which explain 'vulnerability'.

"Vulnerability is the degree of loss to a given element or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude"
UNDRO (1982)

"Vulnerability is the degree to which different classes of society are differentially at risk."
Susman et al. (1984)

"Vulnerability is the capacity to suffer harm and react adversely"
Kates (1985)

"Vulnerability is differential capacity of groups and individuals to deal with hazards based on their positions within physical and social worlds."
Dows (1992)

"Vulnerability is the likelihood that an individual or a group will be exposed to and adversely affected by a hazard. It is the interaction of the hazard of a place (risk and mitigation) with the social profile of the communities."
Cutter (1993)

"By vulnerability we mean the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone's life and livelihood are put at risk by a discrete and identifiable event in nature or in society."
Blaikie et al. (1994)

"*Vulnerability is the differential susceptibility of circumstances contributing to vulnerability. Biophysical, demographic, economic, social and technological factors such as population ages, economic dependency, racism and age of*

infrastructure are some factors which have been examined in association with natural hazards."

Dow and Downing (1995)

With the field becoming popular and more in-depth studies being undertaken, the definition of vulnerability was refined and finally it was understood as the concept that links the relationship that people have with their environment to social forces and institutions and the cultural values that sustain and contest them at the time of disasters and hazards. However, Blaikie's, Bohle's and Dow and Downing's definitions given around the time period of 1994 and1995 are taken as the best for the understanding of the concept of "vulnerability". These definitions lay emphasis on multilayered and multidimensional aspect of the vulnerability defined as in context with biophysical, social, economic, demographic and technological quotients.

Vulnerability can be of various forms, namely, Physical, economic, social, political, technical, institutional, cultural, ecological, etc. The report mainly deals with the socio-economic and institutional vulnerabilities due to climatic and non-climatic factors in West Sikkim and studied natural disasters in context to social root causes in North Sikkim.

Vulnerabilities and climatic risks were studied in the study area across six sectors (Agriculture, Water, Energy, Health, Urban/Rural habitats and Livelihoods) in order to analyse the impact of climatic and non-climatic variablities on them. It also reflected a change in climatic trends and seasonality in livelihoods arising due to these changes. Literature which emphasised upon the climate change impacts upon the six sectors was studied and key issues were identified and then explored on field.

2.1 Socio-economic and climatic vulnerabilities studied in various sectors:

Literature review carried out for the study area helped in determining issues of environmental risks, socio-economic vulnerabilities and adaptive capacities relevant to that area. The issues were further validated by a small number of Key Informant Interviews (KIIs) of experts of the context. The data obtained after literature review mainly dealt with the vulnerabilities faced by various sectors due to changing climatic conditions through KIIs and FGDs on field.

Climate change has contributed to unpredictable or erratic rainfall pattern, drying up of local springs and streams, species migration to higher elevations, shift of sowing and harvesting period of crops, emergence of invasive species and incidence of diseases/pests in crops as well as in fodder species. In Himalayan region, reduced snowfall is emerging as a major problem which means less snow in glaciers and less stream flow. The shorter period of snowfall prevents the snow from turning into hard ice crystals. Therefore more of the glacier is liable to melt when the summer comes. Climate change has also led to rain, rather than snow, falling even at higher altitudes. This also accelerates the melting of glaciers. Meantime, heavy rainfall which was unknown in the high altitude desert has become more frequent, causing flash floods, washing away homes and fields, trees and livestock. (Shiva, n.d.)

Analysis of annual average maximum, minimum temperature and rainfall of the two stations in Sikkim indicates that though there is no change in the maximum temperature, but the minimum temperature has increased by almost by 2.5°C between the 1957 and 2009 (Table 1: Temperature trends by elevation zone for the period 1977-2000 (°C/year)). The total rain fall has decreased by around 250 mm between the periods 1983 to 2009. After the drought of 2001, the annual precipitation rose to maximum of 3700 mm but since then it has been continuously decreasing. (department, March 2011)

Table 1: Temperature trends by elevation zone for the period 1977-2000 (°C/year)

Elevation Zone	Annual	DJF	MAM	JJA	SON
Level 1: Less than1000m	0.01	0.03	0.00	-0.01	0.02
Level 2: 1000-4000m	0.02	0.03	0.02	-0.01	0.02
Level 3: >4000m	0.04	0.06	0.04	0.02	0.03

Source: Shrestha and Devkota, 2010

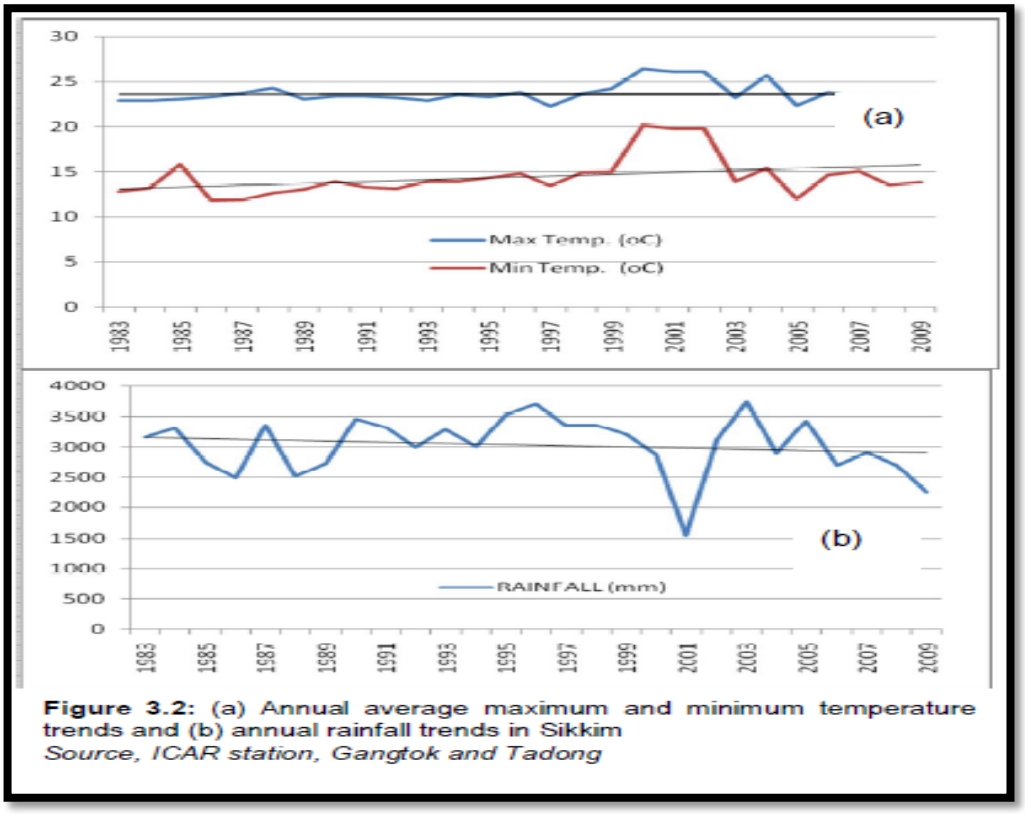


Figure 3.2: (a) Annual average maximum and minimum temperature trends and (b) annual rainfall trends in Sikkim
Source, ICAR station, Gangtok and Tadong

Figure 1 Climate Trends reported by two weather stations of Sikkim, Gangtok and Tadong.

In a study on local perceptions of climate change in the larger context of Himalayan region, various instances from Lachenpas i.e. the inhabitants of Lachen and another pastoralist community named Dokpas were reported. It was pointed out that snowfall had greatly decreased during the past 10 years. Many commented that in places which once had "5 feet" (1.5m) of snow it has reduced to just a "couple of feet "or even less ." Both communities reported that the lowest altitude that received snowfall had shifted upwards to a village at a higher altitude resulting in the range extension or shift in the snow line upwards. Besides, an increase in overall warming, early onset of summer, delayed monsoons and shorter winters were informed in the study (Bawa, August 2012)

2.1.1 Agriculture:

Due to extreme winters and snow covered fields, agriculture has become a **seasonal practice** for the people but still agriculture is vital to the progress of Teesta basin mainly in Sikkim, because more than 64 per cent of population depend on agriculture for their livelihood. Agricultural practices and adaptations to the changing climatic conditions are highly variable in time and space due to varying altitudes and agro-climatic situations in the study area. . (Swaroop, n.d.)

Much diversity in Agriculture is found in the study area. Major crops grown in high altitudes of Sikkim are Cardamom, seed-potato-maize or maize-soybean or seed potato pea/soybean/temperate fruits like mandarin oranges which are also common crop rotations. (department, March 2011). Cardamom is the main cash crop for people living in West Sikkim but the extreme climatic conditions such as long dry spells, emergence of viral diseases such as Chirkey, Furkey and fungal disease Colletotrichum blight have contributed to the decline in large cardamom plantations and their productivity. Sikkim **mandarin orange** has declined both in terms of productivity and plantation area due to increasing temperatures and longer duration of dry seasons. (Kumar, 2012)

Field observation and farmers experiences over the years predict untimely and unprecedented rainfall with longer winter droughts. Consequently, these changes have resulted in reduced soil moisture for crops and higher competition for water resources among users thereby affecting the crop production. According to SAPCC for Sikkim, analysis indicates fall in wheat productivity with rise in winter temperatures (2005-2010). Sowing of maize and production of rice seedlings is delayed due to inadequate/delayed rainfall during the pre-monsoon. Farmers have remarked that the sowing of **maize** in the sub-tropical zone has shifted by 15-20 days, while sowing at temperate zones remains the same. Similarly, the harvest of maize remains the same in the sub-tropical zone while harvest time has shortened by 15-20 days in the temperate zone. (Kumar, 2012)

Farmers have observed a **decline in productivity of crops** (e.g., cardamom, ginger, orange, paddy, maize, wheat and buckwheat etc.) resulting in emerging food insecurity in the mountain region (mainly to those farmers living in highly inaccessible areas). (Kumar, 2012)

In the Himalayas villagers have started growing new crops which they could not before, which has enhanced crop diversity and in turn influenced local diets of people in high altitudes. Such alterations need deeper exploration for climate change adaptation. (Pashupati Chaudhary, 2011) There are also reported incidences of range extension due to shifts in snow line where crops which were previously grown at lower altitudes can now be grown even at higher elevations due to increasing temperatures (Kumar, 2012) It has been observed that the agriculture of subtropical villages (less than 1000m) especially in the drought prone zone is more vulnerable due to an increased outbreak of pest, disease and infestation of invasive species. Due to reduced winter rains farmers have shifted

from multiple crops to single crop dependent on monsoon. Seed storage and preservation is difficult due to pest, disease and dry winter (Swaroop, n.d.). Unusual and **untimely snowfall** has severely impacted the life and livelihood of the Dokpas (high altitude pastoralists). This has significantly impacted the **fodder productivity** for livestock. The nomadic herders are experiencing increased summer temperatures with decline in snowfall. Elderly farmers remarked that 20-30 years ago at Thangu (3900 m), snowfall events use to be continuous for a week to 15 days. In the last 10 years, dramatic changes have been observed at Thangu where snowfall events have become untimely and occasional snowfall takes place that lasts for one to two days only. Due to **untimely rainfall**, **fodder production** has reduced with stunted growth of branches. This is followed by emergence of pests eating up the green foliage of trees.

2.2.2 Water:

With growing impacts of population increase, erosion of the top soils, erratic rainfall patterns, deforestation, forest fires and development activities (road building, building construction etc.) spring sheds which earlier comprised of well-forested catchments are increasingly being reduced to a few trees or bamboo clumps which in turn has resulted in soil erosion, poor seepage of rainwater and recharging of the groundwater. (Sandeep Tambe, n.d.) In Sikkim, the springs are drying up which are further adding to decline in water resources available. There used to be good number of springs between Rangpo and Gangtok out of which only two - one at Martam and the other at Tadong (West Sikkim) are still surviving (Santosh Sharma, 2013). Further, **small streams** that feed the large rivers are drying up more recently due to excessive deforestation in and around the major watersheds of the region (Khawas, 2004).

Moreover, issue of dying springs is being increasingly felt across Sikkim as a result of variability in climate like increase in temperatures, rise in rainfall intensity with reduction in its temporal spread, increase in intensity and a marked decline of winter rain (Sandeep Tambe, n.d.). Even localized study of high elevation areas like Deythang Gram Panchayat Unit (GPU) in Kaluk Block of West Sikkim (1600m AMSL) revealed drying of springs and lakes due to reduced discharge influenced by changing climatic patterns. (Gurung, n.d.). There is also uncertainty regarding flows due to increasing number of

hydropower projects in Sikkim (Ghanashyam Sharma, n.d.). Mainly in Dzongu (3000ft to 20,000ft AMSL) (Sikkim tourism.gov.in), in North Sikkim due to these developmental projects, the stability of the soil is challenged leading to frequent landslides and soil erosion which in turn disrupts the pipelines and also reduce the groundwater recharge. (Ghanashyam Sharma, n.d.)

Lakes are a major storehouse of water, has been degrading with time. Unsustainable utilization of this natural entity through tourism, human habitation and livestock grazing in and around Lake Ecosystem has led to pollution impacting the quality of lakes (Khawas, 2004).Due to climate change, there is a risk of sudden break of a moraine dam that may lead to discharge of large volumes of water and debris causing disastrous Glacial Lake Outburst Floods. (Anon., n.d.)

2.2.3 Energy:

With climate change, the energy demands of the people for heating and cooling their households in upper Teesta basin is also increasing. As there is unregulated extraction of firewood in high elevation villages in Sikkim, the problem of forest depletion is becoming the matter of concern for people in high elevation areas who are heavily dependent upon fuelwood for energy. (department, 2012-2030) A study carried out by Chhetri et al., 2006, to ascertain region wise fuel wood demand, indicates that demand increases with elevation though production decreases. The gap that exists between firewood demand and supply is ever increasing due to population growth, growing tourism and depleting forest resources (Singh and Singh, 1992).

Sikkim has great potential for tapping hydroelectricity owing to its undulating topography and rush-flowing rivers. Due to this potential, Government of Sikkim has decided to install 26 dams in the entire stretch of the Teesta River, majorly in the North district. On one hand, there is appreciation of dams as a source of livelihood generation while on the other hand there are protests against their construction as it is seen to be a threat to land and cultural identity. For example, Dzongu which is abode of the Lepcha community are protesting vehemently against the establishment of Teesta Phase V dam in this region. The Lepchas fear that an intervention like the dam would redefine land use, alter customs of common property rights over the forests and water bodies and usher immigrants ultimately leading to the loss of their unique culture. (Subrata, n.d.)

These dams are also reported to affect the agriculture and crop productivity in adjoining areas of its construction. Some of the settlements located in the vicinity of the existing power plants of Teesta stage V are experiencing reduction in crop production especially Mandarin oranges. The Lepchas feel that the gas used in blasting has adversely affected the productivity of the Cardamom by about 50%. Dust pollution is rampantly affecting the flowering and productivity of fruits. (Subrata, n.d.)

Apart from these issues, dams in the upper reaches also have downstream impacts like regulation of flows can have serious consequences for irrigation in lean season. Frequency of hazards like earthquakes and landslides has also increased due to construction activities in these areas. (Ghanashyam Sharma, n.d.)

2.2.4 Health Implications:

Health has always been an issue of concern in high elevation areas which have become a major problem due to inaccessible and undulating topography. Sikkim claims to have achieved the national norm of 1 Primary Health Centre per 20,000 people and 1 Primary Health Sub Centre for every 3000 people. Considering the small size of population, it was not very difficult for Sikkim to achieve the national norms, but the ratio is in no way satisfactory. In a mountainous area, only 1 health centre for 3000 persons is much less than sufficient. (SAPCC 2012-2030)

Due to increased temperatures, it has become possible for the mosquitoes to breed and thrive even at higher elevations. It has been reported by the local people that due to increased temperatures, the mosquitoes which were never found on the mountains before are now breeding and increasing in population and with them the associated diseases like malaria and dengue. (Rai, 2011) Several people have experienced skin-related diseases like ringworm, measles, prickly heat, etc. likely due to hotter climate, which was non-existent some 5–10 years ago. (Pashupati Chaudhary, 2011).

As mentioned earlier dams construction is rampant in North Sikkim. . These construction activities have some implicit impacts upon the human health. There are reported incidents of new diseases that threatened the mountain areas in the recent years. Cases of dengue fever, malaria, and HIVAIDS have become common in Sikkim. These new diseases are due to heavy immigration in Sikkim

for employments generated in hydropower projects. Human health is also deteriorating due to the increase in pollution and contamination of the water sources. (Ghanashyam Sharma, n.d.)

2.2.5 Urban/Rural Habitats:

This section mainly focuses upon the households, transportation conditions; forest cover and change in land use and land cover in the upper Teesta basin. Rapid and unplanned urbanization stresses urban poor with congestion and limited stocks of assets and resources to face extreme events like floods, landslides, etc. Any change in the magnitude and frequency of such extreme events will have significant implications for the households, livelihoods and lives of these groups of people. (SAPCC 2012-2030)

Studies conducted in Sikkim highlighting the influence of climate change on the forests in Sikkim showed that there is not going to be any impact in the short-term and long-term periods. (H.Ravindranath, August 2011)

Transportation and road conditions are a major problem in various places of high altitude areas of Teesta basin raising issues of access to provisionary services like health and market. Increase in extreme precipitation may increase the number of accidents due to the risk of **skidding on wet roads and increased incidences of landslides**. Further melting of permafrost at higher altitudes may affect the high altitude roads that link the international borders. Therefore, a strong road network that is resilient to climate change is essential for the economy of the state, as it is land locked and goods and people travel in and out of the state using the roads. Improved design of roads to make them climate proof is therefore essential. (SAPCC 2012-2030)

2.2.6 Livelihood:

Studies conducted in upper Teesta basin highlighted different sources of livelihood besides agriculture. They also showed that due to changes in temperature and rainfall trends, people are shifting from their primary source of livelihood i.e. agriculture to different other means of income. Along with decreasing productivity, the problem of seasonality in agriculture due to extreme winters, people are more reluctant in choosing agriculture as a permanent source of livelihood.

