Spatial Variability, Social Vulnerability and Adaptability to Landslide in Sikkim

Dissertation Submitted to Sikkim University in Partial Fulfilment of the Requirement for the award of the Degree of

MASTER OF PHILOSOPHY

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DECLARATION

I, Amrita Singh, hereby declare that the subject matter of this dissertation entitled **"Spatial Variability, Social Vulnerability & Adaptability to Landslide in Sikkim"** is the record of work done by me, that the content of this did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and the dissertation has not been submitted by me to any other University/Institute.

This is being submitted in partial fulfillment of the requirements of the degree of **Master of Philosophy** in the Department of Geography, School of Human Sciences, Sikkim University.

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LIST OF CONTENTS

CHAPTER-IV
TEMPORAL AND SPATIAL VARIABILITY OF LANDSLIDES IN SIKKIM

CHAPTER-V
SOCIAL VULNERABILITY ASSESSMENT AND CASE STUDIES

CHAPTER-VI

FINDINGS, RECOMMENDATIONS AND CONCLUSION

LIST OF MAPS **PAGE NO.**

LIST OF TABLES **Page No.**

LIST OF FIGURES **Page No.**

LIST OF PLATES **Page No.**

Chapter - I

Introduction

Disasters are as old as human history but the dramatic increase and the damage caused by them in the recent past have become a cause of national and international concern. Over the past decade, the numbers of natural and manmade disasters have climbed inexorably. From 1994 to 1998, reported disasters average was 428 per year but from 1999 to 2003, this figure went up to an average of 707 disaster events per year showing an increase of about 60 per cent over the previous years. The biggest rise was in countries of low Human Development, which suffered an increase of 142 per cent (Dey and Singh 2006).

It is notable that the Asia itself, as the most hazardous and vulnerable continent, has been suffering more than 50 per cent of events, 90 per cent of casualties and 49 per cent of the losses of natural disasters in the globe, leading to an average rate of 41 thousand tolls and 29 billion dollars loss a year (Jadda, et al. 2009).

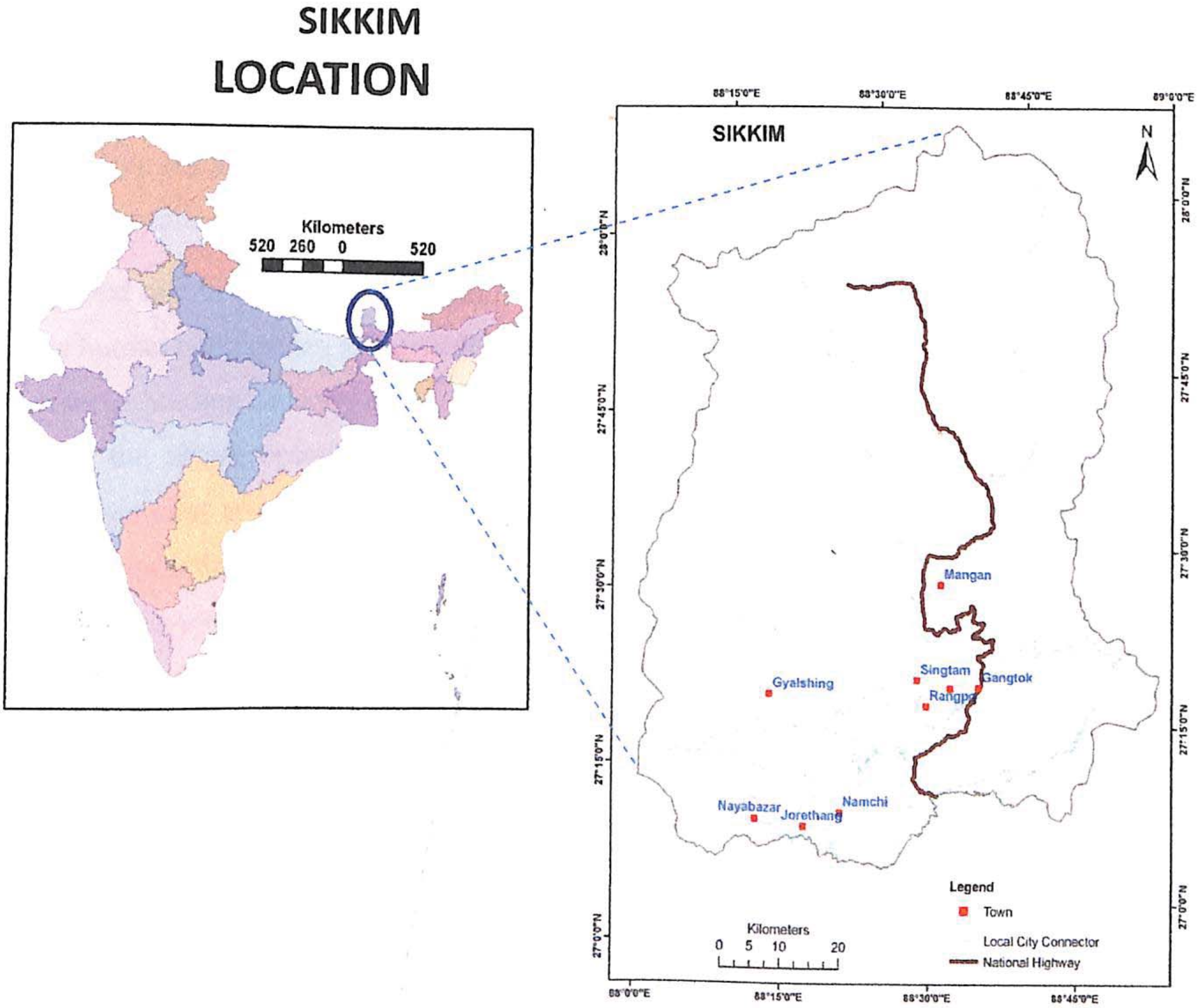
Landslides have represented 4.89% of the natural disasters that occurred worldwide during the year 1990 to 2005 (Kanungo et al. 2006). The landslides are among the most damaging natural hazards in Himalayan region (Saha et al. 2005). In many urban areas of the world, the problems of slope stability are numerous and varied, ranging from first-time failures to reactivated landslides and from minor, localized slope movements to catastrophic events. There are many challenges in the accurate assessment of slope reliability on the one hand and landslide susceptibility on the other.

The study of social vulnerability mainly depends on the peoples view and their exposure to the natural disaster and the risk they are bearing. It can be defined as follows: *"Social Vulnerability is one dimension of vulnerability to multiple stressors and shocks, including abuse, social exclusion and natural hazards. Social vulnerability refers to the inability of people, organizations, and societies to withstand adverse impacts from multiple stressors to which they are exposed".*

Social vulnerability is partially the product of social inequalities—those social factors that influence or shape the susceptibility of various groups to harm and that also govern their ability to respond (Cutter et al., 2003). However, social vulnerability is not registered by exposure to hazards alone, but also resides in the sensitivity and resilience of the system to prepare, cope and recover from such hazards (Turner et al., 2003).

1.1 STUDY AREA:

MAP 1.1: Location map of Sikkim (study area) in the country India



Sikkim is among the India's most vulnerable regions both to both natural and human-made disasters since it is situated in the very high zone in regard to earthquake and high zone with regards to landslides according to multi hazard map of UNDP. It is one of the places where landslide is a common hazard and the state is badly affected by it. A tough weave of rampant and unplanned urbanization has come up in the state and unsafe buildings compound the risks. The Sikkim Himalaya has never been and will never be free from ubiquity of weak geology, slope instability, frequent seismicity, soil erosion etc. mainly due to natural causes and partly as a result of accelerated degradation. Landslides triggered by heavy rain been constant sources of destruction of property and loss of lives. Dormant as well as active slides are threat to human life and property. Removal of basal support through cutting of slopes for construction of the road is an important anthropogenic factor that triggered massive landslide.

Most of the Sikkim is covered by Precambrian rocks. The rock consists of phyllites and schist's producing generally poor and shallow brown clay soils and is highly susceptible to weathering and erosion. This combined with the state's heavy rainfall causes extensive soil erosion and the loss of soil nutrients through leaching and is susceptible to earthquakes (in terms of frequency and intensity). As a result, landslides are frequent often isolating rural towns and villages from major urban centers.

It is reported that in Rangpo, East Sikkim the number of landslides has increased in recent years with the human interference along with weak geology which are susceptible to landslide and due to high water holding capacity of the soil.

Based on the above description the study area has been selected Sikkim for studying the temporal variation and for identifying spatial variation it is further divided into districts and blocks from each district, according to the division of the state.

So it is necessary to study geology, slope, rainfall, and vegetation, anthropogenic factors of the area which influence the landslide and also the vulnerability of the people due to this hazard both in scientific and social terms.

1.2 LITERATURE REVIEW:

It is said that the extreme events of the nature is increasing in the present global scenario. The loss in property from natural hazards is rising in most regions of the earth and the loss of life is increasing among the poor nations of the world.

Moon, Wilson and Flentje in 2005 in a conference paper on "Developing and using landslide size frequency models" discusses how models can be presented graphically, gives an example of its recent application and discusses the knowledge and evidence on which models are based. The paper describes about the methods and techniques in regards the scientific side of analyzing and interpretation of landslides through graphical presentations to show how observations, interpretations and judgments are interrelated and allows different models to be compared.

Similarly, Flentje and Chowdhury in 2006 in his proceeding Conference paper on "Observational Approach for Urban Landslide Management, Engineering Geology for Tomorrows Cities", focuses on the development of an "observational approach" for landslide risk management and its application within an important landslide study area, the Wollongong Local Government Area, in the state of New South Wales, Australia. This paper proves helpful with its understanding about the physical aspect of subsurface shear movement and pore water pressures at a number of places in a study area and proved very useful in combination with rainfall data from a number of existing rainfall stations. However, GIS-based methods and techniques for landslide Susceptibility and Hazard Mapping have not been included, added to it inclusion of land-use maps and technique represents insufficient for assessing and managing the landslide.

Akbar and Ha in "Landslide hazard zoning along Himalayan Kaghan Valley of Pakistan" in 2011 discusses the effect of the landslides and its zonation. The paper analyses the occurrence of landslides and its prominent locations using Satellite imagery and GIS applications.

Roslee, Rodeano, Jamaluddin, Talip, Collin, & Rudding in their paper entitled "Integrated Geospatial Technology On Landslide Susceptibility" examines the ability of geospatial technology in handling semi-quantitative data of Landslides Susceptibility Analysis (LSA) research as powerful integrated tools. It encourages a rational, systematic approach for assessing the safety of slopes, and a framework to put uncertainties and engineering judgment into a system and allows comparison of hazards and risks for different slopes. The paper also brings together the different variables of geological understanding into the usage of GIS to orient description of the velocity and intensity of the existing or potential land sliding.

The above paper as compared to the Project report submitted by CISMHE in 2007 on "Carrying Capacity Study of Teesta River Basin in Sikkim" the contribution to the geological interlinking of slope, land-use and susceptibility have less concerned.

In local level, a paper on "Landslide Susceptibility Zonation and Geotechnical Mapping of Gangtok and Suburbs" by Tashi, 2003 provides a first hand overview to the existing landslides in the local to national scale. The paper provides primary source of access to the archives over landslides in Sikkim and Gangtok. Further, GIS application and direction render support to the basic notion of emergence and existing landslides.

Another Report published by the Land Revenue and Disaster Management Department (LRDMD),2008 under Government of Sikkim contribute a vast knowledge in the Disaster management approaches, and provides preliminary data of the past disasters and provides a detailed study on the landslides vulnerability and zonation of landslides using GIS application and location based photographs and zonation. This report together provides a basis for understanding landslides in this region of the Himalaya but it has not clearly mentioned anywhere about the people who are mostly vulnerable to these type of hazards, neither it talks about the people's reponse towards it and the adaptibility and coping mechanisms related inthis field. It is necessary to understand the communities and there practices in the this regard and the policies which is being made needs to be implemented in a proper manner to reduce its effects.

Corominas in 2001 mentioned in a Symposium on "Landslides and Climate, Keynote Lectures from the 8thInternational Symposium on Landslides". One of the factors influencing the occurrence of landslide is rainfall. It is widely accepted that high duration rainfall events are the most important triggering mechanisms of landslides worldwide.

Another paper on "The Influence of North Atlantic Oscillation on Rainfall Triggering of Landslides near Lisbon" by Ricardo, Zezere, Rodrigues & Trigo in 2005 has mentioned about the case of Lisbon where rainfall, precipitation and the influence of North Atlantic Oscillation are compared and showed how they are interrelated with each other. The discussions bring forward that large inter annual variability of winter precipitation is largely modulated by North Atlantic Oscillation.

Another case study by Brown 1991, in his paper entitled "Landslide Control on North Island, New Zealand", North West Argentina in a subtropical mountain ecosystem has been discussed and shows the relationship between precipitation and landslide and between climate and landslide. It shows that the mean precipitation in years with landslides is significantly greater than the mean precipitation in years without landslides.

In case of the first study the effect of North Atlantic Oscillation on rainfall and precipitation is shown whereas in later study the precipitation is itself compared with landslide. In the later case, land use is not come up as major issue because of the general trend of decrease in land use intensity in montane forests. This reinforces the role of precipitation as the main triggering factor for landslide occurrence and increase in precipitation for over long intervals also favors the landslide occurrence.

One more factor giving rise to the occurrence of landslide is increasing deforestation. In most of the studies it is being mentioned that deforestation is one of the cause landslide which results in loss of vegetation in the area but according to Guariguata, 1990 in his paper on "Landslide Disturbance and Forest Regeneration in the Upper Luquillo Mountains of Puerto Rico", post landslide effects is also positive in the sense that it helps in the recovery of many vegetation. His observations during this study suggests that some species almost exclusively benefit from landslide openings like light demanding ferns, herbs and one particular tree species named cyrilla racemiflora, in Luquillo mountains of Puerto Rico. This can be referred as one of the positive point allied to landslide occurrence, which has been observed very less in any region.

It is also true to say that deforestation may lead to increase in number of landslides anywhere in the world together with the nature of rock and slope of the area. The argument supported by 'W. Jeffery Brown,1991in his paper on "Landslide Control in North Island, New Zealand" about the use of different plant species clears it that the importance of vegetation in the area is very important for the reduction of landslide occurrence in particular and increasing the richness of the area in general. Compared with engineering measures, the control of landslide through vegetation is seen relatively inexpensive. The steep terrains for farming in the hilly regions become difficult with the problem of landslide in the area and in order to reduce its effects vegetation can solve the problem to some extent. Tree planting can prevent reactivation of rapid mass movements and can reduce the probability of new landslides. The article clears the view that many farmers believe and realize that a forest cover provides the best soil protection on slopes experiencing repeated severe land-sliding.

The papers, Hoek & Bray in 1977 in "Rock Slope Engineering" & McCarthy in 1977 in "Hill Slope Stability and Land Use" have mentioned that geotechnical specialists in soil and rock mechanics have developed sophisticated methods of site investigation. The paper comes with an idea that things like road cutting, increased vegetation etc. is associated with different types of landslides.

In case of India, the situation is almost the same as there in global level. As mentioned earlier, landslides are a major hazard along the Himalayan highways and there is need for better methods of hazard evaluation. In 1976 in a periodical article "Landslides, the Nightmare of Hill roads" they explained that fragile nature of the mountain ecosystem coupled with unplanned construction activities renders this terrain vulnerable to mass wasting processes. Landslides are a nightmare for all concerned with the new hill roads according to them.