Animal Husbandry is another important source of livelihood but there have also been studies highlighting the loss of livestock due to their degraded health as a result of reduced quality of fodder. Studies conducted in Lachen village pointed out that due to reduced fodder quality, sheep in this area are becoming weaker and more susceptible to predator attacks. Hence, the population of sheep is decreasing. (Bawa, August 2012)

With increasing temperature, the issue of souring and curdling of milk is on an increase. This comes as a blow for dairy farmers as despite many efforts they are not able to improve the milk quality. With climate change, the monsoons are becoming more unexpected, torrential and erratic. They are aggravating the frequency of landslides which causes disruption and closing of roads and routes. The transportation delay results in rapid multiplication of bacteria and results in increasing acidity and spoilage of milk before they could reach the markets. This has resulted in economic losses upto 60% as sour milk has got very less market value and usage. (Kumar, August 2011)

The objectives of the study are:

- To identify drivers of socio-economic and environmental vulnerabilities in North and West district of Sikkim.
- To assess the livelihood vulnerability due to socio-economic, political and climatic factors and their relation with natural hazards.
- To understand the impact of climate change and natural disasters on the socio-economic and environmental vulnerabilities.

For attaining these objectives, vulnerability assessment framework is used namely Pressure and Release Model or “Disaster crunch model”. In order to identify the vulnerability posed by landslides in North and West Sikkim due to natural factors (like slope angle, geology, geomorphology, proximity to HEP tunnels, Road networks and Rainfall), a GIS based approach namely Weighted Overlay Analysis is used.

3. Details of study area:

3.1 General description of the study area:

The study area comprises the upper Teesta basin lying in the state of Sikkim in India. The main focus of study is the West and the North districts of Sikkim.

North Sikkim is the seventh least populous district in the country and the largest of the four districts of Sikkim. The landscape is mountainous with dense vegetation all the way up to the alpine altitude before thinning out to desert scrub towards the Northern Tundra. The most prominent effect of the steepness of the valleys is the prevalence of landslides that at times drop to anything between 3000 to 5,000 ft (1,500 m) carrying devastation along their course. Most of the people of the state reside near Mangan, the district headquarters which is about 2,000 feet (610 m) above sea level. Further north the elevation increases with the vegetation turning from temperate to alpine to tundra. The Khangchendzonga National Park (previously named Kanchenjunga National Park) also Kanchenjunga Biosphere Reserve is a National Park and a Biosphere reserve which is also located in this district. The region has many power projects and enjoys almost uninterrupted electricity. The steep gradient and the innumerable lakes on the higher reaches facilitate ideal conditions for generation of hydroelectric power.

Dzumsa is a traditional administrative institution of the villages of Lachen and Lachung in North Sikkim. It is a self-government system where a headman, known as the 'Pipon', is elected to chair the community where all the disputes are settled in a democratic manner. This system of self-governance was established during the first half of the 19th century in order to provide structure and cohesion for societies and their activities. The traditional system of Dzumsa is still prevalent in North Sikkim.

In 2006 the Ministry of Panchayati Raj named North Sikkim one of the country's 250 most backward districts (out of a total of 640). It is the only district in

Sikkim currently receiving funds from the Backward Regions Grant Fund Programme (BRGF).

West Sikkim is a beautiful land, characterized by great tracts of virgin forest and deep river valleys, is home to ancient monasteries. It has the ancient capital of the state Yuksom. The economy is mainly agrarian, despite most of the land being unfit for cultivation owing to the precipitous and rocky slopes. This district is considered as the cardamom belt of the state and is one of the leading producers of "seremena" variety of cardamom. In 1977 West Sikkim district became home to Khangchendzonga National Park, which has an area of 1,784 km^2 (688.8 sq mi).[3] It shares the park with North Sikkim district.

West Sikkim is mainly known for its tourism attractions. It is also popular as a trekking destination and it receives huge populations of trekkers and tourists throughout the year.

3.2 Climatic characteristics of the study area:

The study areas experience five seasons: winter, summer, spring, autumn, and a monsoon season between June and September. The north and western districts mainly are high altitudinal and hence experience a temperate climate, with temperatures seldom exceeding 28 °C (82 °F) in summer. The average annual temperature for most of the parts is around 18 °C (64 °F).

Sikkim is one of the few states in India to receive regular snowfall. In north Sikkim the snow line is found at around 6,100 metres (20,000 ft). The tundra-type region in the north is snowbound for four months every year, and the temperature drops below 0 °C (32 °F) almost every night. In north-western Sikkim, the peaks are frozen year-round; because of the high altitude, temperatures in the mountains can drop to as low as −40 °C (−40 °F) in winter.

During the monsoon, heavy rains increase the risk of landslides. Fog affects many parts of the state during winter and the monsoons, making transportation perilous.

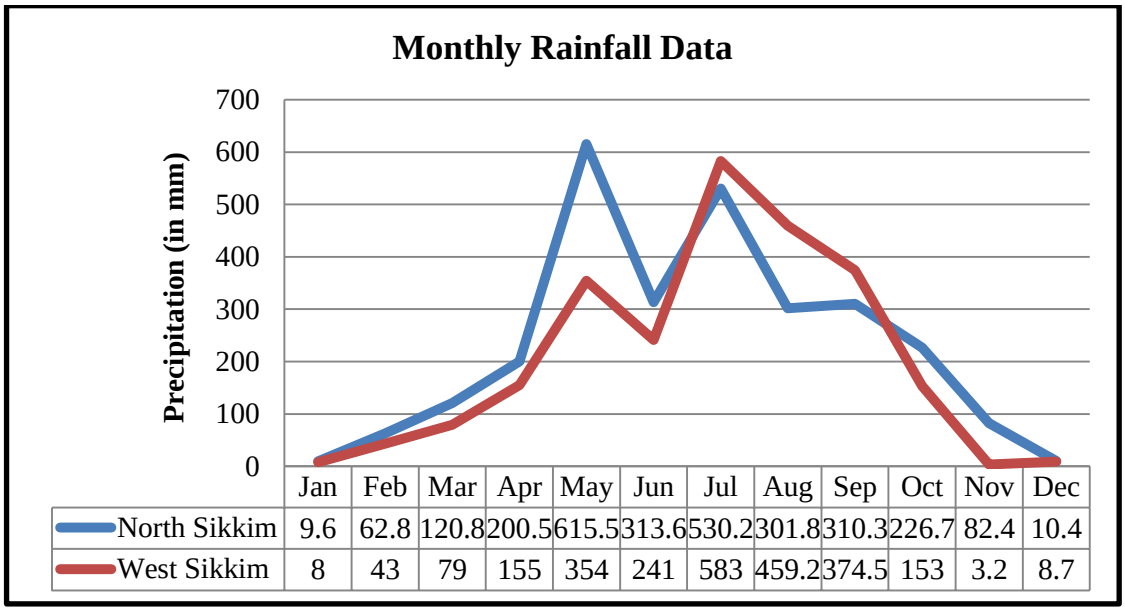
The main seasons can be listed as:

1. Cold Weather Season: December to February

2. Spring Season: March to May

3. South-West Monsoon: June to September

4. Period of retreating Monsoon: October to November



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
North Sikkim	9.6	62.8	120.8	200.5	615.5	313.6	530.2	301.8	310.3	226.7	82.4	10.4
West Sikkim	8	43	79	155	354	241	583	459.2	374.5	153	3.2	8.7

Figure: Monthly Rainfall trends in North and West districts of Sikkim (2013) *Source: IMD*

3.3 Database for study area:

The area selected for the study mainly comprises West Sikkim and North Sikkim where PAR is used for assessing the livelihood vulnerabilities and their relation with natural hazards. Landslide Mapping using GIS as well as Landslide vulnerability assessment is carried out.

Digital Elevation Model (DEM) of our area of interest was obtained from ASTER GDEM (**gdem**.ersdac.jspacesystems.or.jp/). With the help of ASTER-DEM, watershed of the area of interest was delineated using GIS software called ArcGIS.

DEM was used for delineating the watershed of the entire Teesta basin. From that watershed, the study area lying in upper Teesta basin i.e. west and North districts of Sikkim were obtained. The DEM of North Sikkim was used for obtaining slope angle maps which was used as in important criterion in Landslide Probability mapping using weighted overlay analysis.

Data for the other criteria used in Landslide Mapping of North Sikkim was obtained from the following sources:

- Road Maps: www.indiamapssite.com
- Rainfall map: http://nidm.gov.in/PDF/DP/SIKKIM.PDF
- Lineaments and Faults: **bhuvan**.nrsc.gov.in/
- Geology Map: Geological Survey of India (GSI)
- HEP Tunnels: www.sandrp.in

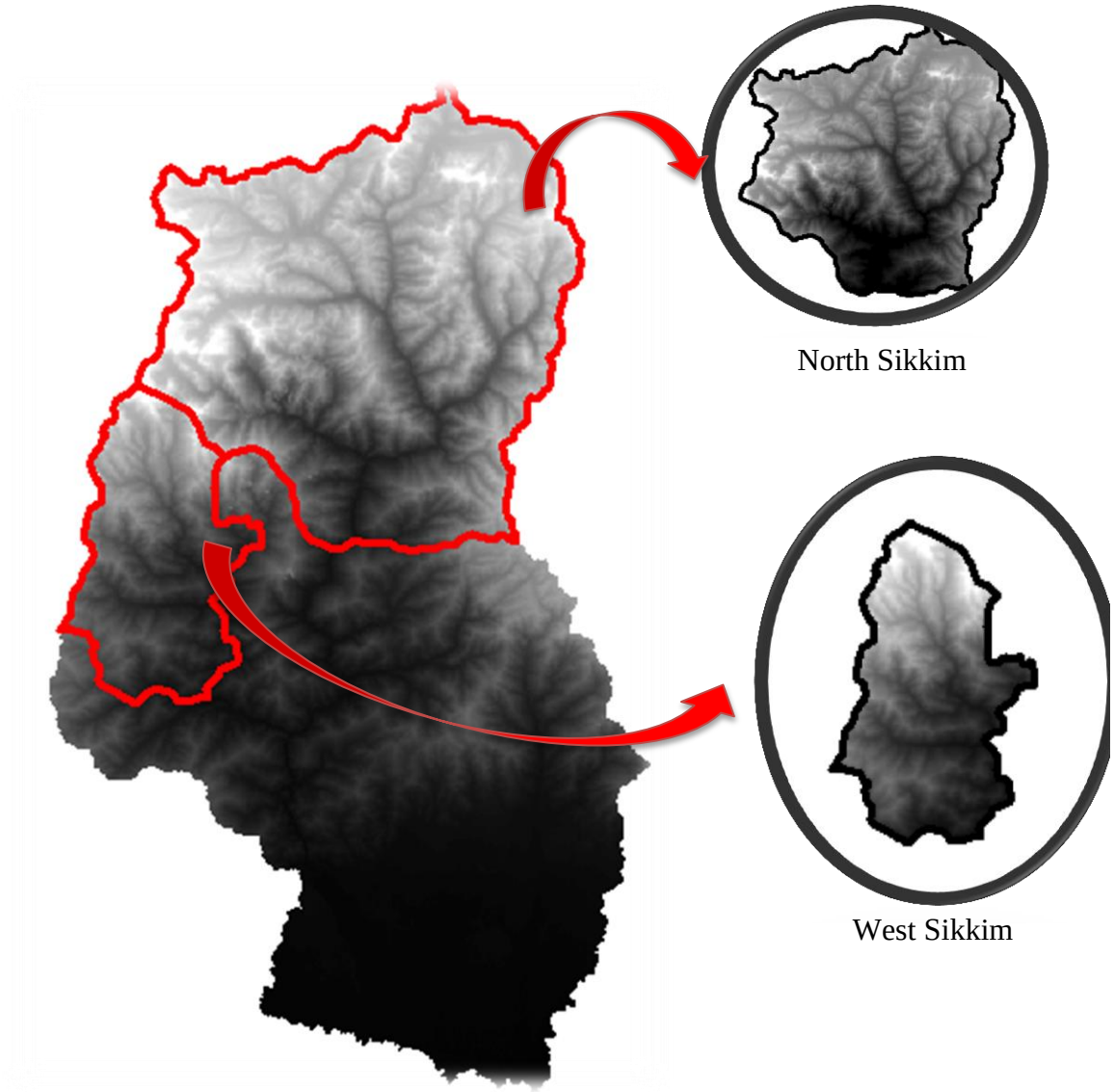


Figure 2: DEM of Teesta Basin: Extracted North and West districts of Sikkim

4. Qualitative methods for vulnerability assessment

4.1 Introduction:

The term vulnerability assessment can be defined as understanding underlying vulnerability and risks in a particular area so as to implement appropriate measure to mitigate the effects. It helps in identifying and ranking the vulnerabilities in an area on the basis of the balance between the risks, resilience and adaptive capacity in that area.

Many frameworks have been proposed for the assessment of vulnerability in a particular area.

Vulnerability and Hazards Frameworks

1. **Anderson and Woodrow, 1989 (Vulnerability and capacity analysis):**
   The vulnerability and capacity analysis is based on the premise that it is necessary to identify capacities in order to know what strengths exist within societies-even among disaster victims- on which further interventions can then be done. It defines development as the process in which vulnerabilities are reduced and capacities increased. The three areas of vulnerabilities and capacities of the community are represented in a matrix form. The three areas are: Physical/material, social/organizational and motivational/attitudinal.

   Physical/material: It includes land, climate and environment, people's health, their skills and labour, infrastructure, food, housing, capital and physical technologies.

   Social/organizational: Social/organizational vulnerabilities include divisions due to race, religion, ethnicity, language, class or caste while capabilities include social coping systems like family, groups, community, organizations.

Motivational/attitudinal: Motivational/attitudinal vulnerabilities include people's beliefs that make them feel victimized, fatalistic or dependent, while capabilities include a sense of empowerment, awareness and a sense of purpose within communities.

2. **SUST Framework:** This framework operates at multiple spatial, functional and temporal scales (world, regional, local level).Below are the different components to the framework that operate at different spatial levels —

(a) Human influences outside the place (macro, political, economy, global trends, institutions and transactions) (b) environmental influence outside the place (biosphere, nature and global environmental change) (c) variability and change in human conditions (d) variability and change in environmental conditions (e) interaction of hazards (perturbations, stresses and stressors) (f) impact/responses (g) adjustment and adaptation responses.

However, local spatial level of vulnerability includes exposure, sensitivity and resilience:

- **Exposure includes** (a) components, for example, class, firms, flora, fauna, ecosystem etc. (b) characteristics includes frequency, magnitude, duration.

Exposure = interaction between component and characteristics

- **Sensitivity includes** (a) human conditions (e.g., social, human capital and endowments) (b) environmental conditions (e.g., natural, capital, biophysical).

Sensitivity = interaction between human conditions and environmental conditions

- **Resilience includes** (a) coping response→ extant programs, policy etc., (b) impact response→ loss of life, soil, economic production, and

ecosystem and (c) adjustment/adaptive response→a new program policy and autonomous options.

There also exists a link between adjustment and adaptive responses to sensitivity.

3. **Watts and Bohle (1993):** In their framework, Watts and Bohle have tried to map vulnerability by potentiality, exposure and capacity. It involves into a play between endowments, entitlements and political economy.

4. **Double structure of vulnerability (after Bohle2001):** This framework has dual structure formed by exposure and coping. Exposure is the external side of vulnerability which involves human ecological perspective, entitlement theory and political economic approaches while coping is the internal side of vulnerability which has action theory approach, models of access to assets and crisis and conflict theory as subordinate approaches to it.

5. **ISDR Framework 2004:** International Strategy for Disaster Reduction gives a framework for disaster risk reduction in context to sustainable development — social, economic, cultural, political and ecological. It shows interplay between risk factors (vulnerability and hazards), vulnerability/capability analysis, hazard analysis and monitoring disaster impact — early warning, response, preparedness, recovery, awareness for change in behavior, knowledge, public commitment and application of risk reduction measures. These are the broad outlines to the framework and include many sub-criterions.

6. **Vulnerability by mc. Entire (2001-2005):** This model divides environment as physical, social and organizational sub parts involving play of liabilities and capabilities. In short, it emphasizes vulnerability as risk, resistance, resilience and susceptibility.

7. **Vulnerability and Capacities Index (VCI):** VCI is a data organizational tool rather than a data collection tool. It defines and quantifies

appropriate criteria related to material (income, education), institutional (infrastructure, social capital) and attitudinal (sense of empowerment) vulnerability, and can be used to measure differential vulnerability at the household and community level in both rural and urban areas. VCI helps understand which communities within a region and which households within a community are more vulnerable than others and why it is so. VCI is a simple tool to aid developers and policy makers. It defines appropriate criteria related to material, institutional and attitudinal vulnerability at household or community level in rural or urban areas. The VCI is simplification of complicated interactions. VCI has 12 parameters contributing either to material, institutional or attitudinal vulnerability. They are:

- Material vulnerability
  - Income source
  - Educational attainment
  - Assets
- Exposure
  - Institutional vulnerability
  - Social networks
  - Extra local kinship ties
  - Infrastructure
  - Earning members in the household
  - Membership of disadvantaged members of the lower caste
- Attitudinal vulnerability
  - Sense of empowerment
  - Knowledge

In this report, Blakie's Pressure and release model is used for assessing livelihood vulnerabilities through climatic and non-climatic drivers along with their relations with natural disasters (landslides) in North and West Sikkim.