In this context, tackling landslide problems in Himalayan terrain had always appeared as a major challenge to engineers and town planners while implementing development schemes. This problem turned acute when disproportionate urbanization in hill stations aggravates existing condition of slope stability and posed major threat to human establishment. Hence, the need of the hour is to go for an effective landslide hazard management program by which appropriate remedial measures can be sought for hazard prone slopes and thus avoiding future disasters. A study has been done by Haigh, Rawat and Bartarya 1989, in Kilbury Road, Nainital to reach the problems faced in the field of transport. It would be highly dangerous or even fatal experience if a road is built around a very steep slope. This highlights one of the major problem of constructing roads along the steeper slopes for better transport facilities in the high lands. Blasting process for the construction of roads leads to the occurrence of landslides in the high hills which is also in one way hinders the development process. But it can also be said that if the construction of roads will be stopped in these areas, then the area will lack behind in transport facilities and linking it with other part of the country & which will ultimately lead to under-development.

The literatures that have been reported over landslide research have fundamentally been the landslide hazard zonation mapping but it is also true to some extent that these mapping are very rarely used in the ground level.

The perfect example comes from one of the case study in La Paz city in Bolivia by O'Hare and Rivas. In this city even after huge damage of property and human life in 2005, many peoples are settled in the same area of destruction which is affected again and again. These people are mostly the marginalized one who are poor or have low income. They stay in 'Self-built settlements' where the people themselves take the responsibility for organizing their design and construction. The ability to pay for the land and construction of their houses is beyond their reach.

Human behavior is of different kind and there adaptability and coping mechanism differs from place to place. No doubt scientific methods are important for the understanding of landslide process but there is also need to understand the behavior pattern of the communities and the population residing in these zones. Hazard mapping can show the areas which are not suitable for settlement for the people but it is also necessary to identify the vulnerable sections of the society. Whether they are poor, marginalized or weaker section of the society or whether the rich people also comes under its effects.

In the book 'Environment As Hazard' by Burton, Kates and White, 2005 has been clearly mentioned that Neoclassical economists allow only minimal government intervention and wanted the market processes to engender more sensitive assessments of the risk run by individuals and firms whereas radical critics attribute to these self-same free enterprise processes of hazard as a result of the marginalization of the third world countries and the result of such a process is that the underdeveloped population is isolated from the traditional indigenous resource base, they are forced to accept strategies that contain fewer insurance or adaptive mechanisms for survival. The new strategies leave them to the more vulnerable, more disaster prone, to the unexpected mysteries of the environment. When people move into a new environment they carry with them biological and cultural adaptations developed in their previous environment. Depending on the character of those adaptations, a people may be able to cope better or worse with the environment into which they move. In any society these adaptations and coping mechanisms are absorbed commonly and in general.

The first mode of coping with hazard is loss absorption. A society absorbs the impact of environmental extremes and remains largely unaware that it is doing so. In each situation society & environment interact and of resilience to extreme events. Moreover, two societies occupying the same environment may, by virtue of their different adaptations and their incidental adjustments be differently affected.

The second mode is loss acceptance in which a society arranges to bear the loss often by sharing it with a wider group than those directly affected. People prefer to bear known ills rather than take action the outcome of which may be equivocal or uncertain. People have a capacity for learning to live with hazard events, and provide that the impact is not great they may prefer to live with it rather than do something about it.

The third mode is reduction and this mode of response is characterized by efforts to control the hazard event itself or to reduce the vulnerability of individuals and groups. In any case the goal is loss reduction.

The last is intolerance and before this threshold is reached both societies and individuals explore fully the methods of loss reduction. When individuals or groups exhaust their capacity for action or find the choices open to them are no longer effective for use, some changes are possible like- substantial changes in resource use, change in location or combination of these.

All these questions together put a big question on the part of government that whether these sections of society can be moved at a safer side or else it will remain the same for the people bearing losses and damages at the cost of their life and property because it is much hard for the poor one to cope again and again with these kind of hazard.

1.3 RESEARCH GAP:

The reported readings shows that most of the GIS based studies had been limited to physical assessment of land slide such as mapping of landslide. However there are few studies that deals with the social vulnerability but none of the studies are dealt with the spatial variability, temporal variability and social vulnerability in case of Sikkim.

1.4 OBJECTIVES:

This study has made an attempt to focus on the vulnerability of landslide of each community who are having different standard of living at different locations.

The main objectives of the study are given below:

- To study Spatio- temporal variation of landslide in the state and analyze their nature and distributional pattern,

- To access the vulnerability level of landslides in each districts and to compare vulnerability of landslides in rural and urban area selected from each districts and
- To examine the preventive measures to combat landslide both traditional knowledge and government initiatives.

1.5 RESEARCH QUESTION:

1. What are the Spatio-temporal variations of landslide in the selected area and how it differs from each other?

2. Which strata of society are vulnerable to these kinds of risk and what could be the best strategy to improve their capacity?

1.6 DATA BASE:

The data were collected from primary and secondary sources. Primary data have been generated from scheduled questionnaires, interviews and observations in the month of March to May, 2014 whereas the secondary data were obtained from government organizations such as Geological Survey of India (GSI), Department of Science and Technology; Land Revenue and Disaster Management Department and from Official Reports and articles as well as books and journals. Census 2011 data were used to calculate SVI (Social Vulnerability Index) for each districts.

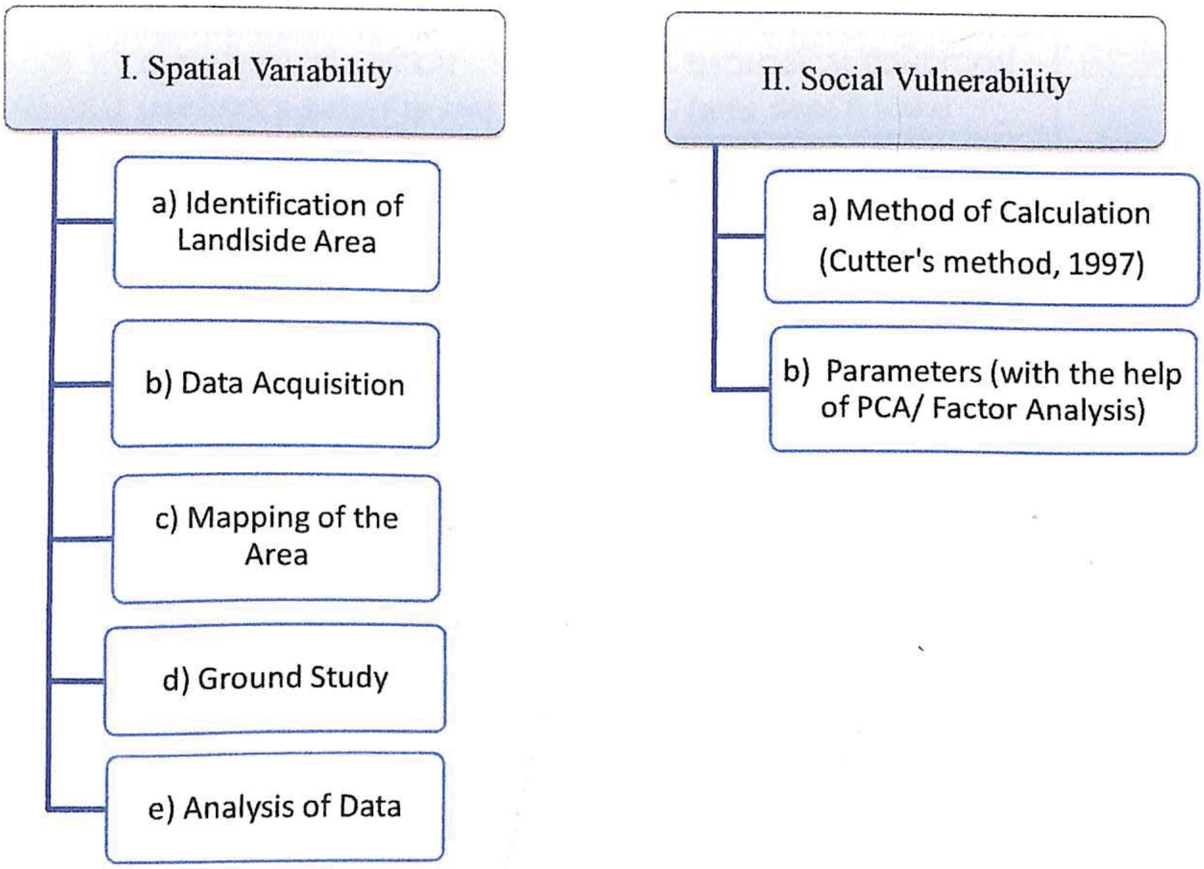
The Spatio-temporal variation of landslides in the state was studied from the data collected from the Sikkim Now (Daily local English Newspaper) from 1999-2013.

Two sites have been selected from each districts one from urban and another from rural having different physical and social aspects. Thus 8 sets of data has been collected and analyzed for social vulnerability. Based on the population size of the area, its geology and rock structure the main areas near MCT and MBT is selected, named Gyalshing (Urban-West), Namchi (Urban-South), Singtam (Urban-East), and Mangan (Urban-North).

Likewise in rural areas Lachung Dzumsa (North), Rakdong-Tintek (East), Temi-Tarku (South) and Dentam (West) has been selected for the present study. Total 330 household samples have been collected for the study which varies from one area to other.

1.7 METHODOLOGY:

In order to fulfill the objective of the present study the following (steps) methods and materials has been followed:



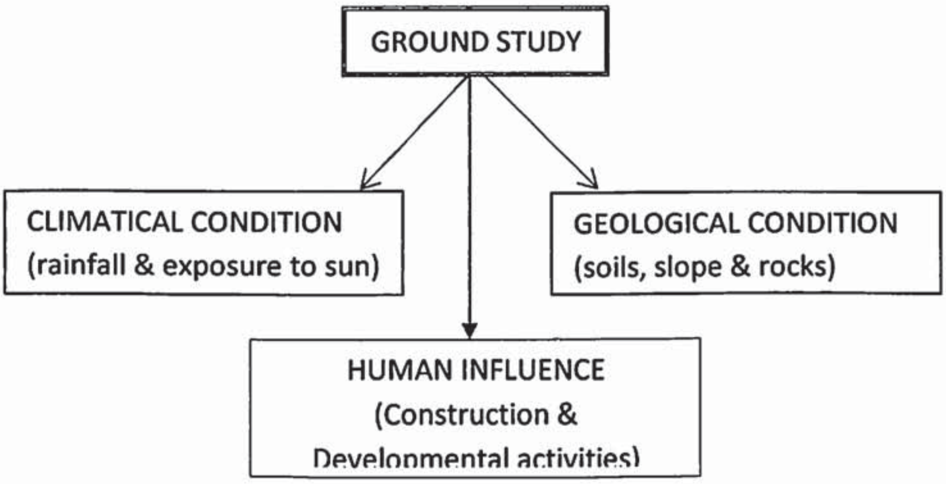
I. Spatial Variability:

a) Identification of Landslide Area: the area is identified on the basis of geological formation and structure of the rocks and the frequency in the mentioned area as well as with the help of literatures.

b) Data Acquisition: the required is collected from the Toposheets, Satellite data from Government organizations such as Geological Survey of India, Department of Science and Technology, Land Revenue and Disaster Management Department and Official Reports and Published Articles and Journals.

c) Mapping of the Area: the next step was to map the acquired data through remote sensing and Geographic Information System (GIS).

d) Ground Study: in this part the selected area has been studied on the following basis:



e) Analysis of Data: the data were analyzed based on the above steps to find out the reasons of the landslide in the mentioned area and the spatial variation of the same.

II. Social Vulnerability:

a) Method for calculation: the level of vulnerability of the population is understood by calculating the Social Vulnerability (SV) in the area to show the overall Social Vulnerability Index (SVI) (Cutter, Mitchell & Scott 1977) of the identified areas and the following formula was used for that:

$SV= X \div X\ max$

And

$SVI= SV_1+SV_2+SV_3+......SVn$

b) Parameters: 51 parameters have been employed for the calculation of SVI with the help of PCA in which number of parameters has been analyzed and 24 parameters finally selected for the study. Some of the parameters which were used for finding out the SVI index like-

i) Age- children & very elderly

ii) Gender

iii) Education level

iv) Employment status and Income level

v) Rural/Urban area

vi) Level of risk awareness and preparedness

vii) Physically challenged people

1.7 LIMITATIONS OF THE STUDY:

Access to all the areas was difficult because of undulating terrain and poor weather condition. The study was huge and time consuming and due to short duration of time in-depth study of many areas was difficult. One of the important limitations of the study was that people were not ready to interact because of their mentality that these kinds of works are not helping them in any way and there is no further development in the act of government and no improve in their condition.

1.9 CHAPTERIZATION:

This work has been arranged into six chapters. The first chapter discusses about the study area, literatures review, objectives, research gap, research questions, data base & methodology of the study, limitation, and schemes of work.

Chapter Two elucidates the basic factors of landslides by which it is influenced and tries to incorporate and relate these factors with the study area explaining that how these factors like geology, climate, and relief, vegetation including some anthropogenic factors affecting the area and making it more vulnerable to landslides in this region.

Chapter Three represents the traditional ways of handling the natural disasters focusing on landslides and tried to explain the basic traditional & common community based practice of preventing from hazards and attempted to narrate some of the stories related to hazards keeping lessons for the human beings that how one should behave in an emergency. This chapter also explains that how the communities tried to adapt or adapting with these disasters since time immemorial& their preparedness and mitigation methods and also attempted to explain the Government policies for the natural disaster management and for its prevention and mitigation.

Chapter Four basically deals with the spatial and temporal variability of landslides with the help of gathered data's from newspapers of last 15 years and tried to compare and find out what could be the basic reason for the increase or decrease of the cases of landslides in this region. Block-wise and district-wise analysis has been done to better understand the situation and vulnerability of the areas during last fifteen years.

Chapter five has dealt with the Social vulnerability of the area in selected sites for the study, with the help of Social Vulnerability Index by doing factor Analysis for the indicator selection which explains the most vulnerable area in the state and also tried to explain the socially vulnerable areas in urban and rural parts of selected sites and compared the outcome of the above two parts of SVI and study area result.

The last chapter basically deals with the main findings which have come from the study of Spatial & Temporal variability as well as by analyzing the SVI of the State and by observation and study of the selected sites in the field followed by recommendations and Conclusion.

Chapter - II

Factors Influencing Landslides in Sikkim

There is no doubt in saying that landslides are the most intimidating geo-hazard in the hill and the mountain terrains. Landslides are the result of the effect of conditioning factors which govern the stability conditions of the slope and the triggering factors. The triggering factor is natural or anthropogenic, intense and short-term, irreversibly altering the slope causing landslides (Sujatha et al., 2012). Hence it is necessary to understand the landslide processes, to analyze the hazards, to asses the factors that contribute to instability of slopes failures and to predict the future landslides to combat the damages caused by it so that suitable mitigation measures can be evolved from it.