4.2 Basic understanding of the framework: Pressure and Release Model (PAR))

1. **Blaikie's Model (1994) (PAR Model):**

Blaikie went to mark the steps in which venerability progresses. He subdivided this progress into three groups: underlying causes→ dynamic pressures →unsafe conditions. He arrived at a relationship between risk, vulnerability and hazards -

RISK = VULNERABILITY x HAZARD

Hazards, according to Blaikie, are a set of triggering events like earthquakes, high winds, flooding, volcanic eruption, landslides etcetera. According to this model a disaster is caused by an interaction between base vulnerabilities and hazards.
This model is also known as **"Disaster Crunch Model".**

This model shows that vulnerability (pressure), which is rooted in socio-economic and political processes, has to be addressed (released) to reduce the risk of disaster. The disaster Crunch Model states that a disaster happens only when a hazard affects vulnerable people. A disaster happens when these two elements come together. A natural phenomenon by itself is not a disaster; similarly, a population maybe vulnerable for many years, yet without the "trigger event", there is no disaster. We can therefore see that vulnerability - a pressure that is rooted in socio-economic and political processes - is built up and has to be addressed, or released, to reduce the risk of a disaster. (Anon., 2012)

According to the authors of *At Risk*, natural hazards on one side of the Pressure and Release (PAR) Model put pressure on people and resources that are vulnerable. On the other side of the PAR model, root causes, dynamic pressures, and unsafe conditions also apply pressure to those in vulnerability. The authors argue that root causes, such as limited access to power and resources, manifest a progression in vulnerability through dynamic pressures like inadequacies in training, local institutional systems, or ethical standards in government. Blaikie et al. further contend that these dynamic pressures produce unsafe conditions in the physical and social environments of those persons and groups most susceptible to vulnerability to risk. Physically unsafe conditions include dangerous locations and unprotected buildings. Socially unsafe conditions

include risks to local economies, inadequacies in disaster preparedness measures, and the like. (Ben Wisner, 2003)

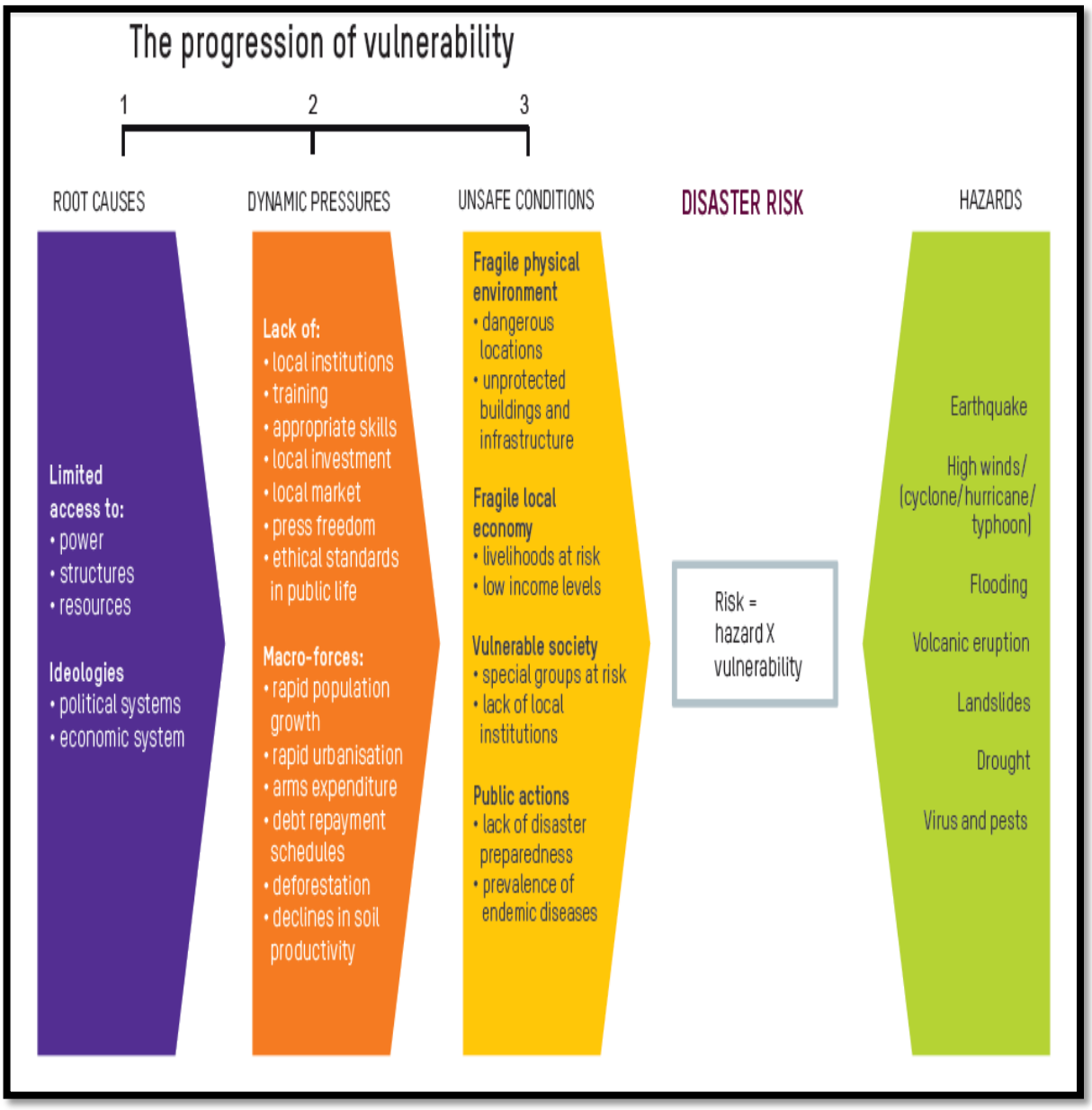


Figure 3: Pressure and Release Model (PAR).

4.3: Identification of Vulnerability drivers:

This objective was fulfilled through Literature review conducted in this field as well as the field work in West and North district of Sikkim. **The Systematic review technique** was used to study the literature and come up with the key issues to be explored on field. The data collected on field was based on the information given by **27 KIIs and 10 FGDs** conducted in West and North districts. The field exercise also included the weighting exercise where people

located in the study area gave their reasons and ratings for the contribution of criteria responsible for bringing Landslides.

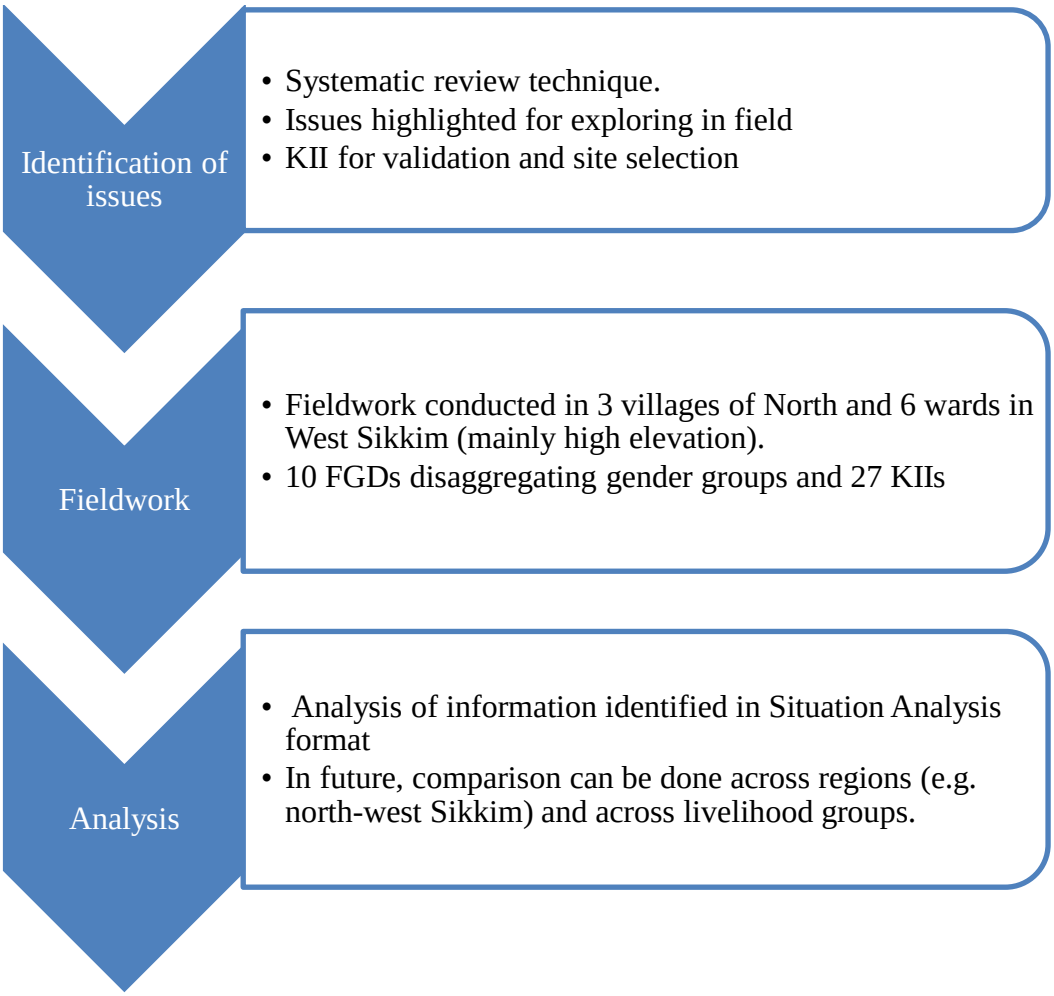


Figure 4: Methodology adopted for Literature Review and Field study

4.4 Application of PAR in North and West Sikkim:

Pressure and release model is chosen for carrying out vulnerability assessment studies in these areas because of the presence of a constant risk from natural hazards in the form of Landslides and earthquakes. The socio-economic vulnerabilities of the people living in the high elevation areas of North and West Sikkim is converted into a risk when they combine with the natural hazard which acts as a 'trigger'. Various developmental projects in the form of Hydro power Projects (HEPs) are also coming up in North Sikkim which further increases the probability of a disaster.

The Pressure and Release (PAR) Model views disaster as the intersection of two major forces: those processes generating vulnerability, on the one hand, and the

natural hazard event on the other. According to this model, vulnerability can be understood within three progressive levels: namely, root causes, dynamic pressures and unsafe conditions. The root causes are closely linked to the aspect of governance, emphasising the lack of access by vulnerable groups to positions of political power, decision-making structures, and resources. It is also related to prevailing ideologies of dominance, mainly the political and economic systems. The concept of dynamic pressure encompasses all processes and activities that transform and channel the effects of root causes into unsafe conditions, such as rapid urbanisation, deforestation or decline in soil productivity (Wisner *et al*., 2004:54).

Through this model, the identified hazards in the study areas namely landslides are studied in context to the deeply rooted socio-economic causes. An effort is made to explain that the area is made "hazard prone" not only due to natural factors involved but also the social, economic and governance process along with the general behaviour of the people living in the area. This model was the first attempt to bring the "human factor" into the disaster management picture.

In this study, the major emphasis has been placed upon the impact of climatic and socio-economic changes on the livelihood activities practiced by the people. In the study area, an attempt was made to study the socio-economic pressures which make livelihood practices in the region more vulnerable. These vulnerable livelihood practices are more prone to damage when exposed to the natural hazards like Landslides.

This model highlights that race, class, gender, and ethnicity all affect social susceptibility to hazards. Social groups on the lower end of a fixed economic level are typically more at risk to natural hazards such as landslides and the like. Resources that are available for hazard prevention may only be accessible to those social groups capable of exerting more political and economic influence. (Ben Wisner, 2003)

The socio-economic causes were identified and how they acted towards progression of vulnerability was studied. This model gives an idea about the type of the vulnerability and its root cause which helps disaster managers as well as policy makers in striking problem at its source.

At the same time, the model also talks about how the adaptive capacities, resilience and recovery help in releasing the pressure of risks. If social vulnerability creates hazard and risk emanation, then mitigation measures and improved recovery efforts aimed at vulnerability should help minimize loss.

A PAR model is depicted through a table which shows how a vulnerability progresses out of the socio-political and economic root causes to become dynamic pressures which act as ‘catalysts’ in creating unsafe conditions. These conditions when encountered with the natural hazard are unable to bear the pressure hence, giving way to disasters. Diagrams are prepared where through PAR model, socio-economic vulnerabilities are highlighted and how they progress to form a disaster on contacting with a hazard, in this case, a landslide. On the other hand in West Sikkim, the socio-economic, climatic and governance related vulnerability drivers were identified and studied to analyse how they are making a livelihood vulnerable. It is the differential vulnerability study across livelihoods in West Sikkim which highlights how different sources of income are affected differently by the same vulnerability driver.

Table 2: PAR model applied in West Sikkim

Root causes	**Dynamic Pressures**	**Unsafe conditions**		**Natural hazards**

• Lack of access to: **1.** Decision Making **2.** Resources and Markets • Climate Change • Poor land use Planning • Non-inclusion of Disaster Risk Reduction in Development policies. • Rapid growth rates • Poor Governance/Policies • Attitude of people	• Non-inclusion of people's perceptions in Developmental policies. • Increasing Population • Increasing migration • Deforestation • Introduction of new diseases. **Agriculture:** • Reduced productivity • Drying water sources. • Shifting cropping patterns • Increased Pests and diseases • Increased damage from hailstorms • Poor land development policies. • Monocultures in cardamom. • Introduction of Organic Mission. • Biased distribution of Government grants and incentives. • Human wildlife conflict **Sheep Rearing:** • Reduced quality and availability of fodder. • Cardamom plantations restrict fodder growth. • More encroachment to non-grazing lands. • Lack of local markets.	• Stress on available resources • Reduced soil stability • Unsafe building codes and infrastructures. • Inadequate warning systems. • No landslide control structures in place. (Proposal for retaining walls, rejected) • New diseases affecting human capital. **Agriculture:** • Reduced prices for the products. • Exploitation at the hands of middlemen. • Incidents of theft. • Ineffectiveness of organic fertilizers and pesticides. **Sheep rearing:** • Low productivity of sheep. • Reduced prices for the products in local markets. **Fisheries:** • Increased infections and diseases in fishes. • Reduced fish stocks. • Landslide and earthquake incidents causing water sources to sink		• Landslide • Earthquake

	• Lack of institutions managing the livelihood security **Dairy:** • Souring or curdling of milk due to increasing temperatures **Fisheries:** • Reduced discharge from water sources. • Lack of public awareness • Lack of institutions managing the livelihood security • Lack of local markets.	deeper. **Dairy and Poultry:** • During rainy seasons, landslide instances increase hampering transportation of milk and poultry.		

Table 3: PAR model applied to North Sikkim

Root causes	Dynamic Pressures	Unsafe conditions		Natural hazards
• Non-inclusion of Disaster Risk Reduction in Development policies. • Presence of traditional institutions called '*Dzumsa*'. • Lack of communication and understanding between the local Government and HEPs' authorities. • Inaccessibility due to high elevation leading to poor land use planning. • Rapid growth rates.	• Lack of disaster preparedness. • Poor roads. • HEPs coming up • Increased siltation • Heavy rainfalls • Lack of proper drainage • Climate change affecting Agriculture and livestock. • Shifting livelihood patterns. • Immigration due to employment generated by HEPs. • Lack of awareness and conservative nature of '*Dzumsa'*. • Fuelwood dependence. • North Sikkim lies in Zone IV of the seismic intensity scale. • Rapid population and urbanization rates. (Tourism coming up) • Drying water sources	• People living in landslide prone areas. (Homestays rapidly constructed) • Traditional housing structures lacking strength. • Excessive soil moisture. • Tunnelling and blasting of rocks involved in HEP. • Reducing livelihood options causing people to encouraging setting up of HEPs. • Increased incidents of new diseases. • Reducing green cover. • North Sikkim experiences frequent shocks and tremors triggering landslides. • Dam burst	**Risk of disaster = Vulnerability * Hazards**	• Landslide • Earthquake • Flood

4.5 GIS Application for Landslide Hazard probability Mapping

Geographic Information System (GIS) helps in collection, analysis, interpretation and processing of data further helping in decision making processes. In this study, two GIS software namely ArcGIS and ERDAS Imagine are used for working on the study area and deriving to the conclusions. It is helpful for representing data spatially, and permits the overlay of many different features. It can combine all different features graphically into a map for simultaneous visual representation of data. It functions by utilizing data stored as layers in shape files (with extension .shp), which are positioned on top of each other.

Landslide Probability Mapping is done using **Weighted Overlay Analysis** is a group of methodologies applied in optimal site selection or suitability modelling. It is a technique for applying a common scale of values to diverse and dissimilar inputs to create an integrated analysis. Overlay analysis often requires the analysis of many different factors. The factors chosen in our analysis may not be equally important so there is a need to prioritize them.

The following lists the general steps to perform overlay analysis:

1. Define the problem. (In this defining the problem of Landslides)
2. Break the problem into sub-models. (Choosing factors)
3. Determine significant layers. (Preparing maps for each factor)
4. Reclassify or transform the data within a layer.
5. Weight the input layers.
6. Add or combine the layers.
7. Analyse.