2.1 GEOLOGY:

Geology is one of the main factors for the occurrence of landslides and tectonically Sikkim Himalayas are under high risk zone and tectonically instable which gives rise to the high incidents of landslide in this part of the Himalayas. According to GSI report 2011: The Himalayas traditionally had been divided into linear geo-tectonic belts with distinct geological characteristics. Like other parts of the Himalaya, in Sikkim-Darjeeling Himalaya, the Sub-Himalayan domain comprises the molasses type deposits of the Siwaliks. It is followed Northward by a thin strip of Sandstone, Carbonaceous shale and Coal (Gondwana), Stromatolitic dolomite and variegated slate (Buxa and Reyang Formation of Daling Group) and a thick meta-sedimentary sequence of dominantly pelites with subordinate psammite and Wacke (Gorubathan Formation of Daling Group), constituting the Lesser Himalayan Belt. Towards the North, Daling sequence is overlain by higher Himalayan rocks of medium to high grade dominantly politic Schist with minor inter-banded quartzite, calc-silicate and meta-basites (commonly known as Chungthang/ Paro formation) and small bodies of Granites (Lingtse Gneiss). This sequence in turn towards North overlies a migmatitic terrain known as Darjeeling Gneiss/ Kanchenjunga Gneiss and is equivalent to what is variously described as Central Crystalline/ Greater Himalayan Crystalline/ Higher Himalayan Crystalline (GHC/HHC). In the far North a thick file of fossiliferous Cambrian to Eocene sediments, belonging to the Tethyan Belt (Tethyan Sedimentary Sequence) overlies the HHC.

The Main Boundary Thrust (MBT) separates the Siwaliks of the Sub-Himalayan domain from the overlying rocks of the Lesser Himalayan from Higher Himalayan. In the western as well as in the eastern part of the Sikkim-Darjeeling Himalayas, the Lesser Himalayan Package is exposed as thin strip between MBT and MCT. However, in the central part of the

Sikkim-Darjeeling Lesser Himalayas, a domal shaped culmination structure (known as Tista/Daling Dome) has exposed a wide expanse of the Lesser Himalayan rocks. The MBT, with the Mio-Pliocene Synorogenic Siwalik Group in the footwall and the Permo-Carboniferous Gondwana in the hanging wall, has not been affected by this culmination structure and have a roughly East-West trace. The Gondwana rocks as well as the Buxa and Rangit pebble slate are exposed in the Rangit window zone where these are surrounded by Daling group of rocks (Gansser 1964) (Acharyya 1989 & 1992). The tethyan belt is exposed on the hanging wall side of a series of north-dipping normal faults constituting the South Tibetan Detachment System (STDs), Higher Himalayan Crystalline being the footwall.

In recent years Geological Survey of India developed unified legend for all the formations of India. The formations exposed in Sikkim can be classified as given in below table:

TABLE 2.1.1: Generalized Stratigraphic Succession of Sikkim Himalaya

LITHOLOGY	FORMATION		GROUPAGE
Variegated clay, fine and medium sand, pebble bed	Sesela Formation		Upper Pleistocene Holocene
Tourmaline / biotite leuco granite, schroll rock/ pegmatite, aplite (Undifferentiated)	Intrusive		
Syenite / basic dyke/sill (Undifferentiated)	Intrusive		
Fossiliferous sandstone, limestone, shale	Tso Lhamo Formation		Triassic
Boulder bed, Fossiliferous limestone and sandstone	Lachi Formation		Carboniferous to Permian
Sandstone, shale, carbonaceous shale with coal Pebble/boulder slate, conglomerate, phyllite	Damuda Group Rangit pebble state Groups	Gondwana Super-group	
Fossiliferous limestone with quartzite	Everest Limestone Formation		Ordovician
Granite gneiss (mylonite)	Lingtse Granite Gneiss		Meso Proterozoic
Phyllite, quartzite, biotite gneiss	Everest Pelite Formation		Meso Proterozoic
Amphibole schist / amphibolite	Sill		
Dolostone, Ortho-quartzite, purple phyllite / slate, chert	Buxa Formation		Proterozoic Undifferentiated

Ortho-quartzite, pyritiferous black slate, variegated cherty phyllite, meta-greywacke	Reyang Formation		
Interbanded chlorite-sericite schist / phyllite and quartzite, meta-greywacke (quartzo feldspathic greywacke), pyritiferous black slate, biotite phyllite / mica schist, biotite quartzite, mica schist with garnet, with / without staurolite, chlorite quartzite	Gorubathan Formation	Daling Group	
Banded / streaky migmatite, augen bearing (garnet) biotite gneiss with/ without kyanite, sillimanlte with palaeosomes of staurolite, kyanite, mica schist, biotite gneiss, sillimanite granite gneiss	Kanchenjunga Gneiss/ Darjeeling Gneiss (Undifferentiated)	Central Crystalline Gneissic Complex (CCGC)	Proterozoic Undifferentiated
1. Quartzite 2. Garnet kyanite sillimanite, Biotite schist / Garnetiferous mica schist Chungthang 3. Calc-silicate, carbonaceous schist Formation	Chungthang Formation		Mica and Biotite is much Susceptible to landlsides because of its parallel formation

Source: (As per unified legend scheme of GSI)

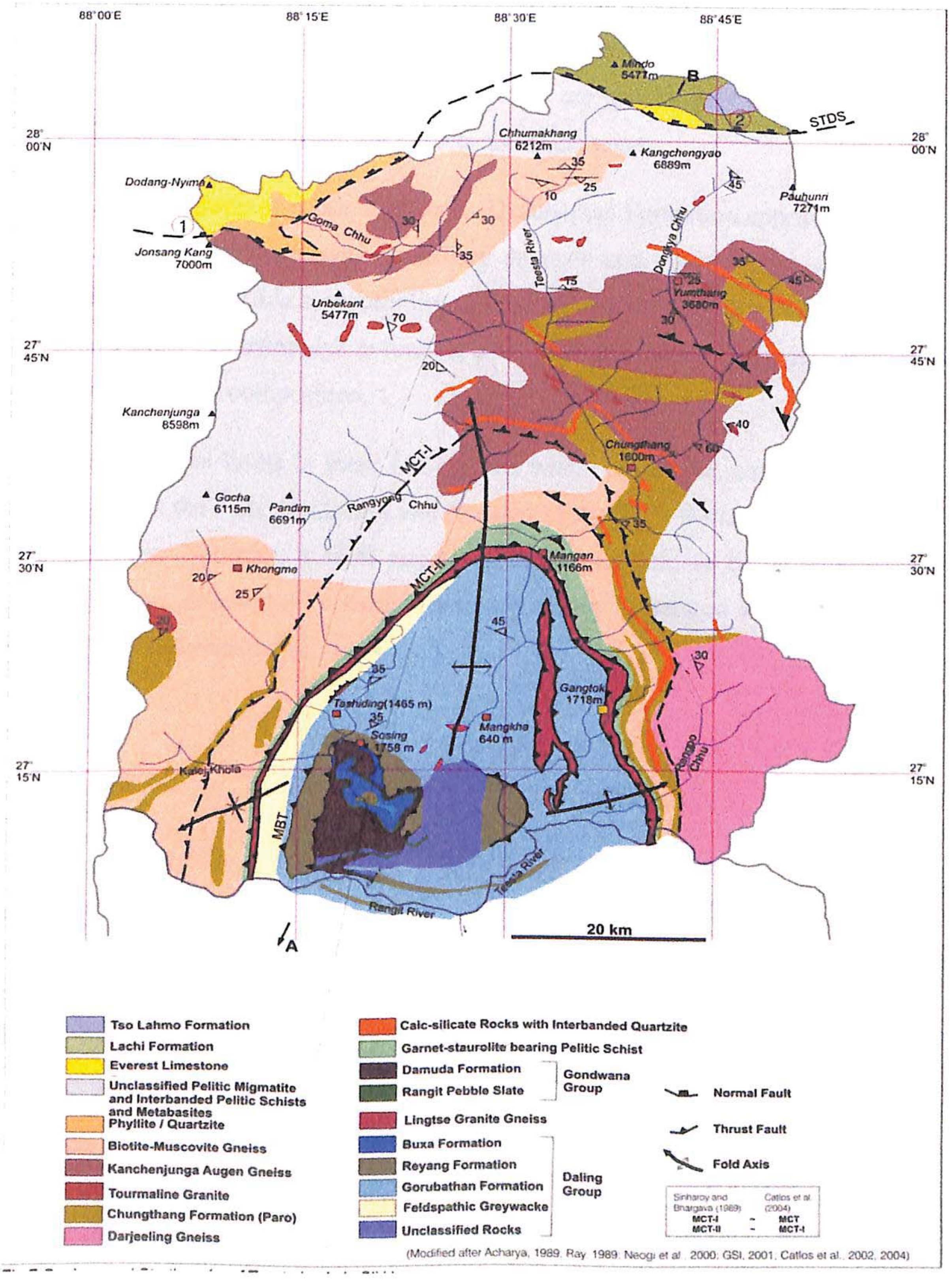
The different lithounits exposed in the area can be grouped into Darjeeling Group of rocks, Lingtse granite gneiss, Daling Group of rocks and Gondwanas. The Darjeeling Group of rocks comprises a sequence of ortho-quartzite, garnetiferous mica schist, calc silicate rocks and thin bands of gneisses supposedly equivalent to the Chungthang Formation and a thick pile of biotite gneisses (Darjeeling gneisses). The Daling Group of rocks comprises quartz-chlorite-sericite phyllite, muscovite-biotite phyllite, slates, quartzose phyllite and quartzites of Gorubathan Formation and dolomite, limestone and variegated phyllite of Buxa Formation (GSI).

Daling group of rocks are more susceptible to landslides because the boundary between Daling & Gondwana and Daling & Darjeeling group rocks is tectonised and thrusted and presence of faults in these formation, makes it highly vulnerable to hazards and ultimately one of the reason for high incident of landslides in this zone. Daling group of rocks are also highly susceptible to landslides because the rocks of Buxa & Gorubathan formation along with Gondwanas, form a tectonic contact with the overthrusted metamorphites of the Daling making it prone to high number of disasters including landslides. East district of Sikkim falls under Daling Group of rocks which covers the rocks of Buxa Formation, Gorubathan formation & Reyong Formation and that is why it much more susceptible to higher cases of in Sikkim.

At the contact of the rocks of Gorubathan Formation and Chungthang Formation, a thick horizon of streaky biotite granite gneiss is observed, which is described as Lingtse granite gneiss. Gondwana Group of rocks are represented by a basal pebble slate (Ranjit Pebble Bed) followed by coal bearing sandstone-shale horizons with occasional plant fossils equivalent to the Damuda Group of rocks of the Indian Peninsular shield. Systematic mapping reveals that most of the area is covered by the Daling Group of rocks and particularly by the rocks of Gorubathan Formation. The rocks of Buxa Formation occur as thrusted wedges along the thrusted contact of the rocks of Gorubathan Formation and Gondwanas, which form a tectonic contact with the over-thrusted metamorphites of the Dalings (GSI).

The contact between Gorubathan Formation and Lingtse granite gneiss is gradational whereas, the contact between Lingtse granite gneiss and Chungthang Formation is tectonised one, represented by intense shearing and mylonitisation of both Formations. The boundary between different rock units of the Dalings have been observed to be gradational except for some localized displacement and truncations whereas, the boundary between Gondwanas and Dalings and between Dalings and Darjeeling group of rocks is tectonised and thrusted (GSI report on "Potential Dolomite Horizons and Sulphide Mineralisation Zone in Buxa and Gorubathan Formation of Sikkim and West Bengal".

MAP 2.1.1: GEOLOGICAL AND STATIGRAPHICAL MAP OF SIKKIM



(Source: GSI, 2001)

The geology of Sikkim is mainly affected by the presence of MCT & MBT zones due to which the rocks are affected and leads to different forms of slides in the region. The MCT zone covers all the districts but not all the blocks. The vulnerability or Susceptibility to landslides increases or is greater in the zones which are geologically termed as active Fault zones and fractures, joints or folds, lineaments and shear zones.

The Daling Group of rocks, especially, Gorubathan Formation appears more prone to landslides then the inhomogeneous quaternary deposits and gneisses and schist of Higher Himalaya. The high landslide susceptibility of the Daling Group of rocks has been attributed to their severe shear distortion due to loading and unloading during or genesis, higher rate of weathering and mineral composition.

The presence of thrust faults in these MCT zones which covers the areas of Mangan in the North, Gangtok in the East, Gyalshing and Dentam in the West district, makes it vulnerable to these disasters. Naturally a fault zone is more susceptible to or capable of creating landslides because disasters like earthquakes are mostly generated along these fault line which also leads to landslide.

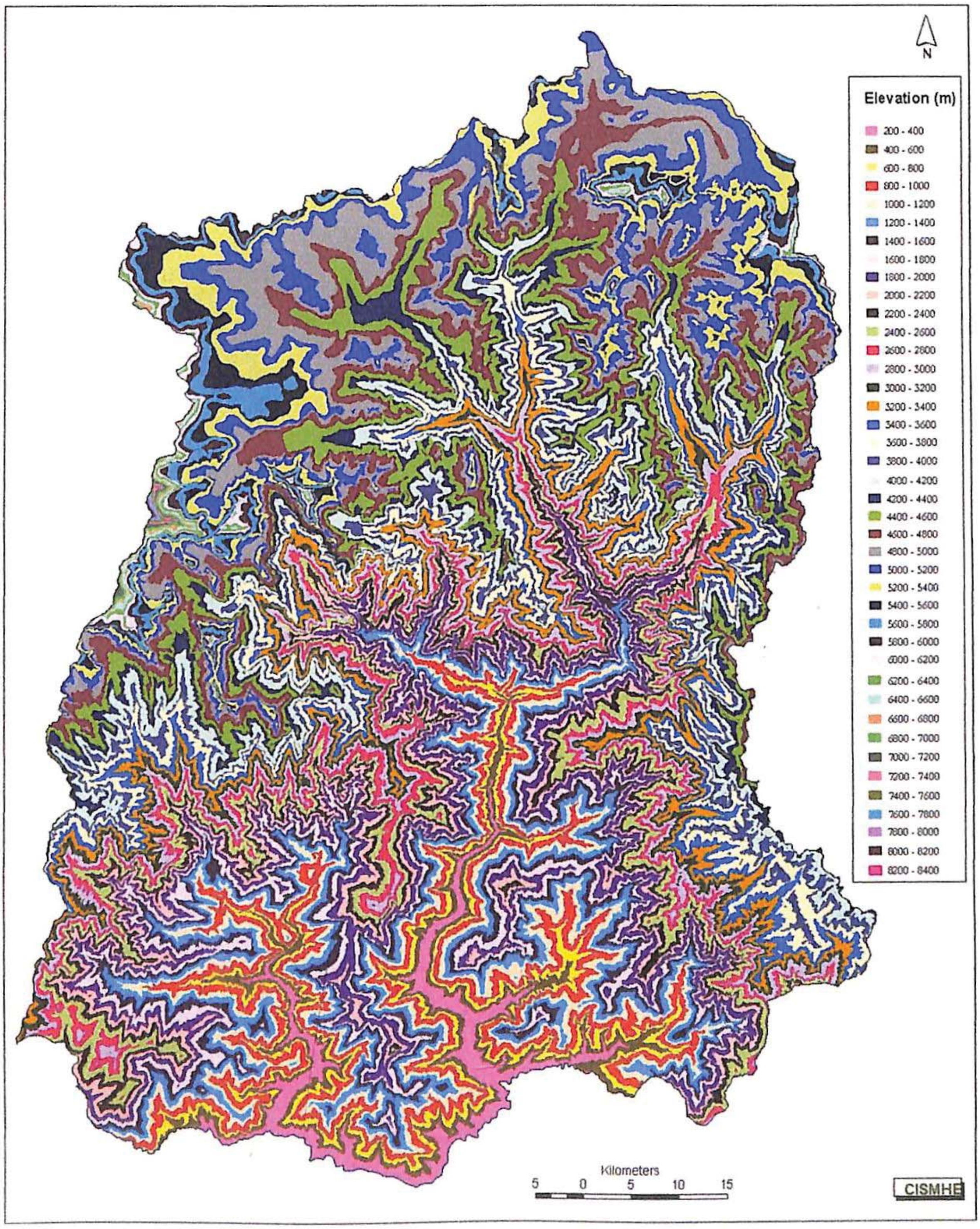
2.2 RELIEF, SLOPE & ASPECT:

The elevation in varies from 213 m to 8,598 m within distance of about 100 km (Map 2.2.1). Along the River descends from 5,280 m up to the confluence of Rangit River with it at Melli Bazar along its traverse of about 175 km. Therefore, the River flows in a gradient of about 29 m/km. Nearly 1/4th of the basin area lies in the elevation range of 4,000 to 5,000 m. As more than 59% of the catchment area of Teesta basin lies above 3,000 m, Teesta basin in Sikkim, therefore, can be classified as high altitude basin. Even the area between 2,000 and 3,000 m elevation range constitutes 16% of the total basin area. Only 25% of the catchment area lies below 2,000 m, whereas sub-tropical elevation constitutes only 6% of the basin. The predominant aspect in the basin is southern aspect followed by eastern aspects. Only 16% of the mountain slopes are north facing (CISMHE 2007).