In this study, there are six factors chosen for determining landslide probability in North Sikkim, namely; Slope angle, Geology, Geomorphology (Lineaments and faults), Proximity to HEP tunnels, Presence of roads and rainfall intensity. Thematic maps were prepared in ArcGIS for each of the factor. The maps were prepared in vector format and attributes were added to them. Because of the potential different ranges of values and the different types of numbering systems each input layer had, before the multiple factors were combined for analysis, each was reclassified or transformed to a common ratio scale. Common scales were used to determine the scores allotted to the factors, such as a 1 to 9 or a 1 to

10 scale, with the higher value being more favourable for triggering the landslides. Once the score are determined, the next step includes the allotment of weights[1]. Certain factors may be more important to the overall goal than others. Hence, before the factors are combined, the factors are weighted based on their importance. Once all the weights are determined, a final score was computed for each of the factor favourable for landslides by using:

Final score of the factor = Score of the factor * Weight allotted

Once the final scores were computed for each of the factor, all the maps and the data were combined and overlaid to get a union of all the factors responsible for landslides. Once a combined map was obtained, the final step was to obtain the final vulnerability score for landslide probability in the study area. The vulnerability score was obtained using:

Vulnerability Score for landslides = Σ (Final score of all the factors)

Using the vulnerability scores, classes were defined and categorized into 5 classes namely, *Very low vulnerability, Low vulnerability, Moderate vulnerability, High vulnerability and Very high vulnerability.*

[1] Weights and score were allotted on the basis of literature reviews and field data. In addition to this, certain studies conducted for Landslide mapping were taken as a reference and their scores and weights were adopted for the analysis.

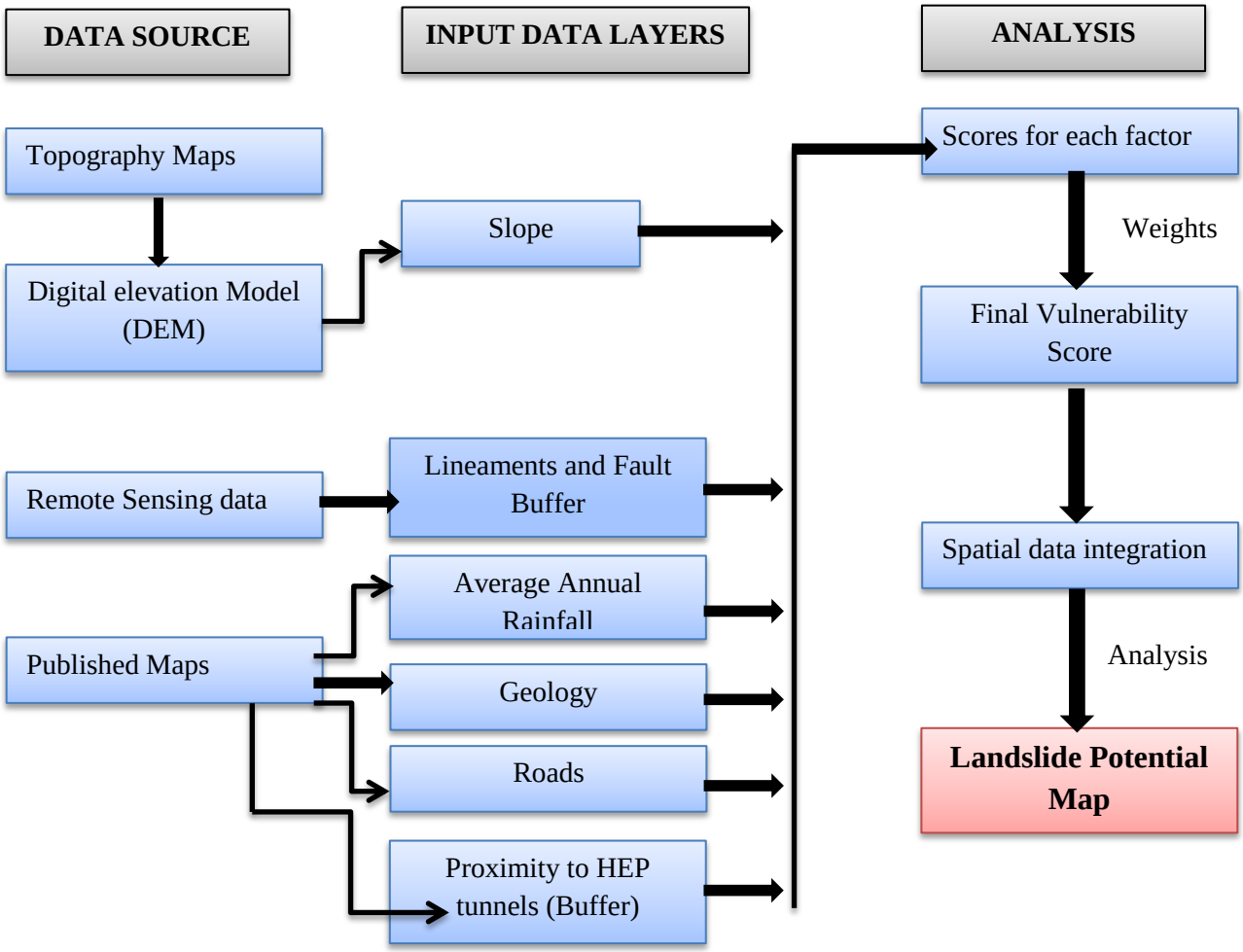


Figure 5: Flow diagram showing methodology involved in Landslide Mapping

5. Results:

5.1 PAR in North Sikkim:

Pressure and Release Model applied to North Sikkim produced results which connected the natural hazard i.e. mainly Landslide in this case, to the socio-economic and political root causes in the study area. At the same time the study also focussed upon the impact of climatic change and the governance systems on the livelihoods of the people. The important livelihoods of the people in North Sikkim are: Tourism, employment at HEPs, Livestock rearing, Handicrafts and Agriculture. In this study area, it was found that climate change is adversely affecting the productivity of agricultural products as well as reducing their quality. At the same time seasonality in agriculture is also causing farmers to

drift away from their occupation as the source income is not a surety throughout the year. Lack of agricultural lands in high elevation areas of Sikkim also restricts the practice of this occupation in north district. Another important occupation found in North Sikkim is Livestock rearing mainly practiced by the nomads or transhumance called ‘Dokpas’ and ‘Lachenpas’. They have reported decreased availability and quality of fodder for their main livestock i.e. Yaks and Sheep. Due to this reason, the sheep population in North Sikkim has reduced drastically owing to the degraded health conditions which made sheep more susceptible to predator attacks. At the same time, fodder is also affecting yaks but being an expensive animal is not afforded by every individual in the study area. Hence, low population of the sheep and decreased profits in the occupation has caused the people to give up their occupation or look for an alternative source of income. Handicrafts and handlooms is a newly introduced occupation in North Sikkim but are mainly restricted to women. Only trained and skilled female members were involved in this hence this source of income is at present at an infant stage.

Tourism and services at HEPs were found to be the most popular and rapidly growing occupations in North Sikkim. Being much profitable, easy and a growing business, tourism has evolved as the most important source of income for the people. In order to promote and expand Tourism, people have started constructing hotels and homestays in high elevation tourist destinations like Lachen, Lachung, Dzongu, etc. These constructions are taking place recklessly, in an unplanned manner exerting additional pressure on the natural resource present in that area. On the other hand, a ‘short cut’ to easy money is coming up in North Sikkim through the installation of various HEPs by the Government. There are reported incidents of increased ground instability and landslides due to blasting and tunnelling taking place in areas where HEPs are proposed. In some areas like Dzongu, the traditional communities like Lepachas are vehemently protesting the setting up of HEPs in their homelands as they fear loss of their culture at the same time, people in other areas are promoting the construction because it is generating employment and also huge compensations. So, HEPs are also becoming increasingly important from the point of view of livelihoods. Hence, the areas being highly seismic in nature as well as landslide prone are becoming more susceptible to the natural hazards because of additional pressures

from unplanned development and construction activities taking place in this region.

The analysis shows how these root causes resulted into the progression of vulnerability thereby becoming a risk on combining with the natural hazard.

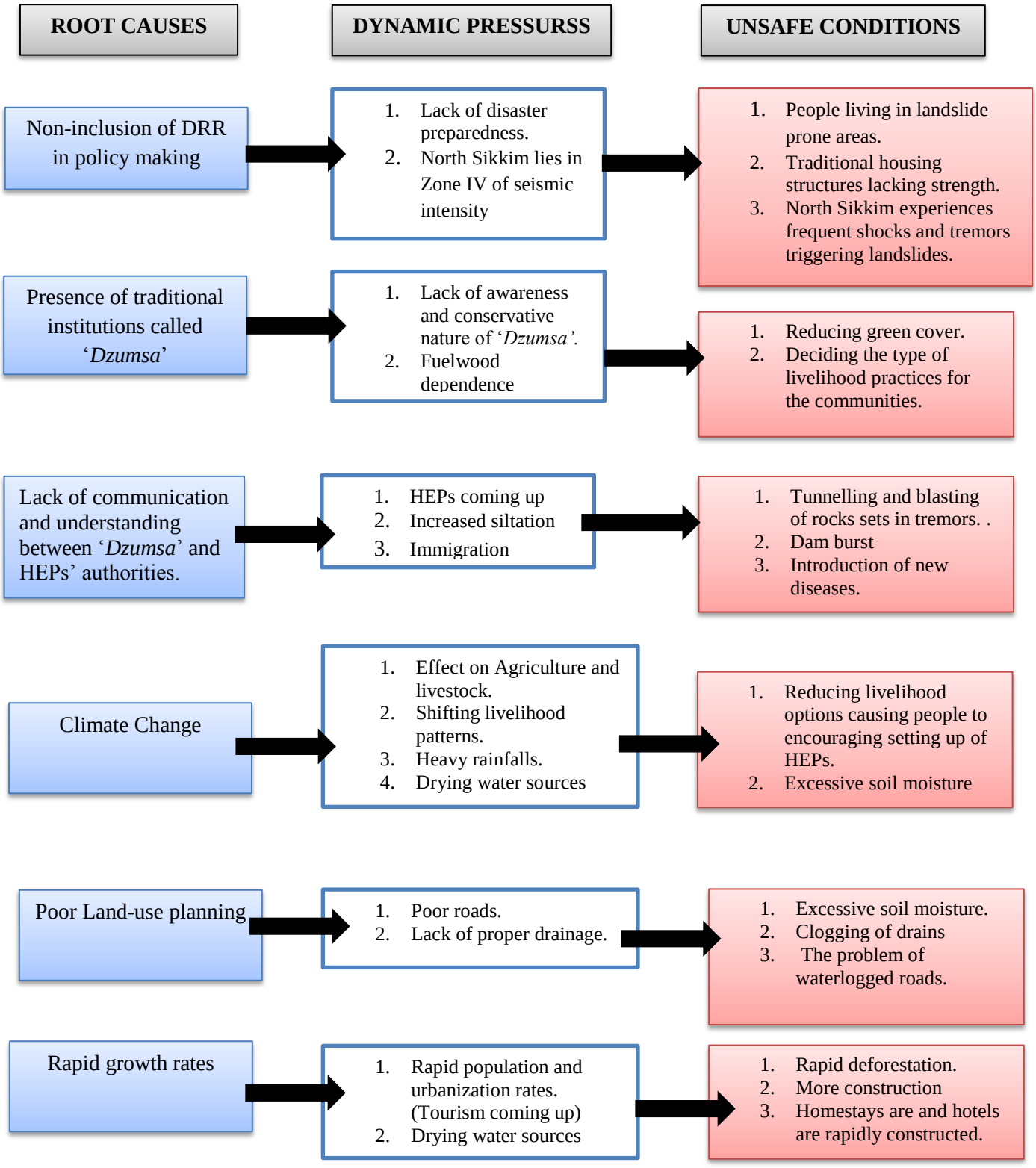


Figure 6: PAR application in North Sikkim for identifying root causes

5.2 PAR in West Sikkim:

The Pressure and Release Model is applied to West Sikkim mainly for assessing the differential vulnerabilities across livelihoods due to climatic, socio-economic and governance related factors. The main sources of livelihood studied in this study area were Agriculture, Fisheries, and Sheep herding and alternate sources of livelihoods in the form of Dairy, Poultry and Apiculture. It was observed that due to climatic changes, the productivity and the production of **Agriculture** has been significantly affected in West district. Being the cardamom belt of Sikkim, this area specializes in growing high quality of 'seremena' variety of cardamom. The farmers in West district reported that due to increasing temperatures and reduced rainfalls, this cash crop is has lost many of its varieties. They have started monocultures in cardamom cultivation as this 'shade loving' plant is unable to sustain the high temperatures and sunshine and was getting damaged due to increased pests and disease infestation. Hence, only 'seremena' variety of cardamom is now grown in Sikkim among all the other varieties which no longer thrive well there. Changing climate is also affecting the water discharge from the sources. Due to reduced water discharge, irrigation has become an issue of concern for the farmers. Pipelines have been laid down by the Government to supply water but due to drying sources and pipeline disruptions due to landslides, availability of water has become a problem. Another problem faced by the farmers is the forceful compulsion of 'Organic Mission' by the Government. In order to make Sikkim a completely organic state, Government has banned the use of chemical based fertilizers and pesticides. The new ones introduced are ineffective against new pests and diseases. Land development schemes are poorly implemented in Sikkim as most of the farms are not terraced by the Government. Frequent landslides tend to destroy the agricultural fields yet neither compensations nor terracing is done after the damage is caused. Hailstorms have also increased over the last few years and with them increased the damage caused to the crops. Farmers are unaware of the concept of 'Crop Insurance' and are thus, subjected to heavy economic losses due to natural hazards. With increasing deforestation, the problem of human wildlife conflict is also becoming an important matter of concern for the farmers as the wild animals destroy their crops. Market accessibility becomes a problem mainly for cardamom farmers due to lack of road connectivity. Due to this, the farmers are forced to sell their produce through middlemen thus subjected to exploitation at

their hands. They have to sell their produce at a very low price due to lack of awareness among them regarding the market prices coupled with the trouble of travelling and searching the markets.

With decreasing water discharge from the sources another livelihood that is severely hit is the business of 'Fish (Trout) cultivation'. This variety of trout fish is indigenous to eastern Himalayas and is found at an elevation of 2000m. This variety of fish requires continuously flowing snow melt water for it culture. But with climate change into play, the dry seasons have increased leading to decreased flows from the springs during lean seasons (December to February). Fish cultivators are facing a lot of problem due to decreased flows. Pipelines often get disrupted due to landslide events which are also believed to cause sinking of water sources further deep. Fish cultivators reported that fishes are becoming more prone to fungal infections due to less water flowing from the springs downstream. They also believe that increasing populations uphill is challenging the water demands of the people living downstream. Above this, lack of institutional support and awareness also makes the fish cultivators more vulnerable to the hazards.

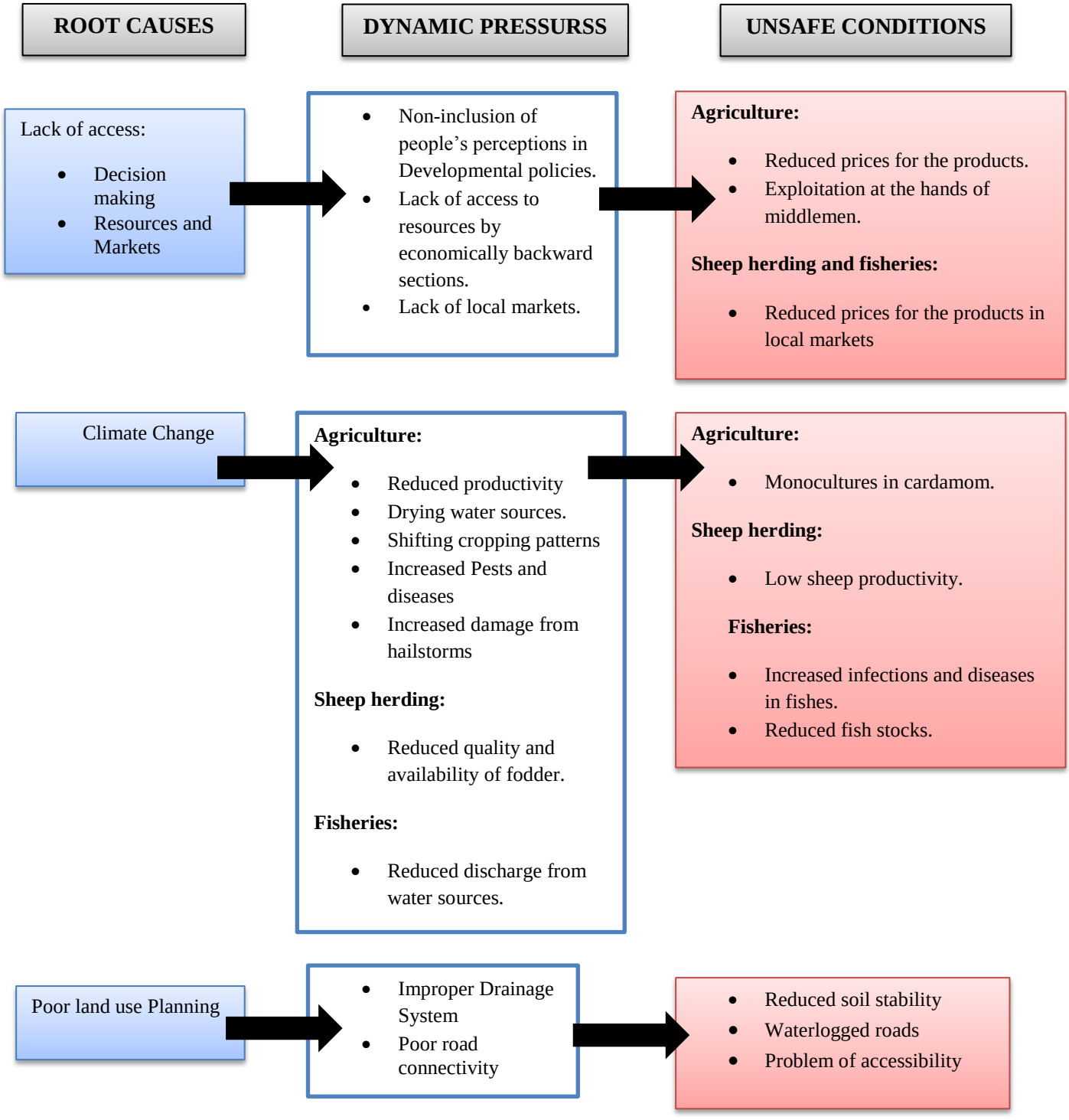
As mentioned earlier, the increasing temperatures and reduced rains have led to extended dry seasons. This, in a way has led to reduction in fodder availability and quality. This is further resulting in low productivity of **sheep** and prices of the wool products. Being the cardamom belt, the farmers cannot afford to grow fodder along with their cash crop as it tends to retard the growth of the crop. Being at a high elevation, most of the forests are reserved by the Government with herders having no access to grazing lands. As a result, encroachment to non-grazing lands is creating a problem by making the soil loose, devoid of vegetation and unstable enough for a landslide to occur. At the same time, access and availability to local markets is another problem arising due to poor road conditions. Lack of training and awareness among the herders is also contributing towards increasing their vulnerability as they have remained primitive and traditional in their practice with low adaptive capacities. The herders do not have sheep insurance and are even unaware of the concept.