The catchment of Teesta River basin in Sikkim is characterized by steep to very steep slopes (Map 2.2.2). As more than 52% of the basin lies in slope category above 27° i.e. steep to very steep slope class. As much as 10.32% of the catchment area is either rocky cliffs or are escarpments i.e. 65° and above slope class. The catchment area under moderately steep slopes category is only 8.61% of the total. Due to high relief features of the state induces instability on the slope and in this condition associated with rainfall and small seismic wave produces large number of landslides.

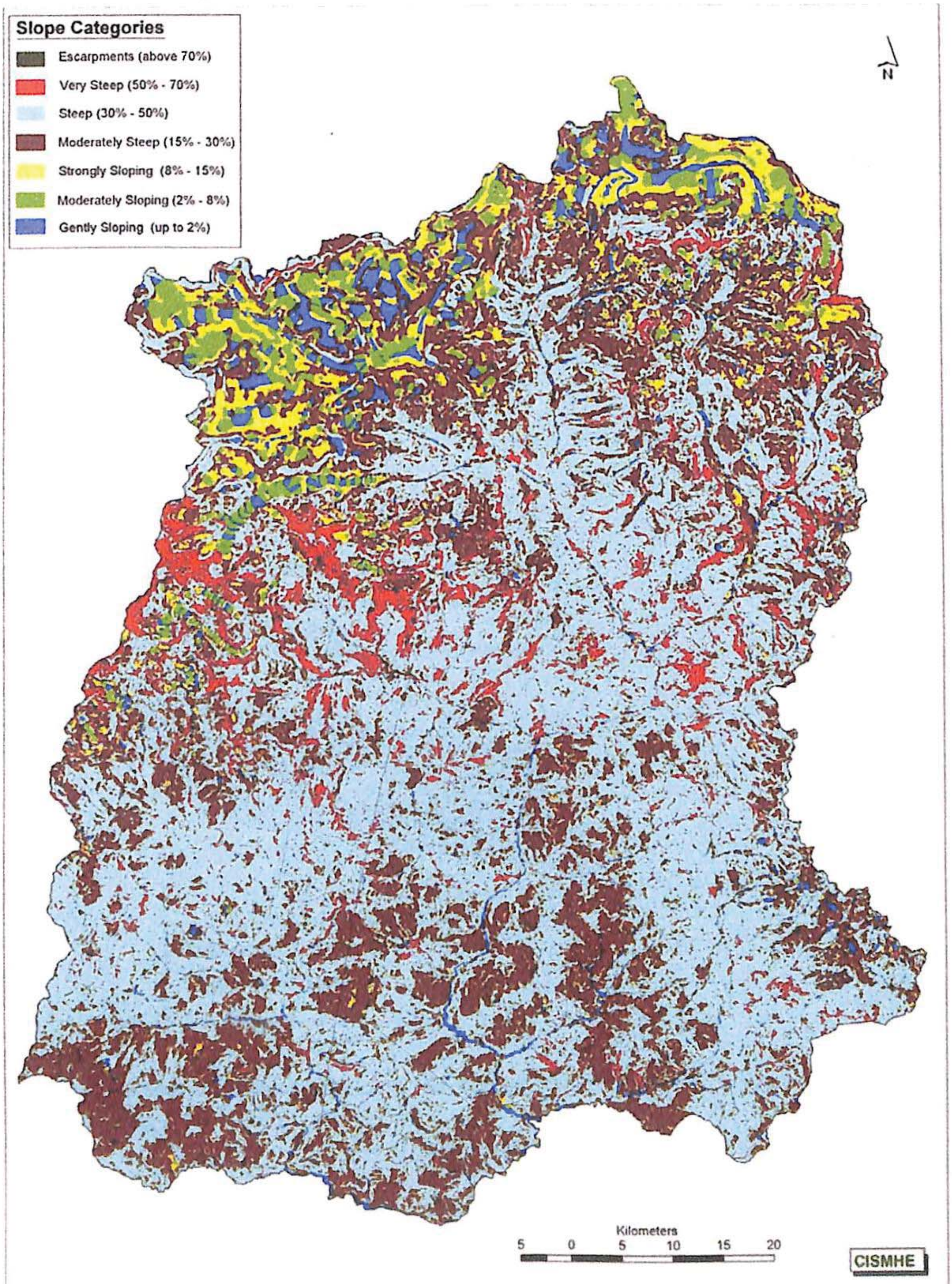
About 4.37% of the basin has area of gentle slope category. Maximum area under gentle slope category is recorded in Zemu valley followed by Chhombo-Chhu, both incidentally are the main sources of water in Teesta River. Zemu valley is characterized by 25 km long Zemu glacier descending from Kanchendzonga peak with steep to moderately steep in the initial stages and gentle gradient in the most of its stretch. Chhombo-Chhu also is characterized wide U-shaped glacial valley with moderately steep to gentle gradient slope near the source of Teesta River up to its confluence with Gayum-Chho near Oakra.

MAP 2.2.1: RELIEF MAP OF SIKKIM



(**Source:** CISMHE, 2007)

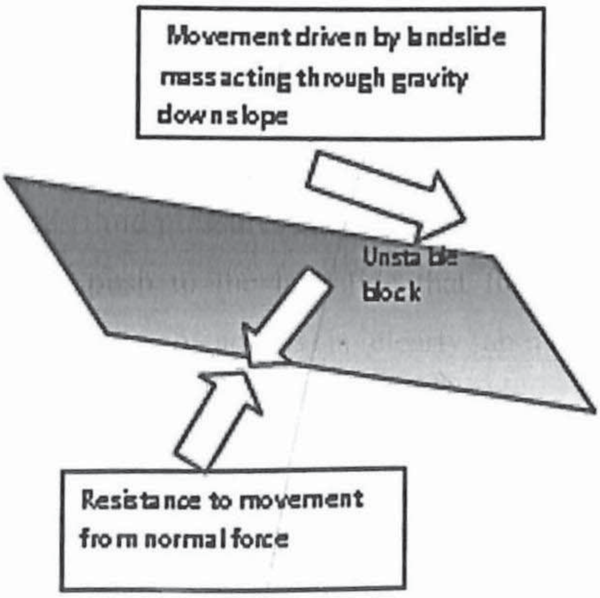
MAP 2.2.2: SLOPE MAP OF SIKKIM



(Source: CISMHE, 2007)

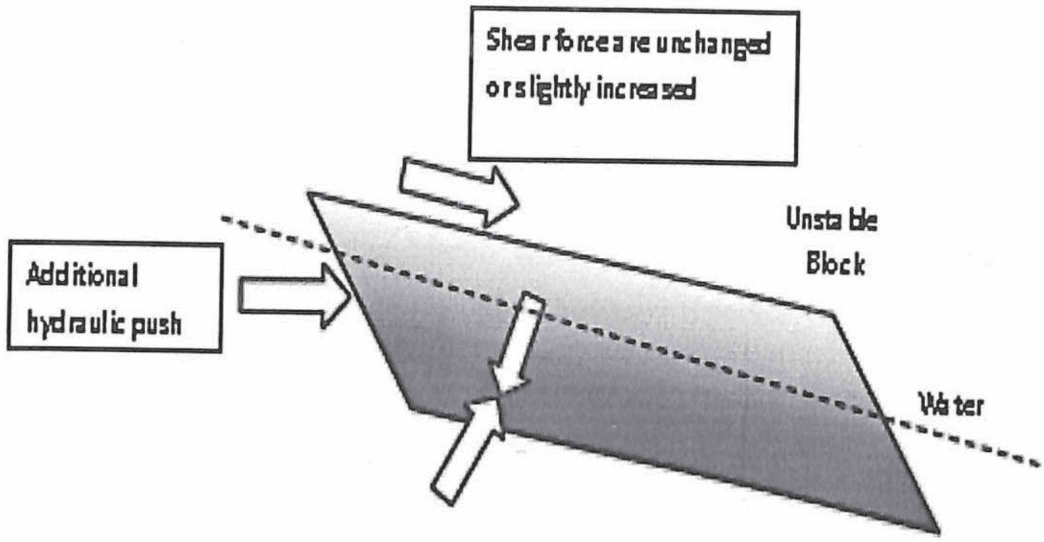
The figure A illustrates the forces acting on an unstable block on a slope. Movement is driven by sheer stress, which is generated by the mass of the block acting under gravity down the slope.

Resistance to movement is the result of the normal load. When the slope fills with water, the fluid pressure provides the block with buoyancy, reducing the resistance to movement. In addition, some cases fluid pressures can act down the slope as a result of groundwater flow to provide a hydraulic push to the landslide that further decreases the stability. Whilst the example given in figure A and B is clearly an artificial situation, the mechanics are essentially as per a real landslide.



A: Diagram illustrating the resistance to, and cause of, movement in a slope system consisting of an unstable block.

a) SLOPE RESITANCE



B: Diagram illustrating the resistance to, and causes of movement in a slope system consisting of an unstable block.

b) SLOPE RESISTANCE

In some situations, the presence of high levels of fluid may destabilize the slope through other mechanism, such as:

- Fluidization of debris from earlier events to form debris flows.
- Loss of suction forces in Silty materials, leading to generally shallow failures (this may be an important mechanism in residual soils in tropical areas following deforestation).
- Undercutting of the toe of the slope through river erosion.

2.3 CLIMATE:

The climate of the state has been divided into the tropical, temperate and alpine zone. The climate is cold and humid in most part of the year. The state receives heavy rainfall throughout the year in its most of the part. As compared to the heavy rainfall, the comparatively drier month is October-March when the rainfall is not at its extreme. The extreme northern part of the state, adjoining Tibet, however receives very little rainfall.

The mean annual rainfall is minimum at Thangu (82 mm) and maximum at Gangtok (3494 mm). An isohytal analysis of these data reveals that there are two maximum rainfall areas (i) South-East quadrant including Mangan, Singhik, Dikchu, Gangtok, Rongli, etc. (ii) South-West corner including hilly terrain. In between these two regions, there is a low rainfall area (around Namchi). There is an area in north-west Sikkim which receives less than 4.9 mm of rainfall.

Rainfall is heavy and well distributed during the months from May to early October. July is the wettest month in most of the places. Places with an altitude of 6065 m and above are snow bound and places as low as 3002 m come within the snowline in the winter. The temperature in the lower altitudes fluctuates between 4°-35° C and a place with moderate height (around 1829 m) such as Gangtok's temperature varies between 1°C and 25°C. In the high altitude area (above 3993 m), the temperature never rises above 15°C and slides down to the freezing point in winter.

In the majority of cases, the main trigger of landslides is heavy or prolonged rainfall. Generally, this takes the form of either an exceptional short lived event, such as the passage of a tropical cyclone or even the rainfall associated with a particularly intense thunderstorm or of a long duration rainfall event with lower intensity, such as the cumulative effect of monsoon rainfall in South Asia.

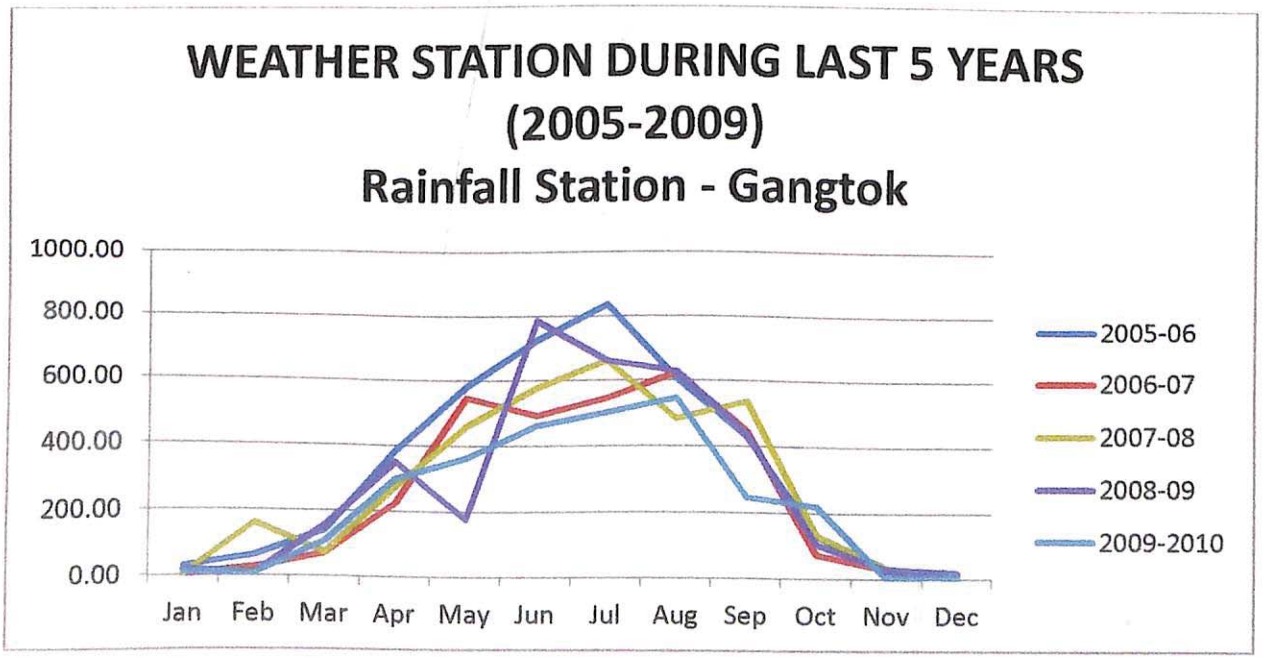
In the former case, it is usually necessary to have very high rainfall intensities, whereas in the latter the intensity of rainfall may be only moderate- it is the duration and existing pore water pressure conditions that are important. The importance of rainfall as a trigger for landslides cannot be under-estimated. Almost all the landslides in Sikkim occur after prolonged exposure to monsoon rains and occasionally during or just after cloudburst or precipitation intensity exceeding 135-145 mm in 24 hours. When soil get saturated from snow-melts or heavy rains the incident of landslides takes place at higher rate and that's why rainfall in Sikkim is one of the main triggering factor for landslide or slope failure's. Negative pore-water pressures start to increase when water starts to infiltrate the unsaturated soil (Tsaparas et al., 2002; Gasmo et al., 2000).