When these socio-economic, political and climatic factors become vulnerability drivers for various livelihoods, they progress with increasing pressure until they

are converted into a disaster on their combination with a natural hazard like landslides.

Apart from the individual livelihoods, the economically backward section of the society is facing lacked access to political power and decision-making structures. Moreover, their access to resources such as cultivable land and water resources has been limited. Non-inclusion of Disaster Risk reduction in policy making creates a problem because development and disaster management should be taken as an integrated concept for reducing the risks faced by the people.

The following figure draws links on how a root cause progresses to become an unsafe condition and finally a risk for the people living in that area.



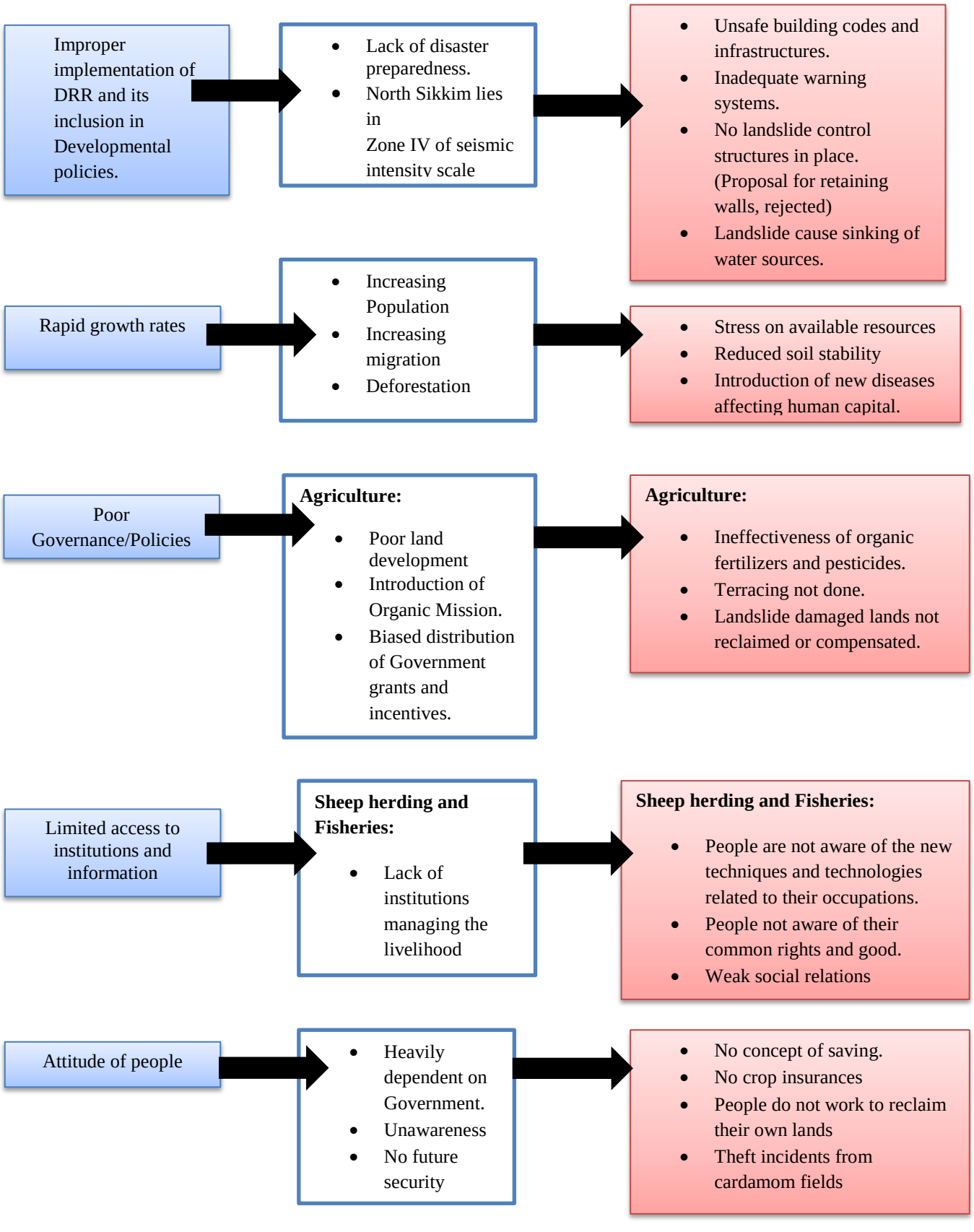

Improper implementation of DRR and its inclusion in Developmental policies.
Lack of disaster preparedness.
North Sikkim lies in Zone IV of seismic intensity scale
Unsafe building codes and infrastructures.
Inadequate warning systems.
No landslide control structures in place. (Proposal for retaining walls, rejected)
Landslide cause sinking of water sources.
Rapid growth rates
Increasing Population
Increasing migration
Deforestation
Stress on available resources
Reduced soil stability
Introduction of new diseases affecting human capital.
Poor Governance/Policies
Agriculture:
Poor land development
Introduction of Organic Mission.
Biased distribution of Government grants and incentives.
Agriculture:
Ineffectiveness of organic fertilizers and pesticides.
Terracing not done.
Landslide damaged lands not reclaimed or compensated.
Limited access to institutions and information
Sheep herding and Fisheries:
Lack of institutions managing the livelihood
Sheep herding and Fisheries:
People are not aware of the new techniques and technologies related to their occupations.
People not aware of their common rights and good.
Weak social relations
Attitude of people
Heavily dependent on Government.
Unawareness
No future security
No concept of saving.
No crop insurances
People do not work to reclaim their own lands
Theft incidents from cardamom fields

Figure 7: PAR application in West Sikkim for identifying root causes

5.3 Landslide Probability mapping using weighted overlay analysis:

Using GIS techniques and weighted overlay analysis methods, Land probability mapping was carried out to generate a map which classified areas on the basis of their vulnerability to landslides arising due to natural reasons. The criteria selected for the landslide probability analysis were:

- ***Slope:*** It is the most important criteria in determining the landslide probability in a region. It was found through literature reviews done and the studies conducted in the field of landslide susceptibility that steep slope i.e. slopes having angle greater than 45 form favourable condition for landslide. In this report, a same criterion is adopted for the determination of landslide prone slope angles.
- ***Proximity to HEP tunnels:*** Literature reviews revealed that due to tunnelling taking place in hydroelectric power project construction sites in North Sikkim, tremors are generated which induce landslides. It was reported by the locals that the effect of tunnelling in the form of tremors and shocks could be experienced upto 14 kilometres from the tunnelling sites. Hence, in the report, a buffer of 10 kilometres has been considered where the probability or risk of landslides is believed to be high.
- ***Rainfall intensity:*** Landslide probability is directly related to the intensity of rainfall in the region. As the study area lies in high altitude, rainfall is high-moderate in intensity while much higher altitudes receive snow in the form of precipitation.
- ***Geomorphology (Lineaments and Ridges):*** Lineaments or faults are basically the linear features on the earth surface. In geology, a **fault** is a planar fracture or discontinuity in a volume of rock, across which there has been significant displacement along the fractures as a result of rock mass movement. These already loosened surfaces are more prone to landslides. For the analysis, a fault buffer map was generated in GIS with

buffer width of 3km from the faults. It has been found in the literature that thrust/faults have an effect on landslide occurrences up to 3-4 kilometres.

- ***Road Linkages:*** Road constructions also play an important role in triggering landslides. The probability of landslide occurrence is more near the construction of highways and other major roads while it is relatively less in case of uncarpeted 'kuccha' routes. Hence, in the analysis the areas in close proximity to the 'pukka' roads are more vulnerable to landslides.
- ***Geology (Rock Structures):*** Vulnerability due to landslides is also dependent upon the type of rocks found in the region. The characteristics and the properties of the rocks determine the strength and ability of the rock to remain stable in case of tremors and shocks. Study areas are mainly composed of Crystalline Metamorphic rocks mainly Gneiss and quartzite of Daling Group and sedimentary rocks of Gondwana origin. Out of these rocks, Gneiss being the hardest does not break easily but due to repetitive tremors and rock movements is subjected to cracks and fractures. They result in the formation of lineaments and hence become prone to landslides.

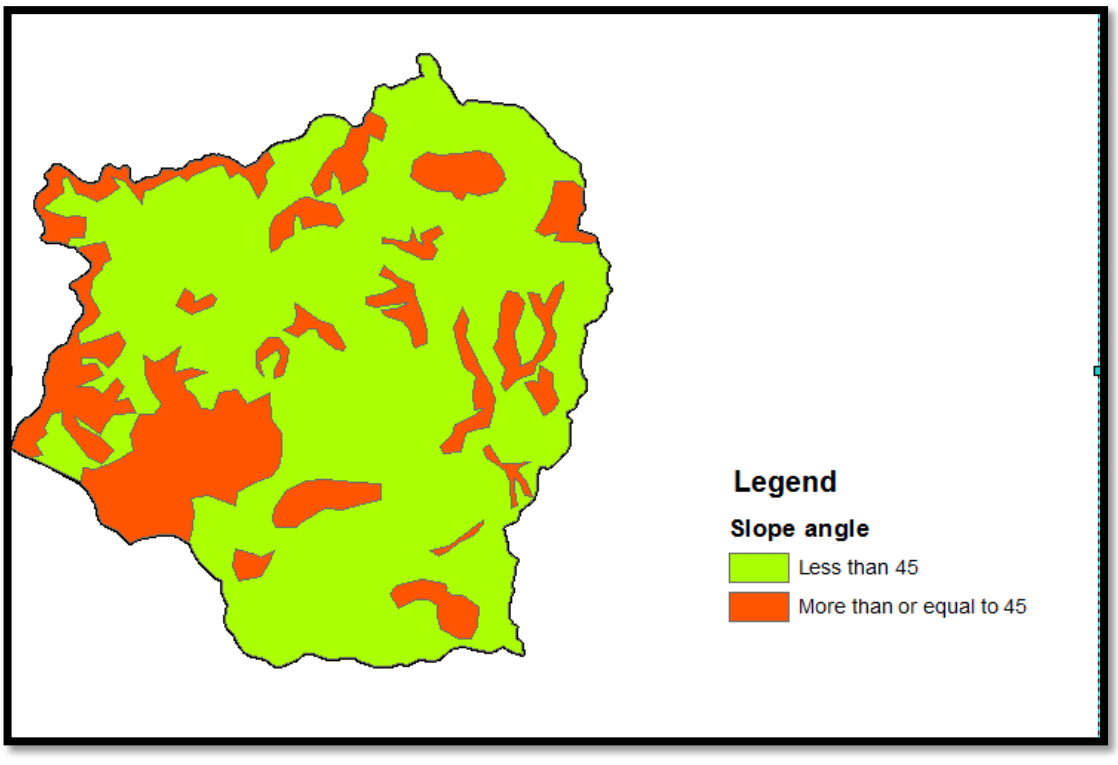


Figure 8: Slope Map of North Sikkim

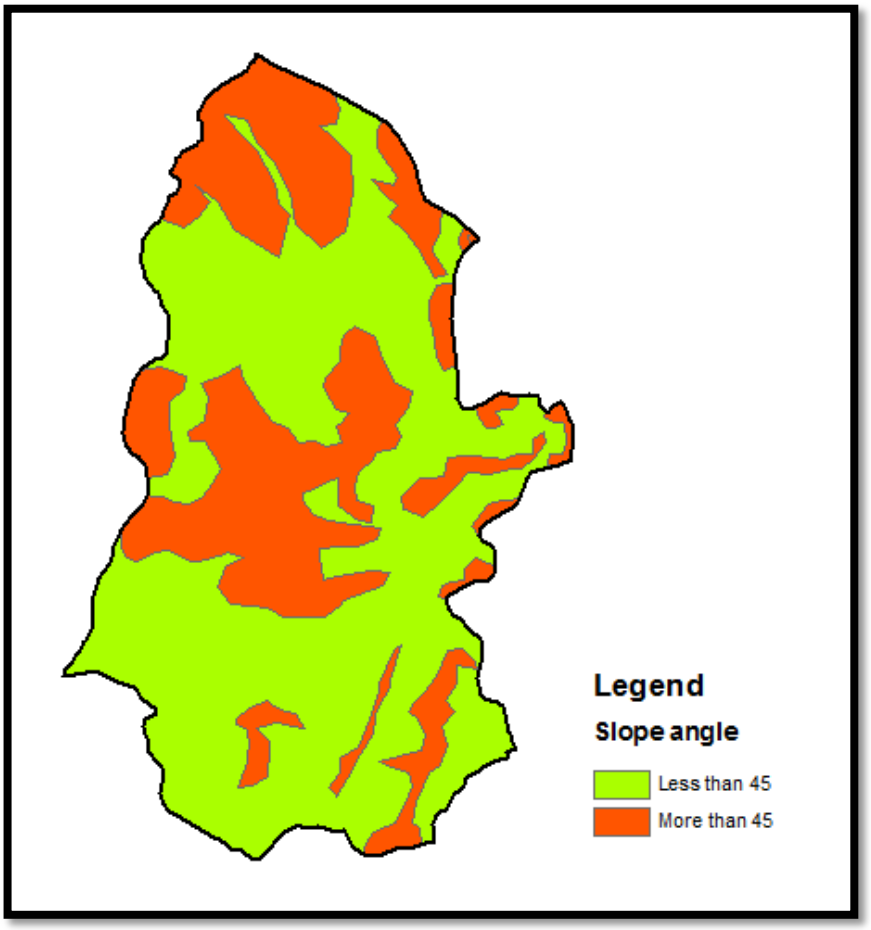


Figure 9: Slope map of West Sikkim

Table 4: Scores/Weight allotted to the criteria of slope

Slope Angle	Scores	Weight
Less than 45	5	6
More than 45	10	6

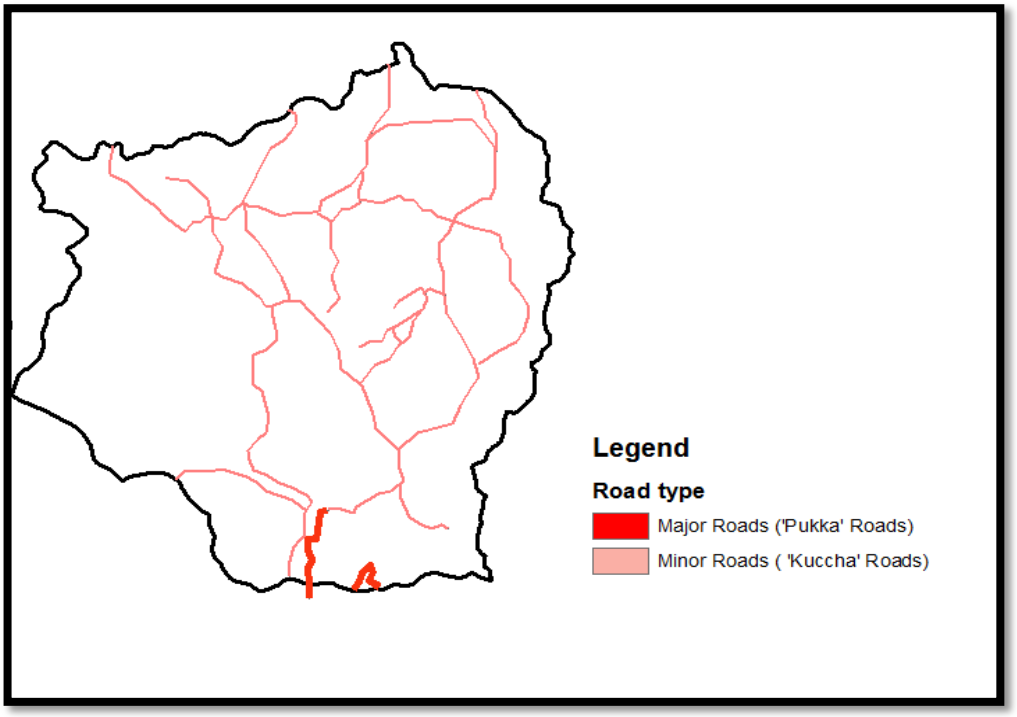


Figure 10: Road Map of North Sikkim

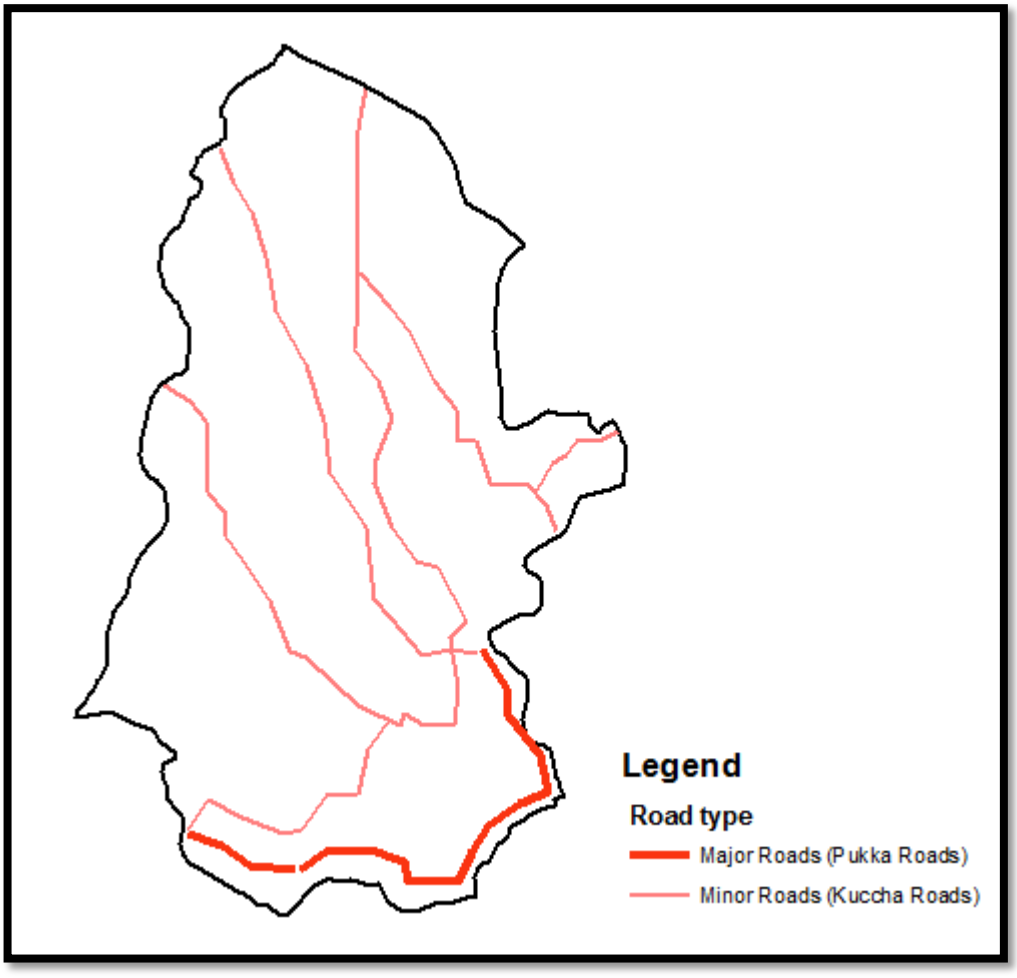


Figure 11: Road Map of West Sikkim

Table 5: Scores/Weight alloted to the criteria of road netwroks:

Road Type	Scores	Weight
Major Roads	2	2
Minor Roads	1	2

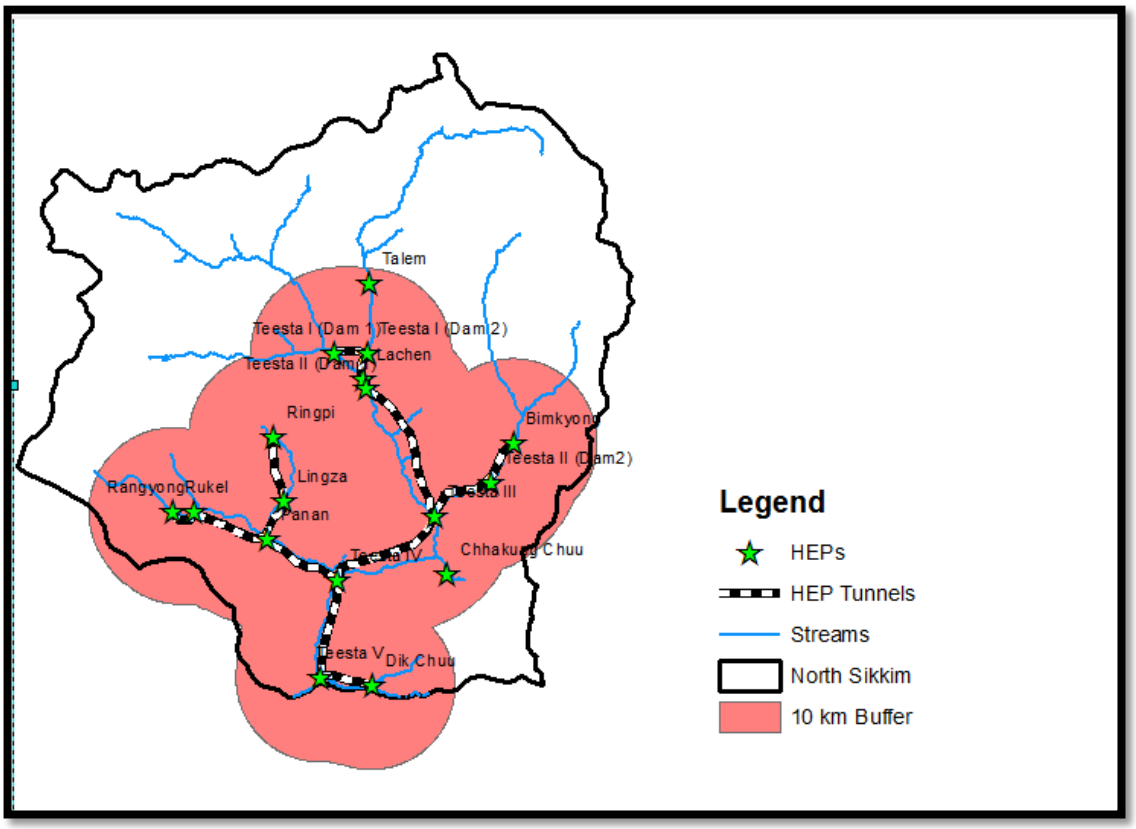


Figure 12: Tunnel Buffer map of North Sikkim

Table 6: Scores/Weight alloted to the criteria of Tunnel Buffer

Buffer (10km)	Scores	Weight
Buffer	6	4

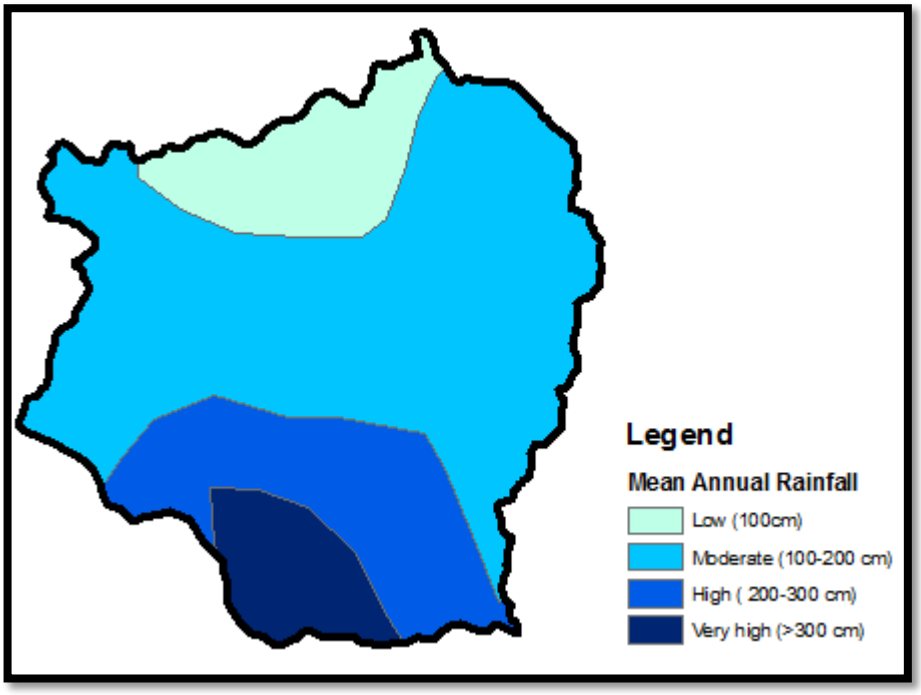


Figure 13: Rainfall Map of North Sikkim

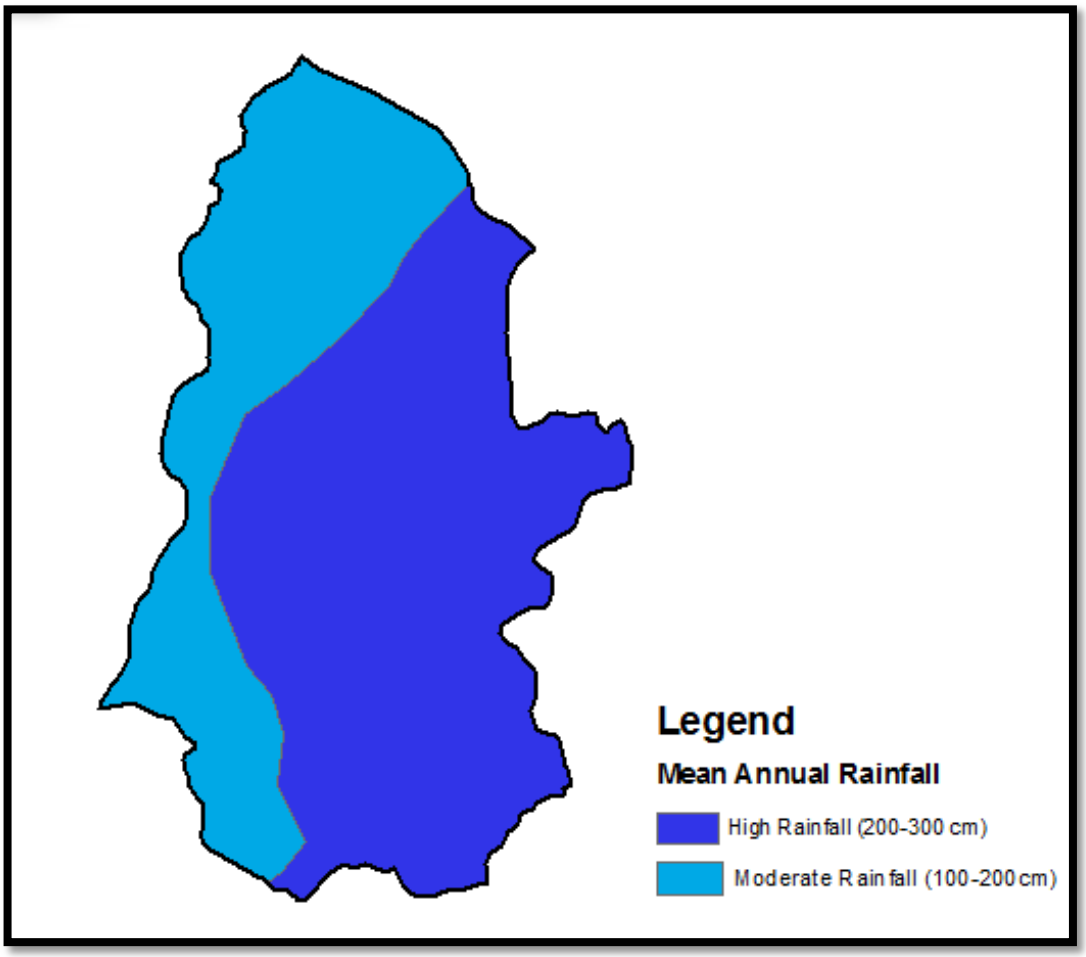


Figure 14: Rainfall map of West Sikkim

Table 7: Scores/Weight alloted to the criteria of Rainfall intensity:

Rainfall Intensity	Scores	Weight
Very High (>300 cm)	4	3
High (200-300 cm)	3	3
Moderate (100-200 cm)	2	3
Low (100 cm)	1	3

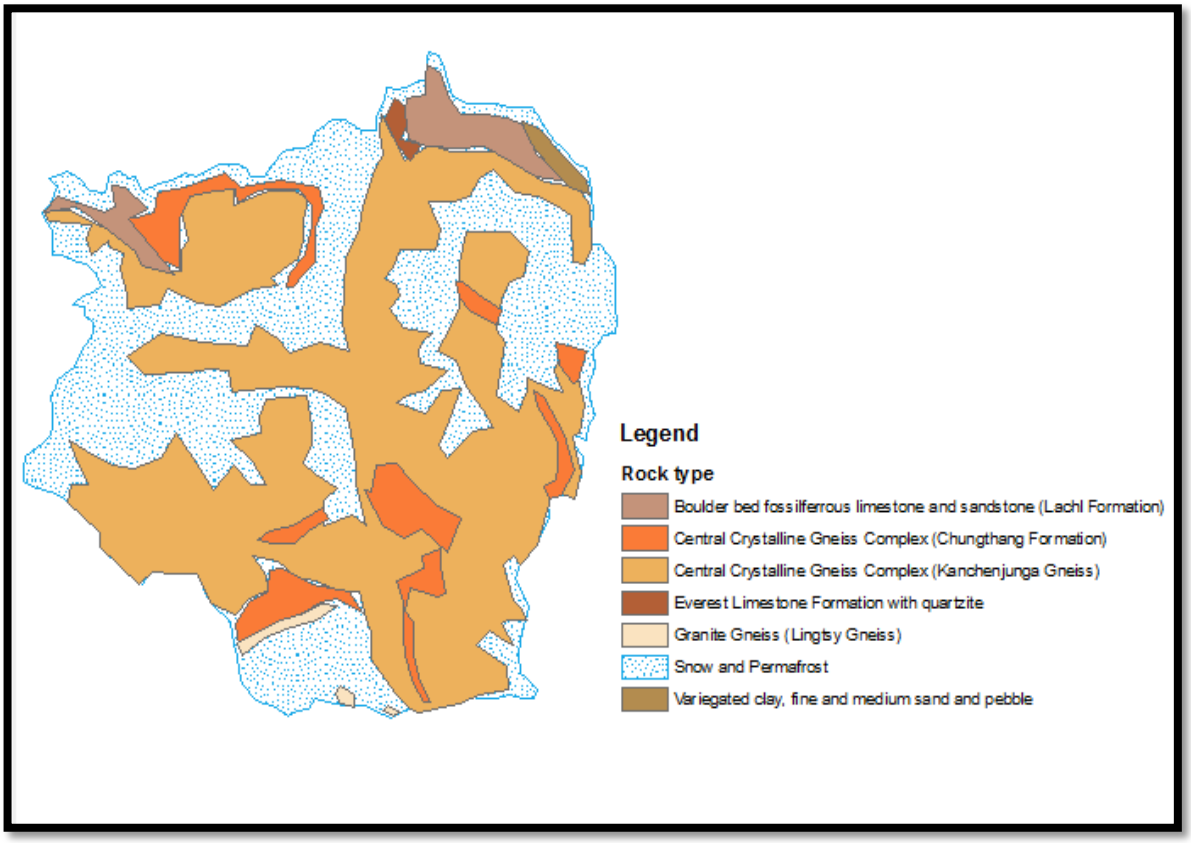


Figure 15: Geology (Rock Type) Map of North Sikkim

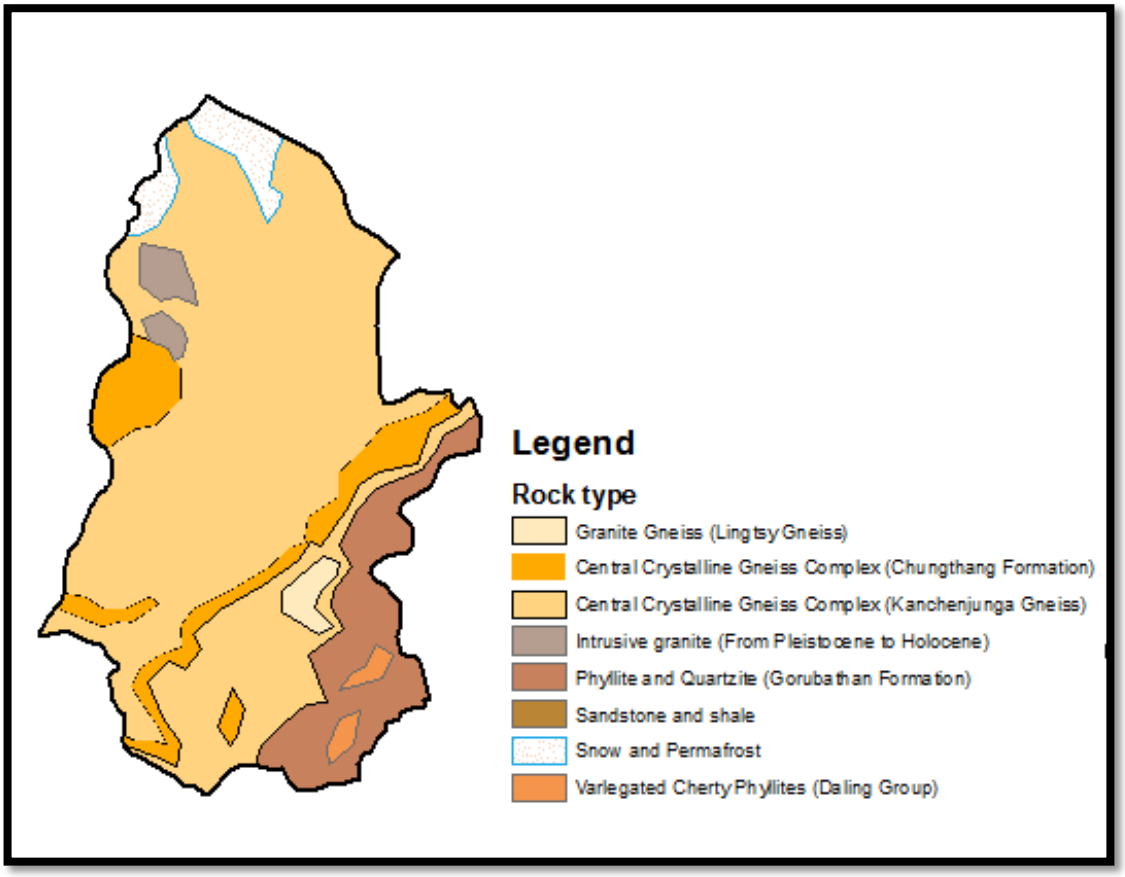


Figure 16: Geology map of West Sikkim

Table 8: Scores/Weight allotted to the criteria of Geology

Rock Type	Scores	Weight
Central Crystalline Gneiss Complex (Kanchenjunga Gneiss)	3	3
Central Crystalline Gneiss Complex (Chungthang Formation)	3	3
Granite Gneiss (Lingtsy Gneiss)	3	3
Everest Limestone Formation with quartzite	2	3
Boulder bed fossilferrous limestone and sandstone (Lachl Formation)	2	3
Variegated clay, fine and medium sand and pebble	1	3
Snow and Permafrost	1	3