TABLE 2.3.1: WEATHER STATION DURING LAST 5 YEARS

TABLE 2.2.1: WEATHER STATION DURING LAST 5 YEARS (2005-2009)					
Station - Gangtok					
Rainfall					
Month	2005-06	2006-07	2007-08	2008-09	2009-2010
Jan	28.20	2.30	3.70	17.70	11.30
Feb	62.20	24.70	162.90	6.80	7.50
Mar	141.30	69.10	72.90	155.90	107.50
Apr	387.10	225.80	275.80	353.50	300.60
May	583.00	549.00	460.50	179.00	365.00
Jun	727.10	493.90	578.00	786.50	463.50
Jul	836.00	546.20	662.20	661.90	502.40
Aug	604.50	624.90	485.00	628.90	546.90
Sep	430.50	448.30	537.70	437.40	248.40
Oct	132.20	73.40	134.00	106.20	221.70
Nov	25.30	28.60	33.40	29.00	2.70
Dec	1.00	14.90	5.20	18.50	9.10
Total	3958.40	3101.10	3411.30	3381.30	2786.60

Source: Food Security and Agriculture Development Department of Sikkim (IMD)

GRAPH-2.3.1: RAINFALL VARIABILITY AT GANGTOK STATION



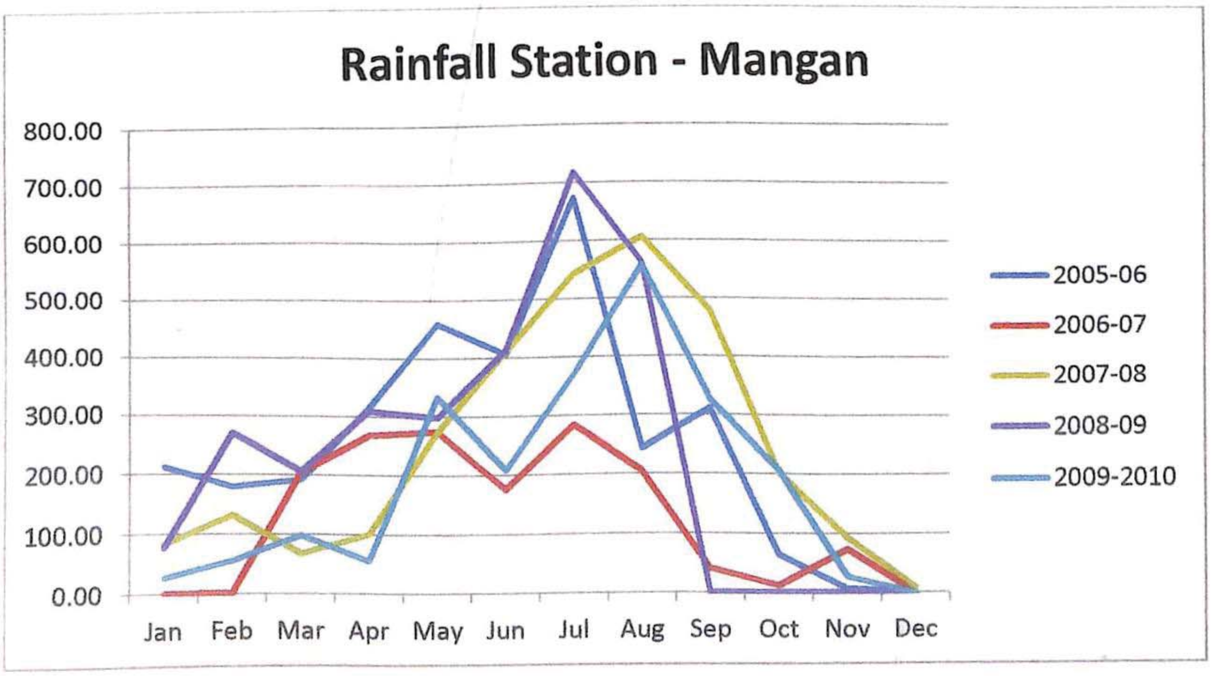
The record at Gangtok station shows that June and July has the highest rainfall in the region and the year 2005-06 has the highest rise in the month of July itself and the months like June, July & August has also the highest landslides incidents.

TABLE 2.3.2: WEATHER STATION DURING LAST 5 YEARS

TABLE 2.2.2: WEATHER STATION DURING LAST 5 YEARS (2005-2009)					
Rainfall Station – Mangan					
Month	2005-06	2006-07	2007-08	2008-09	2009-2010
Jan	213.00	0.00	83.80	78.30	27.20
Feb	180.40	2.00	132.50	270.70	55.40
Mar	193.00	205.40	68.20	207.00	98.90
Apr	314.60	268.00	101.20	309.20	56.20
May	459.20	274.50	273.90	298.70	333.30
Jun	406.70	177.60	411.40	413.40	209.10
Jul	674.00	284.40	544.00	718.50	369.90
Aug	243.60	205.50	607.00	562.40	558.40
Sep	311.30	41.20	480.10	0.00	326.60
Oct	64.70	12.30	203.40	0.00	206.90
Nov	6.60	74.00	93.30	0.00	26.90
Dec	0.00	0.00	9.70	0.00	0.00
Total	3067.10	1544.90	3008.50	2858.20	2268.80

Source: Food Security and Agriculture Development Department of Sikkim (IMD)

GRAPH-2.3.2: RAINFALL VARIABILITY AT MANGAN STATION



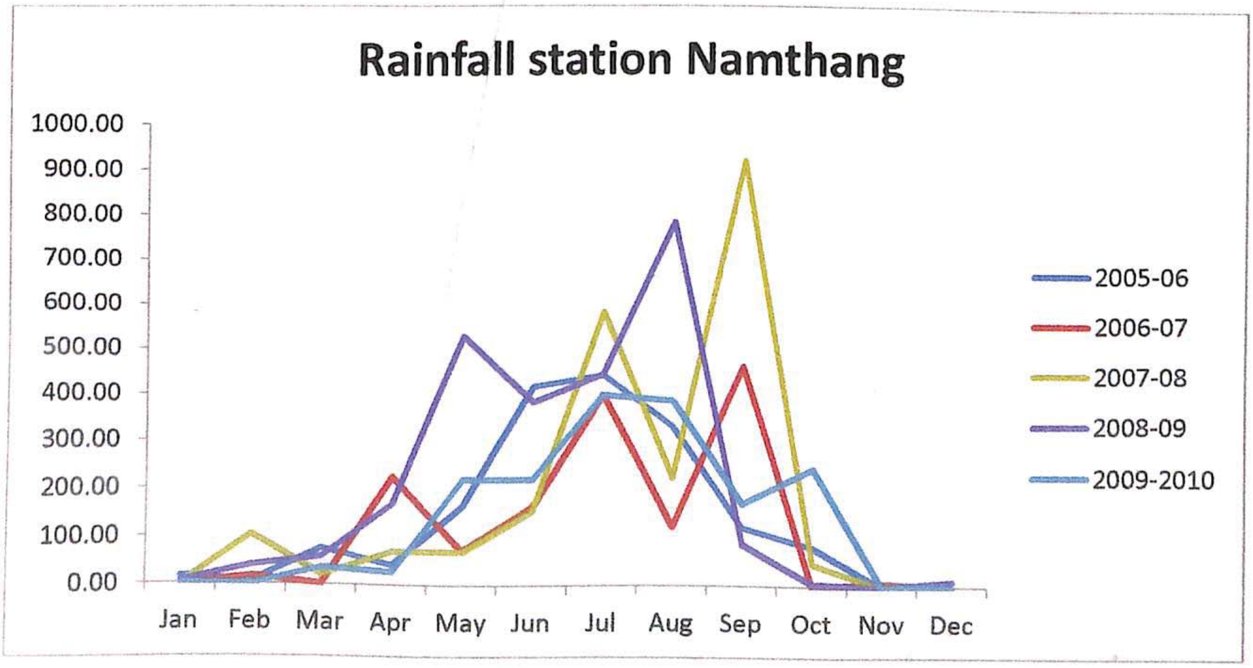
Whereas Weather station at Mangan shows that the month of July and August has the highest record in almost all the given 5 years. The year 2008-09 shows the highest rainfall in the month of July again.

TABLE 2.3.3: WEATHER STATION DURING LAST 5 YEARS

TABLE 2.2.3: WEATHER STATION DURING LAST 5 YEARS (2005-2009)					
Rainfall Station – Namthang					
Month	2005-06	2006-07	2007-08	2008-09	2009-2010
Jan	15.30	0.00	0.00	6.20	0.00
Feb	5.70	16.30	105.60	40.00	0.00
Mar	77.70	1.40	21.30	59.50	36.08
Apr	43.90	231.00	72.30	174.80	27.90
May	170.90	75.40	71.80	537.60	227.30
Jun	428.00	169.40	161.30	393.30	227.90
Jul	450.70	408.90	590.80	454.00	407.10
Aug	339.50	125.70	229.60	785.90	394.00
Sep	125.10	470.30	920.10	89.70	175.70
Oct	84.20	0.00	48.60	5.20	252.10
Nov	0.00	8.50	0.00	0.00	0.00
Dec	0.00	0.00	0.00	11.40	0.00
Total	1741.00	1506.90	2221.40	2557.60	1748.08

Source: Food Security and Agriculture Development Department of Sikkim (IMD)

GRAPH 2.3.3: RAINFALL VARIABILITY AT NAMTHANG STATION

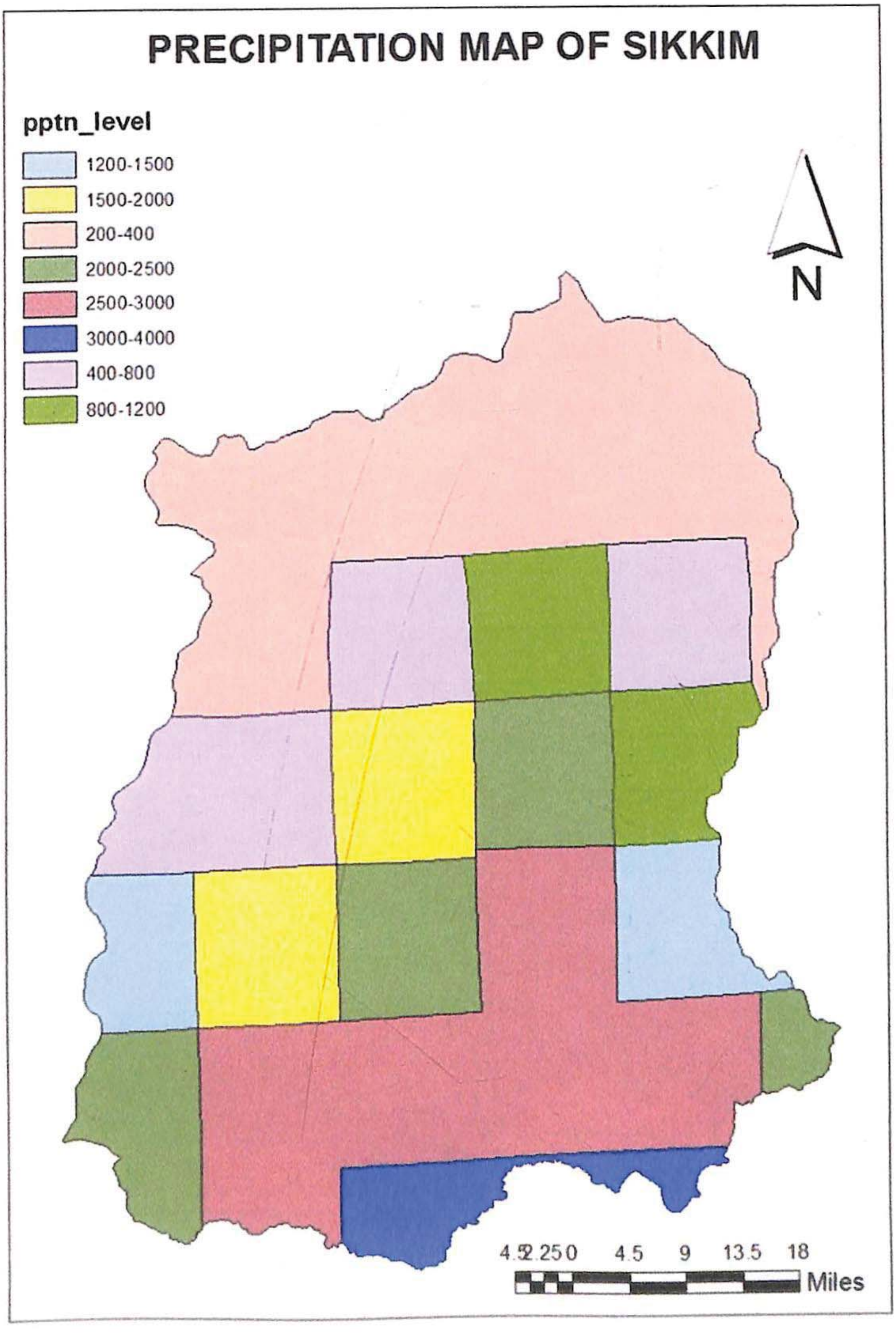


From the above graph 2.2.3, it is clear that the month of July, August and September has the highest rainfall record in the year 2006-07, 2007-08 & 2008-09. In rest of the years the rainfall is almost similar or varies at smaller rate. In Namthang station, South district, the year 2007-08 has the highest rainfall in the month of September.

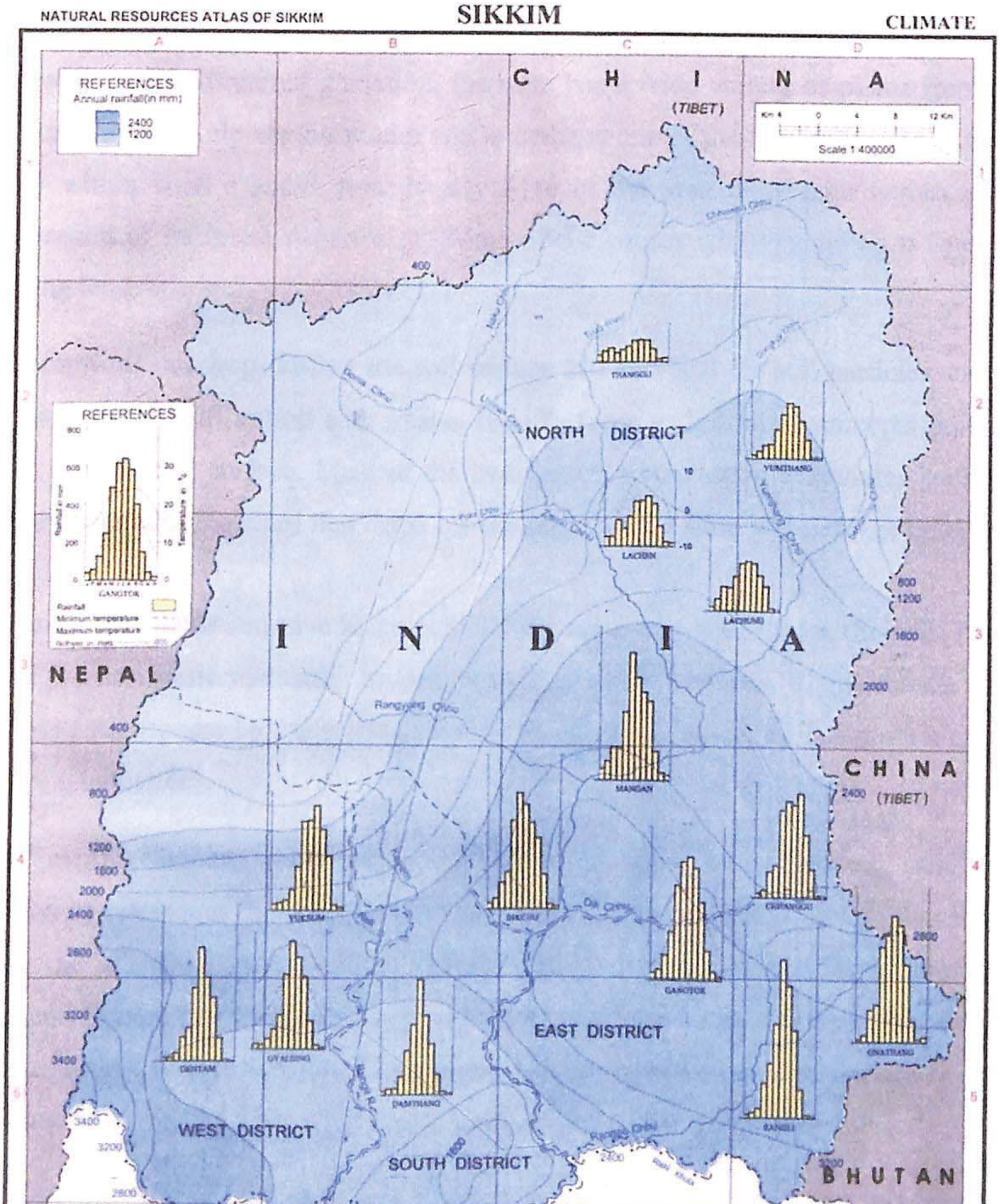
The red letter of October 1968 was considered the most disastrous in recent years of Sikkim history. It took the lives of 3300 people causing a widespread state of terror on the minds of the people. On 5th September 1995 heavy rain triggered off a mud avalanche near Gangtok killing 32 people. Similarly, non-stop heavy rain since early June 1997 damaged 300 houses completely, 1000 houses partially and caused death of 51 people in east and North District of the state. Rain, therefore, has been one of the main triggers besides weak geology; steep slopes with thick overburden, frequent earthquake etc., and causing landslides. So why does the rainfall trigger so many landslides? Principally, this is because the rainfall drives an increase in pore water pressure within the soil.