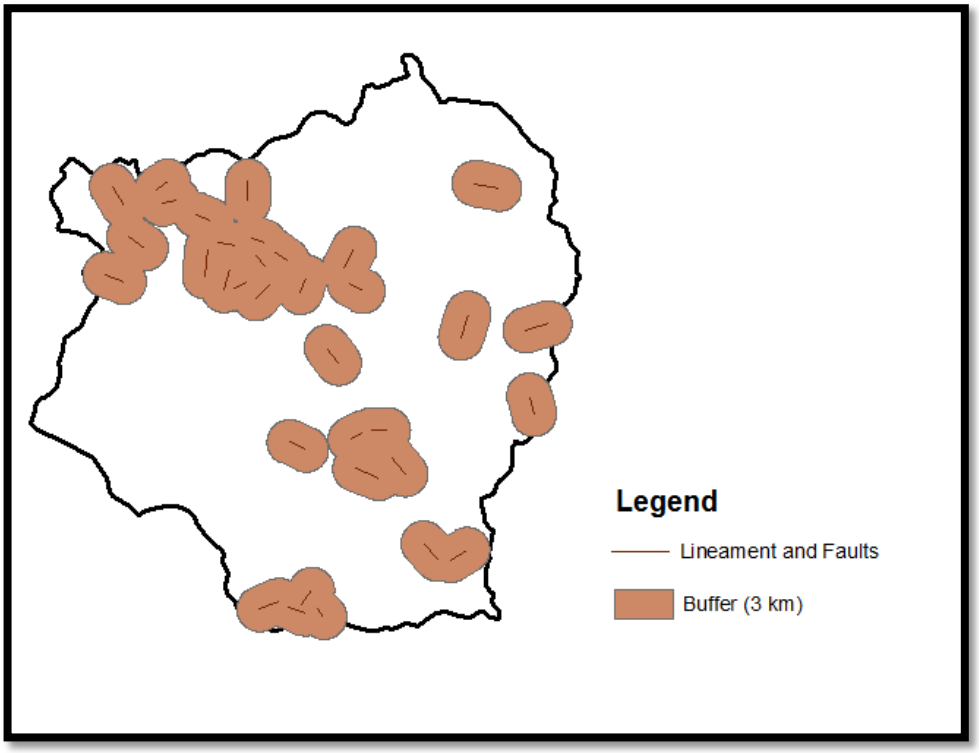


Figure 17: Lineament/Fault Buffer map of North Sikkim

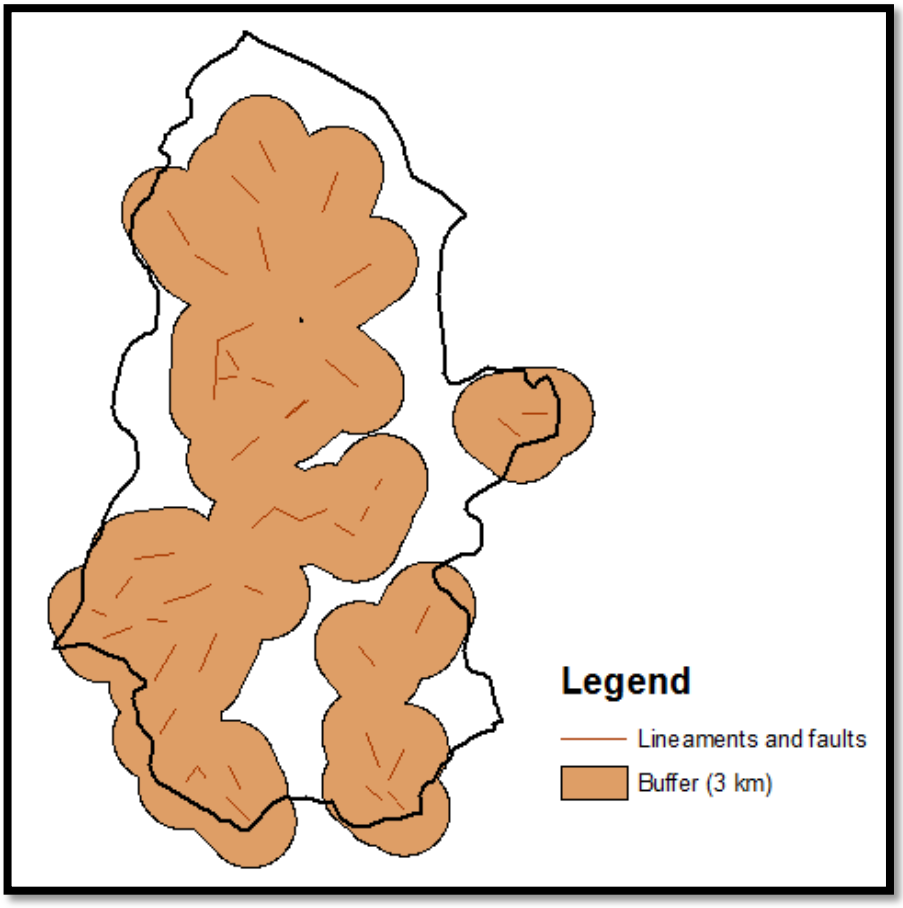


Figure 18: Lineaments/Faults buffer map of West Sikkim

Table 9: Scores/Weight alloted to the criteria of Lineament/fault Buffer

Buffer (3 km)	Scores	Weight
Buffer	5	4

By overlaying all the above thematic layers and analysing the total scores obtained from the above criteria, a landslide probability map was obtained which was the union of all the above layers. Five different classes were obtained and were categorized on the basis of severity. This map gives an idea about the areas in North Sikkim where chances of landslides are less and areas which are landslide prone. This map can also help the disaster managers in locating areas which require preparedness before the disasters thereby helping them in setting priorities at the time of preparing disaster management plans.

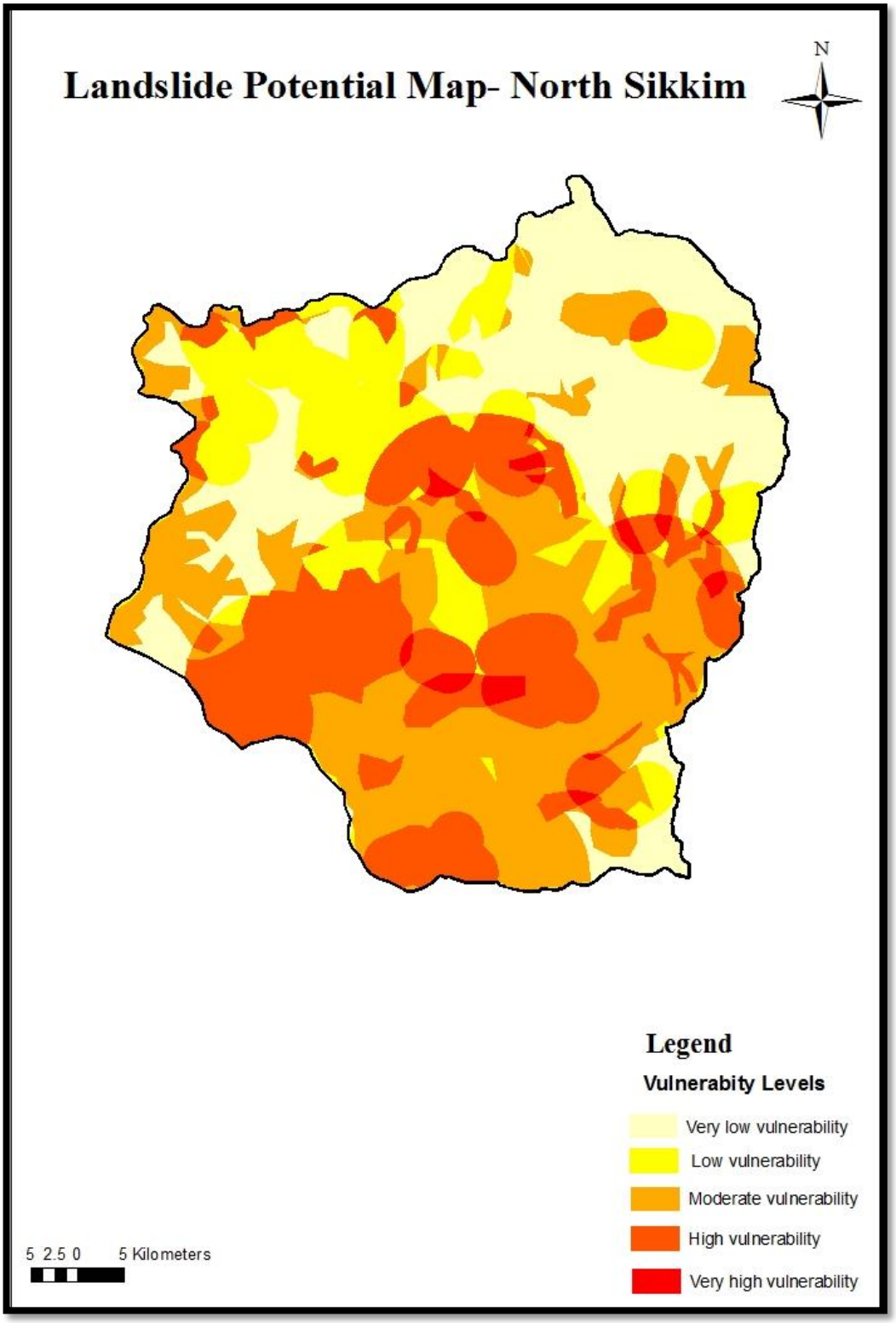


Figure 19: Landslide Potential Map of North Sikkim

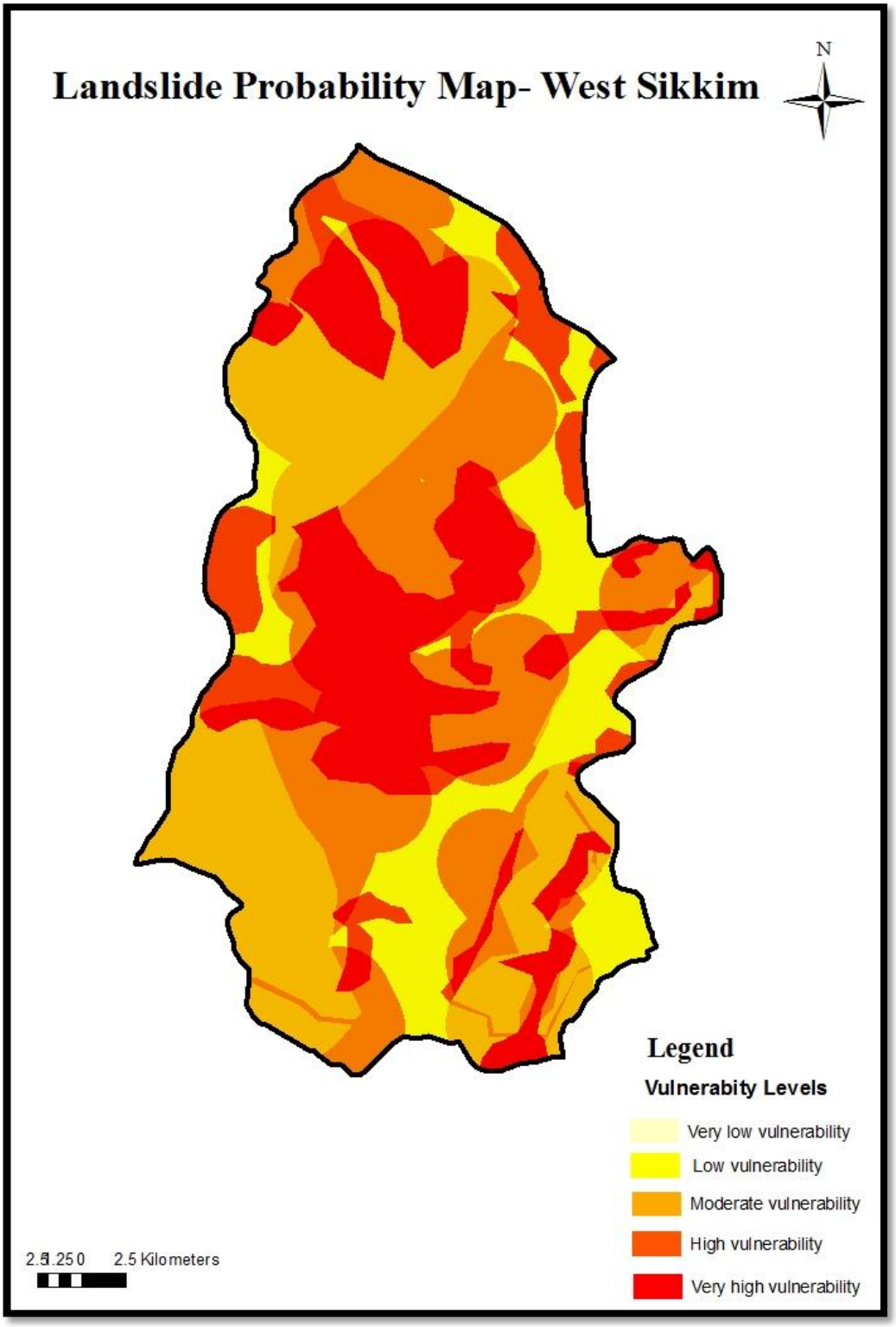


Figure 20: Landslide Potential Map of West Sikkim

Using the above thematic map of landslide prone areas in North and West Sikkim, areas prone to different vulnerability levels due to landslides were calculated.

It was found that about 1.4% of the total area in North Sikkim is subjected to very high risks of landslides and is mainly located near the HEP tunnels. About 22% of the area has least risk from the landslides.