Below is the digitized precipitation map (2.3.1) of Sikkim, which clearly demarcates the area of high to low precipitation in the region. It varies from 3000-4000 (highest) to 200-400 (lowest) in this region and most of the settlement area falls under high precipitation areas due to which also the area is more susceptible to landslides. The precipitation level is highest in East Sikkim which makes it more vulnerable to the hazards like landslide.

MAP 2.3.1: PRECIPITATION GRID MAP OF SIKKIM



MAP 2.3.2: CLIMATE OF SIKKIM



Source: Atlas of Sikkim, NATMO, Kolkata, 2007

2.4 VEGETATION:

Sikkim is situated in an ecological hotspot of the lower Himalayas, one of three among the eco-regions of India. The forested regions of the state exhibit a diverse range of fauna and flora. Owing to its altitudinal gradation, the state has a wide variety of plants from tropical species to temperate, alpine and tundra and is perhaps one of the few regions to exhibit such diversity within such a small area. Nearly 81% of the area of Sikkim comes under the administration of its forest department. Some of the causes why vegetation is important in controlling landslide are:

a) Interception: raindrops hitting the soil surface can also seal the soil particles and make a crust that prevents infiltration and creates runoff. Trees and shrubs intercepts precipitation before it hits the soil surface. Most of the intercepted precipitation evaporates back into the atmosphere, and the moisture that drips off the plant causes little soil damage because it has less force.

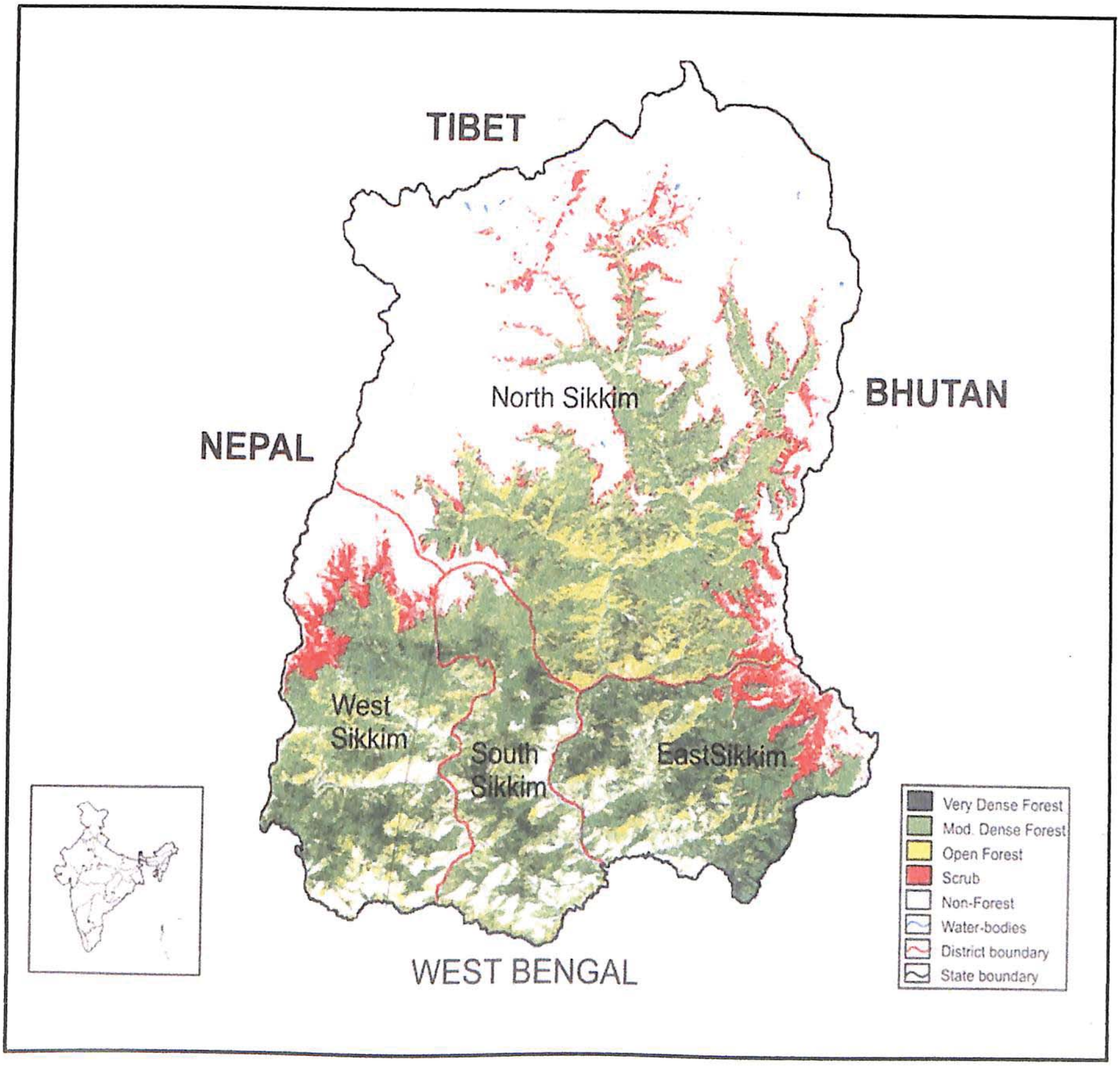
b) Dewatering: plants improve slope stability by removing water from the soil. Plants use water to perform basic metabolic processes such as photosynthesis. Plants release absorbed water to the atmosphere by transpiring through pores on the leaves. Soil saturation can trigger erosion and landslides.

c) Soil reinforcement: roots physically reinforce soils, resist erosion, and increase infiltration of water into the soil. Roots form physical pathways (little tunnel) that help water infiltrate the soil. Deep, woody roots lock the soil layers together and lateral roots connect many plants into an interlocking grid. Fine feeder roots form a network through the upper soil layer, preventing surface erosion. Trees possess better root than shrubs and are essential for slope plantings.

Vegetation actively de-compacts soil through the expansion of the root systems and the addition of organic matter to the site. Water absorbs more readily into un-compacted soil. Vegetation also encourages soil fauna to thrive (soil fauna such as micro-organisms). The cumulative impact of these organisms results in healthier soil that is more resilient during storm events.

Vegetation clearing by fires and logging also favors slope failures in the Himalayas and deforestation reduces the slope stability. Changes in the vegetative cover on steep slopes have increased debris-flow frequency (DeGraff, 1991; Guthrie, 2002).

MAP 2.4.1: FOREST COVER IN SIKKIM



(**SOURCE:** State of Forest Report, 2003)

2.5 ANTHROPOGENIC INTERVENTION:

Landslides are also aggravated by human activities and some of the human activities which cause landslides are deforestation, cultivation and construction which destabilize the already fragile slopes and increase the occurrence of this event in the environment. Vibrations from machinery and blasting process in the hilly terrain also increase the landslide activity. Blasting causes vibrations due to which there is instability of slopes and landslides occur.

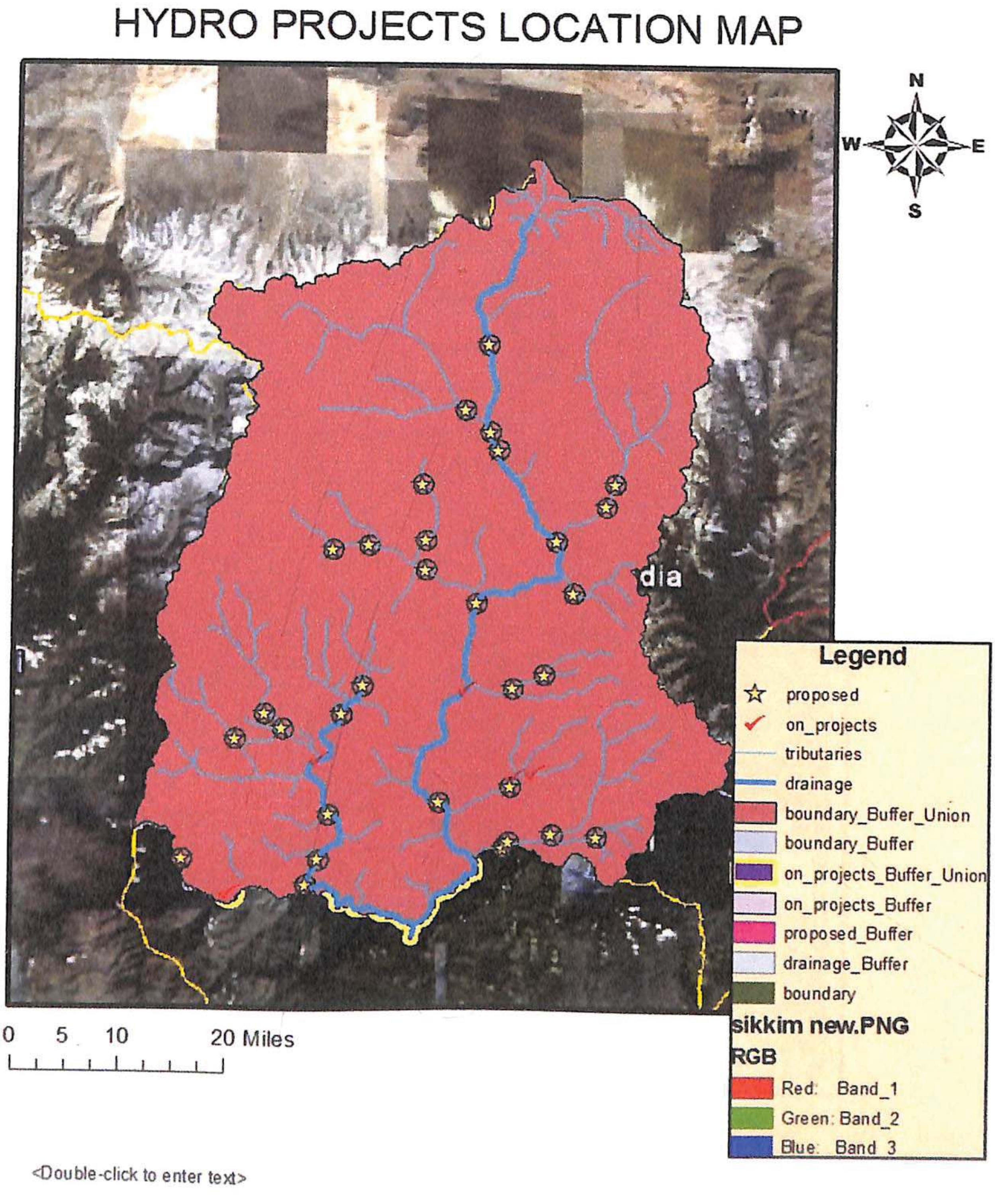
Earthwork which alters the shape of a slope or which imposes new loads on an existing slope is also one of the reasons behind the occurrence of landslide. In-shallow soils, the removal of deep rooted vegetation that binds the colluvium to bedrocks, which loosens the soils and moves down with some rocks in the form of landslide. Construction, agriculture or forestry activities (logging) which change the amount of water which infiltrates the soil is also one of the reason. All these factors together contribute in the occurrence of landslides due to human activities.

There are many human factors that cause or lead to landslide or its increase like:

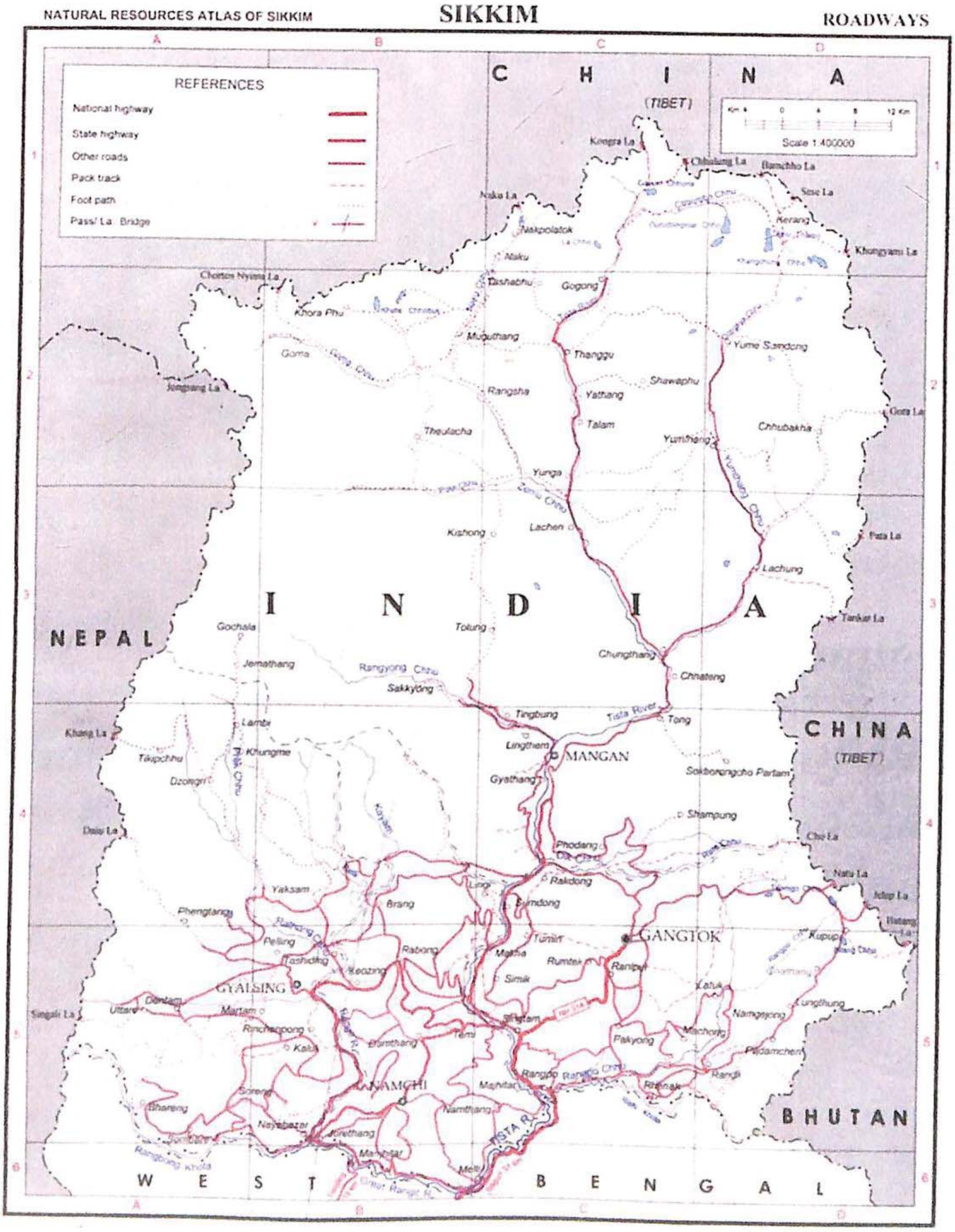
- Cutting and deep excavations on hill slopes
- Incongruous drainage system
- Drastic land cover changes and faulty land use patterns
- Destruction of natural vegetation which also includes deforestations

Humans are the cause for hastening landslides in many ways like removal of soil, deforestations, road networks, tunneling etc. Tunneling affects in a way that if basement of any hills or mountains are cut the chances of landslides increases in the area and it is one of the major cause of increase in cases of landsides in different parts of Sikkim Himalaya's.

MAP 2.5.1: ONGOING DEVELOPMENTAL WORKS IN SIKKIM



Map 2.5.2: National & State Highways of Sikkim & District Headquarters



Source: Atlas of Sikkim, NATMO, Kolkata, 2007

The above mentioned causes are some of the major categorized factors behind landslide occurrence in Sikkim and in general also, these all are common factors which influences the occurrence of this event in any area.

Chapter - III

Traditional Knowledge of Prevention of Disasters & Adaptability Particularly Landslides and Government Initiatives

Traditional knowledge is the innovations and practices of indigenous and local communities. Developed from experience gained over centuries and adapted to the local culture and environment, it is transmitted orally from generation to generation. Lepcha's of Sikkim are known to be the richest in traditional knowledge and practices in Sikkim and they have very strong believes on nature and they worship it.

They have different stories of each and every disaster in this part of the Himalaya and familiar with its impact, and that's why they are also familiar with landslides hazards and prefer to follow their own tradition and ways to cope during a disaster. There is no written document on the ways the Lepcha's used to adapt in different environment with all the different disasters and this knowledge is generally passed through oral representations but with time these traditional knowledge and practices are on the verge of extinction and getting affected, and so according to their opinion these developments and humans desire to extract more and more from nature, forcing them more towards vulnerability in a disasters or hazard which takes place in society.

This traditional knowledge of prevention is important for environment conservation and disaster management and is also important in the livelihood of indigenous people who often live in hazard prone areas. Traditional can be useful input in our attempt to face the defies posed by different disasters in the society so that casualties and damages can be reduced to much extent.

3.1 TRADITIONAL KNOWLEDGE OF PREVENTION

A disaster can be considered as a severe, relatively sudden and unexpected disruption of normal structural arrangements within a social system over which the system has no firm control (Mahbuba, 2004). It is also defined as a crisis situation that outstrips the capacity of a society to cope with (Anderson & Woodrow, 1989). A disaster occur when a significant number of vulnerable people experience hazard and suffer severe damage of their livelihood system in such a way that recovery is questionable without external aid (Davis I. et al., 1994). Social processes generate unequal exposure to risk by making some people more prone to disasters than others and these inequalities are largely a function of the power relations operative in the society (Vanaya & Ajeya, 2011). It is often argued that while hazards are natural, disasters are not.

Natural disasters are often region specific. The most common natural hazard taking place in the Himalayan regions is seismicity, landslide and flashflood. Sikkim and Uttarakhand the two seismically active zones in the Indian Himalayas has experienced several natural disasters from the past decade but the region battled these disasters due to their traditional knowledge and traditional way of construction and taking provisions from the landslides.

3.1.1 COMMUNITY BASE:

Environmental conservation and Natural Disaster Management is important in the livelihood of indigenous people who often and mostly live in the hazard prone areas and who have built up a immense body of knowledge over thousands of years of experience and bosom contact with the environment. This knowledge is exquisite resource that continues to contribute to environmental conservation and natural disaster management in these regions. The Lepcha's of Sikkim are a similar case, who has their own particular knowledge system. Lepcha folklore is rich with elaborate narratives which are often a reflection of scientific reality. They have similarities of tribal ethos with the numerous tribes of North-East India but their cultural and religious beliefs have a distinctive character. It is important to document all their knowledge as it highlights the complex traditional knowledge of an important group of people whose contribution to the general knowledge base has not been well recognized or appreciated. Such traditional knowledge is being lost at a rapid pace so their study is very important in the present day world. It is expected that traditional knowledge system of indigenous people of any region will have some distinct elements relating to pre-disaster preparedness.

Landslide is one of the main natural disasters in Indian Himalayan region which causes loss of life, property and environment quite frequently. The survey carried out by Joshi, V. (2011), in the states of Sikkim and Uttarakhand shows that even the people who cultivated lands in the vicinity of streams and rivers chose to settle down at the up sloppy location where the chance of being affected by these disasters was relatively low. The evidences indicated that temporary migration whereby the people having land interests in the river valleys, migrated to the uphill areas during the summer and returned only after the rains were over. This helped in warding off losses from the incidences of landslides and flashfloods. In order to avert mass movement in the event of exceptionally high rainfall event, these people restored to the maintenance of specially designed the excess water directly into the main stream and helped in maintaining pore water pressures within the threshold limit and avoiding mass movement. These structures were conceived, designed, constructed and maintained by the community without any external input and helped in saving these habitations at critical locations like construction of small network of drainage along the cultivated areas to divert the excess water and putting bamboo or wooden plank in to the outlet of spring which reduces the accumulation of water in the that area.

Sikkim being in the Indian Himalayan Region passes through some of the natural hazards as in other regions of Himalayas. Similarly, the experience of landslide in this state and mass movements at different locations are common. This is also due to the combinations of factors like dominant geological formation with fragile rock, as well as unconsolidated soil material with high intensity of annual precipitation/rainfall and steep slopes. The monsoon months play a crucial role in triggering these landslides along the roads as well as near the human habitations. "Generally the landslides are triggered or induced by rainfall but the cumulative effect of earthquake also triggers such events. These landslides are called as co-seismic landslides. The strong ground motion induced numerous landslides of rock fall type, overburden failures, slumps, debris slides, dislodgements, reactivation of old slide and ground fissures" (Joshi, et al. 2011).

Based on community knowledge Lepcha's of Sikkim has a very unique knowledge and beliefs regarding management of natural disasters. They are known to be one of the most cultured people having their own belief system and worshiping nature is the main focus of their culture. They share a distinctive character of their cultural and religious beliefs and are the most interesting story tellers about different disasters and their occurrences. For them disasters like Earthquake, Landslides, flashfloods as well as forest fires, all have different story and different way of coping mechanisms and mitigations. Based on their narrations some of the stories related to disasters are as follows:

I. STORY OF THE GREAT FLOODS

Lepchas have a very strong memory of flashfloods whose story they use to narrate as "The Great Floods" (Jha V et al., 2011). According to this story, the two major rivers of Sikkim- Rangit and Teesta happened to be husband and wife who in the ancient times eloped to get married. Once because of some misunderstandings they had a big quarrel between them. To surpass each other in vehemence they began to swell beyond themselves and the water in the river began to rise higher. Soon the entire Nye-ma-yel (Sikkim) was flooded and all animals and human beings cried for help, requesting the husband & wife to have pity on them and stop arguing but they paid no attention to the distress they were causing to others because of their quarrels and disagreement and kept on pouring their wrath on each other. With passing time within few days the situation became impossible and the villages situated in the lush green valleys as well as on the top of the mountains were now under water. The animals and the common folk panicked and ran towards the crest of the tall mountains.

Due to the continuous rise in the water level only mounts *"Tendong & Montom"* stood above water leaving all behind. They were known to be the brother and sisters and were unhappy about the plight of the innocent lives & decided to protect the poor animals and humans from the fury by taking them upon themselves. But the water was still rising & to keep others safe, brother and sister peaks rose higher and higher but what could be their limit? Both were exhausted and grew weaker with every passing time. The sister unable to withstand any more sank under the water and prayed to god to protect her dear brother. All the human and animals who had taken shelter on her were thus went under water. The death of her sister was a shock to him but could not afford to shed tears as it will increase the flood level. All of them who took shelter on him were frightened by the death of the other who died with mount *Montom* and they prayed to goddess Na-zong-nyo to come and protect them. She too was distraught by what she saw and knew that there is no point in trying to detain the fighting couple.

She called the blood pheasant and asked him to go and protect them. The blood pheasant perched on *Mount Tendong* and all eye looked towards him with hope. He thought for a while and then accepted the *Chi* (a local drink) from those trapped over the mountain. The *Chi* made him thirsty as never before and he dipped his beak in the flood water began to drink it. Everyone had a moan of relief as they noticed that the water began to recede. Soon the water went down further and with mountains, the lush green valleys and the Lepcha villages that were submerged emerged. The blood pheasant stopped drinking water only after seven days and till than it was normal everywhere. Teesta and Rangit stopped quarreling and were ashamed of their foolish behavior. This story underlines another vital and important disaster management tenet that- *It is up to the Individual to know what to do in an emergency and for that some knowledge and awareness about the disaster or the event is very necessary.*

It would not be wrong to say that disasters in Lepcha culture have been traced back to evil intents of human beings. The stories and interpretation clears that individual always behave aptly and conscientiously to avoid causing disasters. There is no doubt that this approach helps them to promote a strong social fabric and effectively neutralizes the selfish, malicious and wicked impulses of individuals, leaving aside the scientific legitimacy of such a belief. In general view it is also believed that corruption is also a way which results in framing or forming disasters.

In fact Ravenousness, Sleaze and misuse leads to disasters and not only this but it also compromises our ability to manage disasters. Most of the disaster management efforts remain just a subterfuge because of intrinsic human flaws. Hence their relationship with disaster is not a figment of imagination but a sad reality. There are several examples (Anonymous, 2010)- of how corruption can harm those affected by disaster, including aid workers exchanging food for sex in West Africa, survivors of the Tsunami in Aceh losing their homes when contractors built them without foundations and village chiefs diverting foods from the most vulnerable in India in 2001. Most recently in Pakistan the greatest challenge to flood relief that hit the country in 2010 was posed by the prevailing corruption in that beleaguered country. And such a similar Lepcha interpretations according to them explains that corruption and covets of human beings lead to disasters whose after affects are intolerable and which creates wrath for life and property.

II. STORY OF EARTHQUAKES

According to one of the traditional stories (Gorer, 1996), once there lived seven brothers with seven wives, seven daughters, seven sons, seven daughter-in-law and seven son-in-laws and they had to work hard day and night for their survival and food. Yet their widowed sister along with one daughter lived in prosperity not far away. The brothers and their wives grew very jealous of her and decided to kill the sister and her daughter and take away her property. They attacked the helpless sister and chopped her into pieces. The sister was a powerful *Mun* (priestess) and hence she was able to rearrange her all her parts into coherent whole once again. She tells her daughter everything and tell her not to resist her maternal uncles when they came to take away her property. The uncles did just the same, leaving only one hen and a calf for her daughter. The dead sister, meanwhile, entered a cliff and prayed to divine for revenge and her prayers were answered too. Seven days later a handsome man came and married her daughter and they began to live happily. For the seven brothers and their families, however, they suffered a year of disaster and all but two sister-in-laws died. Even these women suffered from disease and soon died. Since then the Lepcha's believe that one should not show off his/her or wealth as otherwise *Ginoo Mung* (the ghosts of seven brothers and their families), invoked by jealousy of others would play havoc in their lives. *Ginoo*

Mung is in a way is incarnation of other people's envious thoughts. Similarly the jealous and malicious ones also go through a year of disaster as a divine punishment for their wicked thoughts.

According to one of the version of this story it is encountered that, once the invocation by the dead sister inside the cliff was over, an earthquake ensued, destroying the evil brothers and their village. Thus, earthquakes too are believed to be caused by the evil acts of human beings according to the Lepcha people.

Above all stories shows the practices and customs of traditional people and knowledge in ancient times and how they used to follow their instincts and beliefs to cope up from natural and man-made disasters. Another story which forms the base of landslide in ancient times and which is narrated by the Lepcha's quite often is:

III. STORY OF LANDSLIDE

According to the folktale of Lepcha's, a male Rhododendron Tree once fell in love with a lady *Utis Tree* (Himalayan Alder) and approached her father to marry her (Vanaya et al., 2011). But he was refused by her father because Rhododendron tree was very dwarf and shabby looking. The Father rebuked him and took a promise that he will never come up again with this proposal. This incident happened in autumn and he sadly returned home. A few months passed and it was time for spring season. The father called her daughter and told her about the shabby Rhododendron tree and laughed a lot but the daughter did not shared her sentiments and she went looking for the rejected suitor. She was surprise to see the view which was in front of her. There stood the Rhododendron tree with full bloom and heavenly looking. Lady *Utis Tree* fell in love with him and begged him to marry her but the Rhododendron tree told her that he has promised to her father and now he cannot marry her. The Lady *Utis Tree* was crestfallen and in intense agony she jumped from the mountain and died. Since then the Lepchas believe that the *Utis Tree* grows in landslide prone areas and the Lepchas repeat this story every time whenever an *Utis Tree* is swept down in landslide.

This knowledge about the *Utis Tree* which grows in the landslide prone areas and which trees grows in these areas, can be useful to control the landslides by planting herbaceous plants rather than hardwood trees over fresh landslides. Once these plants hold root and its topsoil, progressively hardwood plants can be planted to convert the landslide area into a forested area.

In Sikkim, the local dwellers utilized the soil binding plant species in mitigation of landslides. They know which plant is suitable for stabilization of land and so still in many parts they follow the same practices which have been trailed from earlier times.

Thus traditional knowledge is as helpful as the scientific one and the merge of both the knowledge could bring drastic changes in coping up with natural disasters and will help communities to overcome from it at a rapid pace.

Preparedness is generally level of awareness and alertness about any disaster in an area. Mitigation includes any activities that prevent an emergency, reduce the chance of an emergency happening and lessen the damaging effects of unavoidable emergencies.

The indigenous method of preparedness and mitigation was quite different and valuable in its own world. The way people use to mitigate and prepare themselves for disasters were based on their own knowledge and observation and it is expected that in any region people have some discrete elements relating to pre-disaster preparedness based on the traditional knowledge.

The Lepcha people possess knowledge of the annual timing when the natural disasters are expected to occur. Like according to them, a drought is related to rainless winter and hailstorms happens in March. Similarly Landslides and Flashfloods occur during the monsoon season (June to September) and so on. It is not surprising to hear that wild animals have evolved to respond to their natural environment, coping with seasonal flooding, wild fires, landslides and earthquakes. The Lepcha people believe that the behavior of various pheasants, cries and nervousness, as displayed right before a major earthquake is an important indicator. Likewise landslide prone areas can be identified easily by them through visual scrutiny, and they know well not to construct houses in landslide zones.