Table 10: Total and Percentage of area under different vulnerability levels in North Sikkim:

Vulnerability levels	Area (in sq. km)	Percentage of area
Very Low Vulnerability	933	21.7
Low Vulnerability	1244	28.9
Moderate Vulnerability	1108	25.6
High Vulnerability	958	22.3
Very High Vulnerability	59	1.4

Table 11: Total and Percentage of area under different vulnerability levels in West Sikkim:

Vulnerability levels	Area (in sq. km)	Percentage of area
Very Low Vulnerability	164	15.7
Low Vulnerability	278	26.6
Moderate Vulnerability	262	25.1
High Vulnerability	88	8.4
Very High Vulnerability	252	24.1

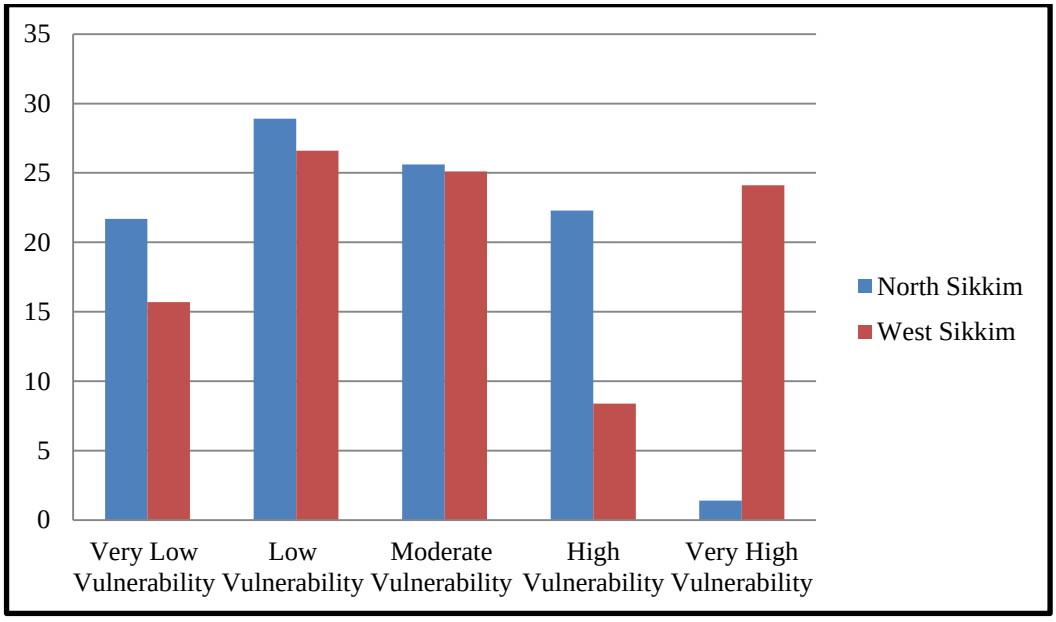


Figure 21: Percentage of area under different levels of Vulnerability

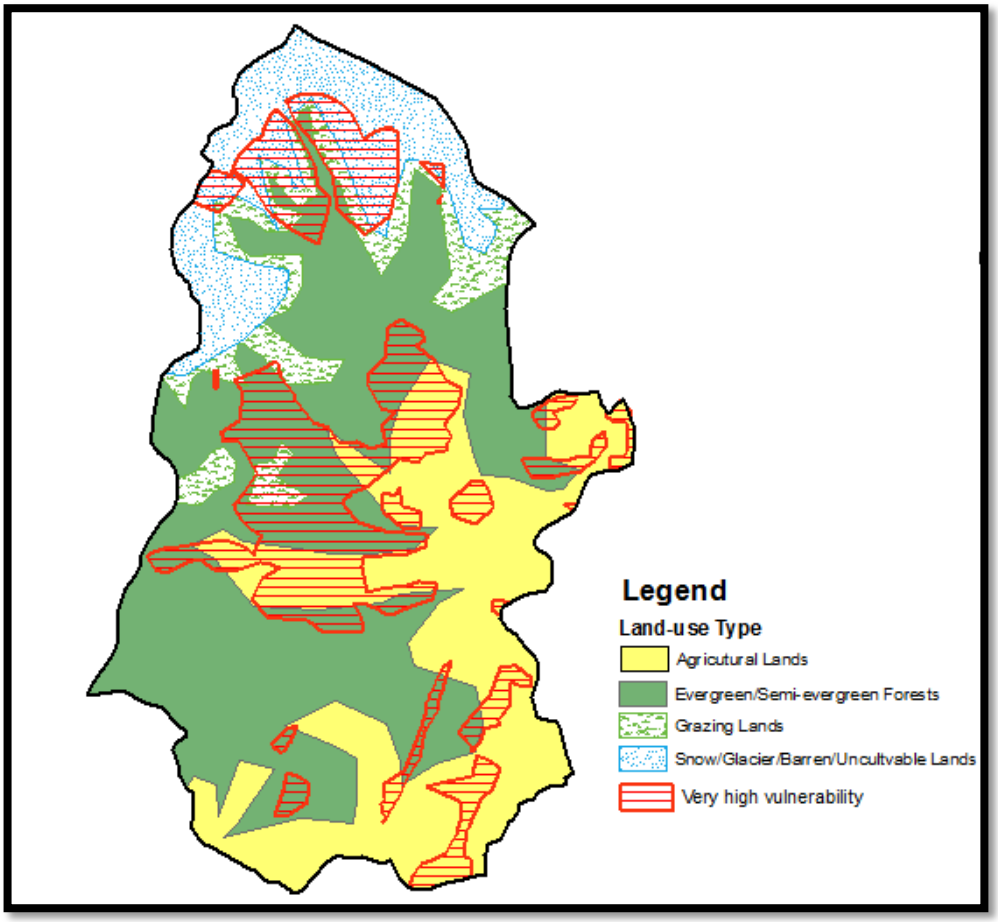


Figure 22: Land-use map of West Sikkim with very high vulnerability zones

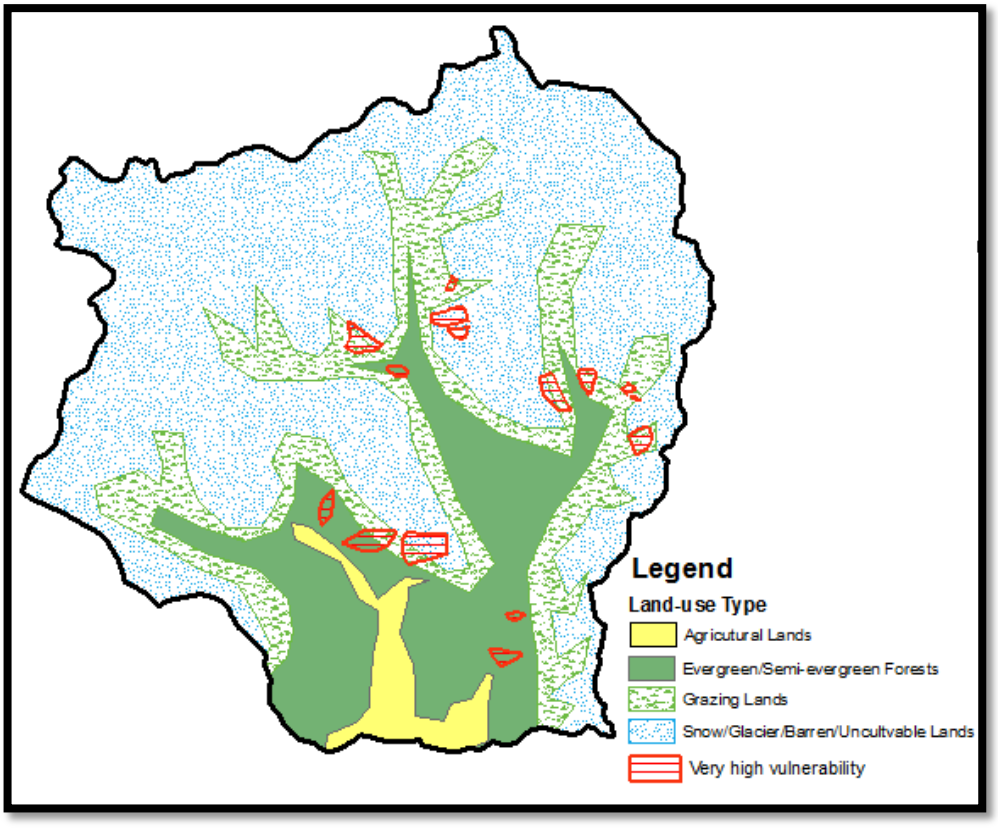
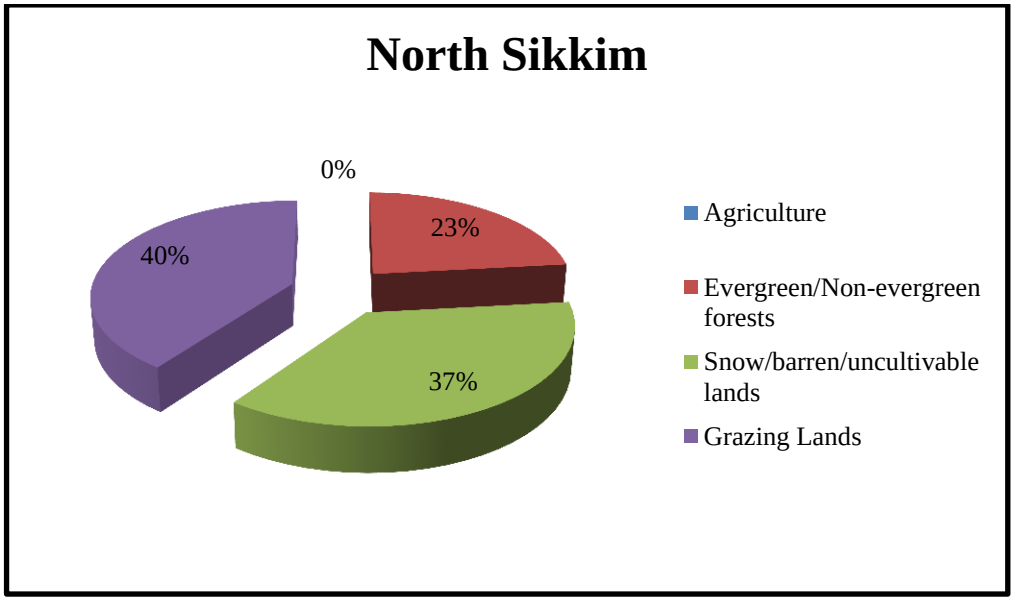


Figure 23: Land-use map of North Sikkim with very high vulnerability zones

Table 12: Percentage of area under very high vulnerability zones in North and West Sikkim:

Land use type	North Sikkim	West Sikkim
Agriculture	No Risk*	35
Evergreen/Non-evergreen forests	23.3	41.7
Snow/barren/uncultivable lands	36.7	13.5
Grazing Lands	40	9.9

* There are no agricultural lands lying in very high vulnerability zones in North Sikkim. However, about 5% of agricultural lands lie in high vulnerability zones.



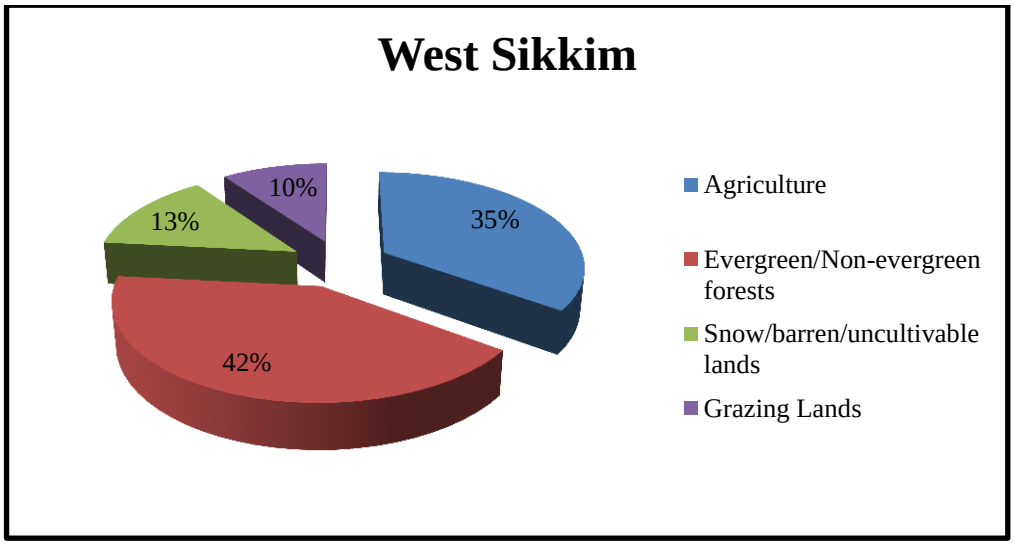


Figure 24: Percentage of area under very high vulnerability zones in North and West Sikkim

It was inferred from the above study that in North Sikkim, the vulnerability posed by the landslides is least for Agriculture. As mentioned earlier, agriculture is not an important source of income in North and not many people practice this as their livelihood. It can also be seen from the maps and the data obtained there are no agricultural fields lying in very high vulnerability zones. And only 3.5% of the total area of North Sikkim is under agriculture.

On the other hand, the high risk is posed by the landslides over grazing lands. Additional pressures are created by the problem of overgrazing and loosening of soil which causes soil instability and hence, landslides. Being a major source of income for people, efforts should be made towards reforestation in this area and rotational grazing practices.

Since, climate change is also causing the herders to drift away from this practice and involve in alternate sources like tourism and HEPs, is also increasing the risk of landslides. Being profitable, many people are involving in these businesses but if not undertaken with planning, this would majorly increase the landslide risks in the area. Since tunnelling is mainly taking place near the important cities, the risks are very high in those areas.

Hence, shifting from Agriculture and Sheep herding is not a good option for the people as the other livelihoods are landslide inducing. Efforts can be made in the field of Agriculture and Livestock herding to overcome the problems (like changing cropping patterns, regulating sheep slaughtering, etc.) as they are not much vulnerable and can become a source of stable economy in future. While HEPs and Tourism though quite lucrative in the initial stages may result in magnifying risks in future.

In West Sikkim, Agriculture is an important source of livelihood for the people. It can be deduced from the data that it is highly vulnerable to landslides in this district. About 35% of the total land under very risk falls under the category of Agriculture. As mentioned earlier, due to socio-economic, political and climatic factors, Agricultural sector is highly vulnerable and when vulnerability due to landslides adds over it, the outcome is devastating. Being the major source of income, efforts should be made towards its stability. Agriculture may help in reducing the landslide instances as crops/plantations help in binding the soil.

Since grazing lands are not much vulnerable to the landslides, appropriate measures taken for improving the conditions and eliminating socio-economic problems in this sector can result in making this a reliable source of income in future.

5.4 Mitigation Strategies:

Comparing the two districts, it is observed that West district is more prone to landslides than the North. It is important to implement landslide reduction strategies in this area.

- The developmental policies should integrate disaster risk reduction as its vital part when implementing it in landslide prone areas like West Sikkim.
- Efforts should be taken towards soil stabilization and slope modification in order to heal the already damaged and loosened soil in the study area.
- Structural as well as non-structural measures should be in place to prevent the risk of the hazard. Strict building codes (BIS) should be provided to make the buildings resistant to the landslides.
- Proper land use planning should be done in order to demarcate areas where probability of landslide occurrences is high or low.
- Roads are a major issue of concern in Sikkim. There almost no major roads in North and West Sikkim. Attempts should be made for linking every village with good roads for better connectivity.
- Insurance of the buildings as well as of human life should be promoted in these areas.
- Hazard assessment studies should be undertaken in these areas to make easy for disaster managers to understand the areas of high risk and implement the policies accordingly.
- Training and awareness programmes should be conducted by the Government as well as active NGOs in these areas in order to make people alert about the preparedness before the disasters and self-safety and evacuations during the disasters. It is also necessary to raise trained and equipped search and rescue volunteer groups throughout the state, particularly in these vulnerable areas.
- Presently there exists no debris disposal policy in the state and rock mass excavated in slope modification is disposed off in down slope areas. This

is leading to i) initiation of new landslides, ii) loss of vegetation, iii) loss of agricultural lands and water sources that are often overrun by the debris, and iv) increased pace of siltation of the downstream reservoirs. It is therefore a must to have a Debris Disposal Policy that could well be a part of a comprehensive Land use Policy for the state. There should be provision of notification of debris disposal sites in the Policy and punitive measures should be put in place for those not complying. There should be budgetary allocation for the same.

6. Conclusions and Discussions:

This study mainly concentrates upon the livelihood vulnerabilities having its roots in social, economic and political causes which tend to progress and aggravate into a disaster when a landslide event takes place. Through the PAR framework, a conclusion relating to the socio-economic and governance related vulnerability drivers for various livelihoods was identified and studied. It gave an idea about how the risks of natural hazards are magnified when the society is already vulnerable due to various other factors.

This study has identified areas with risks of landslides and intersected it with the areas under different land-uses. This study gives an idea about how a particular livelihood is vulnerable to politico-ecological and climatic causes as well as natural hazards like landslides. Hazard Mapping gives an idea about the most vulnerable areas in North and West Sikkim. The integrated study of the above two concepts helps in explaining whether the present livelihood patterns will be stable or they need a shift or a change in near future. It also takes into account the changing livelihood practices in North Sikkim and the impacts of these newly emerged income sources on the landslide probability. In this study it was seen how tourism and employment at HEPs is weakening the stability of other livelihood practices and also inducing landslides. In the end, it also suggests various adaptation strategies in North and West districts for selection of a stable livelihood depending upon its sustainability in future.

The report is helpful for carrying out disaster management studies in future as it takes into account the effects of Hydropower projects and the tunnelling taking

place in the instalments. The effect of HEPs is more pronounced in North district as many projects have been proposed in near future. The hazard maps take into account the present as well as proposed HEPs and are capable of predicting their impacts on landslide probability in the study area. In West Sikkim, there were no reported instances about the negative effects of HEPs because there are very few projects proposed in this area. Hence, in hazard mapping for West Sikkim, the criterion of HEPs was dropped.

The scores and weights assigned for the assessing hazard prone areas were based upon the literature reviews and field work. No techniques and methods were used for calculating the weights and scores but report mainly follows various papers and research findings done in this field for the same.

There are many research questions that arise from the study and also from the finding on field. The relation between the landslides and declining water sources is another issue of concern which requires in-depth study. This was reported by the people on field and giving this a scientific backing can help in answering a research question.

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8. ANNEXURE(S):

Figure 25: Snow covered agricultural fields in Thanggu, North Sikkim

Figure 26: Agricultural fields (potato cultivation) in Uttarey, West Sikkim

Figure 27: Cardamom Cultivation in West Sikkim

Figure 28: Apiculture in West Sikkim

Figure 29: Wine Making in West Sikkim

Figure 30: Fish (Trout) Cultivation in Uttarey, West Sikkim

Figure 31: Fisheries in West Sikkim

Figure 32: Handicrafts in Lachen, North Sikkim

Figure 33: Stonewall fencing and stacked yak dung at Dokpa (Yak herders) house in Gurudongmar, North Sikkim

Figure 34: Dokpa shearing a sheep *Source: Google Images*

Figure 35: Lachen, Present: The sprawl

Figure 36: Dzumsa, the traditional institution in North Sikkim

Figure 37: Landslides in Sikkim ***Source: Google Images***