The strategies of the Lepcha's to overcome or to mitigate the after effects of a disaster can be identified through their living adjustments. They construct their houses of timber and these houses are known to be quite stable during earthquakes. Even if such houses break they do not result in loss of lives. This could be or probably one of the reason why earthquakes in the modern settlements tend to create huge damage with heavier house construction than in traditional Lepcha settlements. In order to avert mass movement of exceptionally high rainfall event, these people restored to the maintenance of specially designed the excess water directly into the main stream and helped in maintaining pore water pressures within the threshold limit and mass avoiding (Rautela & Thakur, 1999). These structures were conceived, designed, constructed and maintained by the community without any external input and helped in saving these habitations at critical locations.

The farmers are conscious that the increased accumulation of water in the terraces might exacerbate the problem of landslides by increasing the degree of soil saturation and adding the wait of the ponded water itself (Johnson et al., 1982; Ives & Messerli, 1989). The role of vegetation cover in reducing the effect of landslide and also checking the pace of mass wastage is well recognized by the people of this region and to some extent they do follow it so that number of cases can be reduced and life could be saved. Keeping this in mind, people have restricted some of the places of forest for pruning for local use, while at other places they resorted to rotational pruning of forest cover at critical locations. These people even resorted to divine endorsements by devoting these forests to local deities. The local dwellers here utilized there the soil binding plant species in mitigation of landslides. They know very well that which plant is suitable for stabilization of landslides in the area. One of the important plant species used for binding the soil is also utilized for local broom named *Amliso* (*Thysanolaena Spp*). Other plant species which is which in soil binding processes are *bamboo, Young shoots or Tama* (*Dendrocalamus Spp*), *Utis* (*Alnus Nepalensis*), *Phalado or Amacisa* (*Erythrina Spp*), and *Kadam* (*Jatropa curcas*), etc. which helps in stabilization of soil to a great extent. Plantation of *Amliso* is mostly preferred by the community because it is also utilized for making brooms and used for commercial purposes and the good thing about this plant is that it can be grown whole year without any interference.

The resource use of the communities is governed by the local community level management as well as by the government departments and this help them to balance everything but with time these many aspects has been changed and people are moving towards more advanced society ignoring the ill effects and nature's wrath to some extent and are now forced to face the unavoidable situations. Lepcha traditional knowledge of disaster indicators is bounteous and can be used in the direction of mitigation to overcome the effects of various disasters including landslides and which can help people to identify proper areas for settlement and living their life lessening the damages during and after a disaster in their area and also saving life and properties together.

It is also true to say that the impact of any disaster or hazard on communities not only affects human life and property but also cause huge devastating damage to the agriculture commodities, livestock's, crops and businesses associated with these areas including the transport and communication system very wildly. Adding to it, it would not be wrong to say that small communities lack in the emergency or response resources or is limited to them, so in the event of a disaster or emergency situation, individual, business or community may need to be self-sufficient for a while until the further assistance from local, state or federal agencies can be obtained. These efforts will help to minimize the impact and protect you during disasters.

This may be the one reason why the Lepcha communities use to follow their traditional knowledge which make them one and help each other during emergency. Their culture and belief fosters a spirit of unity, harmony and camaraderie that is so essential for disaster management. Mitigation such as planting ground cover (low growing plants) on slopes or installing flexible pipe fitting to avoid gas or water leaks will help to reduce the impact of landslides and mudflows in the future and investigation in these fields are prime call of the time.

At the end it can be concluded that their (Lepchas) knowledge is local, practical, empirical and scattered in nature. It is embedded within pre-existing partial systems, tradition and culture, therefore justified and static but loaded with values, symbolic, subjective, ethno-scientific & humanitarian and biased to some extent. Often technical and rational parts are highly overlapped with non-technical and non-rational parts.

PLATE 1: *Amliso*/Broom (*Thysanolaena Spp*)

3.2: GOVERNMENT INITIATIVES:

Government has taken many initiatives for the mitigation and prevention of disasters in Sikkim. In the year 2005, the State government has taken initiative and led the foundation of State Disaster Management Authority under Disaster Management Act, 2005. The government has built many bodies to take care of the disaster at different levels and these bodies are further divided into small groups to control it in a better way. Government has also started District Disaster Management Authorities and for helping them in a more systematic way further Village level authority has been started. Allocation of funds to these authorities and establishment of early warning system has also done. Mock drills and Awareness programs are also introduced by the government for helping these authorities so that they can further help the next level authorities for the proper manage of disasters and injured people's during disasters.

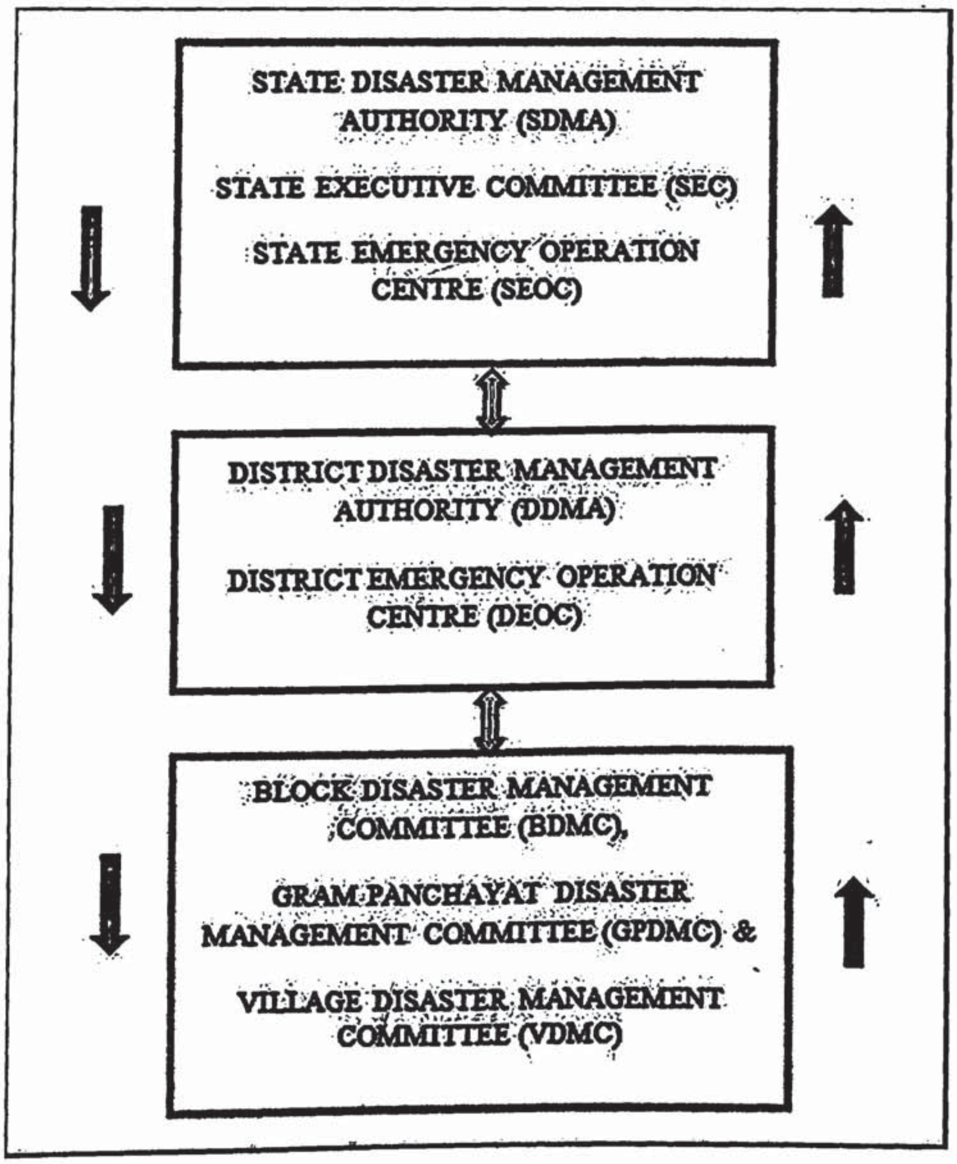
Remedies like retaining structures, sub-surface water including the pore pressures, nailing, and afforestation, commonly practiced by the government for improving the stability of slopes.

3.2.1 STATE DISASTER MANAGEMENT PLANNING (SDMP, 2010-2011):

Land revenue & Disaster Management Department is nominated as the department responsible for the planning and coordinating state government's physical assistance to the state and territories.

The State Disaster Management arrangements are based upon partnerships between State and Local governments. These partnerships recognize that each level of the disaster management arrangements must work collaboratively to ensure the effective coordination of planning, services, information and resources necessary for comprehensive disaster management.

The SDMP tier's disaster management arrangements are based on bottom to top approach i.e. local, district and state level. The tier system enables a progressive escalation of support and assistance among all the three levels so that at all the levels communities can be helped in coping with any kind of disasters and also help them to overcome and educate about a particular disaster or hazard to which the society is much vulnerable.



The arrangements comprises of several key management and coordination structures. The principal structures that make up the arrangements are:

(A) Disaster management committee operates at local, district and state level. The committee is responsible for planning, organising, coordinating and implementing all measures required to mitigate, prevent, prepare, respond and recover from disasters.

(B) Emergency Operation Centres at local, district and state level supports disaster management groups while coordinating information, resources, and services necessary for disaster operations.

(C) State government functional agencies, SDMA and SEC, are responsible to coordinate and manage specific threats and provide support to Disaster district on and as required.

1. Different Bodies:

The state has developed some policies regarding disaster management in Sikkim and implementation of the same is very necessary on the ground level. Developing and implementing an effective early warning system requires contribution and coordination of a diverse range of individuals and groups. The groups that will be involved in early warning systems are:

Communities: They should be actively involved in all aspects of establishment and operation of early warning systems. They should be aware of the hazards and potential impacts to which they are exposed, and should be able to täke actions to minimize the threat of loss or damage.

Local governments: local government will have considerable knowledge of the hazards to which their communities are exposed and be actively involved in the design and maintenance of early warning systems.

Non-governmental organizations (NGO's): NGO's will be involved in raising awareness among individuals, communities and organization's involved in early warning, particularly at the community level. They will also assist with implementing early warning systems and in preparing communities for natural disasters.

The private sector: They play an important role in early warning, including developing early warning capabilities in their own organizations. The media plays a vital role in improving the disaster consciousness of the general population and disseminating early warnings. The private sector also can provide skilled services in the form of technical manpower, know-how or donations (in-kind and cash) of goods or services.

The science and academic community: They play a very critical role in early warning. They can provide specialized scientific and technical input to assist governments and communities in developing early warning systems. Their expertise is central to analysing natural hazard risks facing communities, supporting the design of scientific and systematic monitoring and warning services, supporting data exchange, translating scientific or technical information into comprehensible messages, and to the dissemination of under-stable warnings to those at risk.

2. Emergency Operation Centres:

Emergency Operation Centres in the state are as follows:

a. Local Emergency Operation Centre – LEOC

b. District Emergency Operation Centre – DEOC, and

c. State Emergency Operation Centre – SEOC.

Responsibility to respond to an event lies with the local committee, coordinated through the LEOC. Requests and confirmation about resources and passage of information are passed between emergency operation centres to support the disaster management committees. These clear lines of communication allow for an effective and measured response to a disaster event.

a) Local Emergency Operation Centre (LEOC):

LEOC may be permanent or temporary facilities provided within each local government area or combined local government area to support the local committee during disasters. Each LEOC is responsible to provide prompt and relevant information to the DEOC concerning any disaster event or potential disaster event occurring within their area. These centres are also responsible for the coordination of all local resources as well as those allocated to it for disaster management purposes.

In particular, LEOC is responsible for:

i. Collection, collation and dissemination of information to the DEOC, relevant local agencies and officers, and the public.

ii. Implementation of operational decisions for the Chair of the Local Committee and

iii. Coordination of available resources including those allocated from the State Government and Disaster district, in support of the disaster affected community.

b) District Emergency operation Centres (DEOC):

DEOC may be permanent or temporary facilities provided within each District to support the District Authority during disaster events. Each DEOC is responsible to provide prompt and relevant information to both LEOCs and the SEOC concerning any disaster event occurring within their District. These centres are also responsible for the coordination of all local and state resources within their district and those allocated to it for disaster management purposes.

In particular, a DEOC is responsible for:

i. Collection, collation and dissemination of information to the SEOC, relevant Local government Disaster EOC, and the public

ii. The provision of advice to the Chair(s) of relevant Local Committees

iii. Implementation of operational decisions of the Disaster District Chair, and

iv. Coordination of allocated Local, District and State government resources in support of the disaster affected community.

c) State Emergency Operation Centre (SEOC):

SEOC has a small permanent cadre staff and a continuous Duty Officer system to monitor events within the State on behalf of the State Authority. When activated in support of disaster-affected communities, the SEOC establishes communication with relevant DEOC for the purpose of coordinating necessary information and resource support. The SEOC provides 'situational awareness' of disaster events to the State Government and is accountable to the State Executive Committee.

The functions carried out in the SEOC include the:

i. Collection, collation and dissemination of information to the State government, the Minister for LR&DMD, the Chair and members of the SEC, Disaster districts and the public.

ii. Provision of advice to the Disaster District Chair and Chairs of Local Committee, and

iii. Coordination of District and State Government resources in support of disaster affected communities.

The occurrence of disaster would essentially bring into force the following functions:

- The EOC will be on full alert. The EOC can be expanded to include branches with responsibilities for specific tasks.
- An on-going VSAT, wireless communication and hotline contact with the relief commissioner and collector/s of the affected district/s.

3. Arrangements at all the three levels to coordinate during disaster:

State, District & Local level arrangements has been made by LR & DMD to handle the disaster related queries and management in a systematic way so that at all the three levels it will be easy to communicate and knob with each other.

A) Arrangements at local level:

The arrangements are flexible and scalable, enabling escalation of support and assistance through the local, district and state government arrangement as required. Within the arrangements, it is at the local level that manages disasters within their own communities. State and district levels are to provide additional resources, support, assistance and expertise as required. Local government is the key management agency for disaster events at local level. Local government provides specific disaster management at community level giving its knowledge and understanding of social, environmental and economic issues at the local level.

Local government achieves coordinated disaster management approach through "Local Disaster Management committees".

b) Arrangements at district level:

Sikkim has four districts; each of these districts has a District Disaster Management Authority (DDMA), to coordinate regional level whole-of-government support for disaster events.

c) Arrangements at State level:

The State group is the peak policy and planning group for disaster management in Sikkim. It is established under the Disaster Management Act 2005, section 14, as the principal organization for the purposes of disaster management throughout the State. In particular, the State group is responsible for disaster mitigation and disaster planning and preparation at a State level and for coordinating whole-of-government response and recovery operations prior to, during and after an event. This includes accessing inter- district and state government assistance when local and district resources are exhausted or not available.

3.3 ROLE OF MEDIA:

During Disasters media will play a major role to lead to appropriate individual and community action, which is the key to implementing effective prevention strategies including evacuation and survival of people. Such communications can educate, warn, inform, and empower people to take practical steps to protect themselves from natural hazards. The role of media, both print and electronic, in informing the people and the authorities during emergencies thus, becomes critical, especially the ways in which media can play a vital role in public awareness and preparedness through educating the public about disasters; warning of hazards; gathering and transmitting information about affected areas; alerting government officials, helping relief organizations and the public towards specific needs; and even in facilitating discussions about disaster preparedness and response. During any emergency, people seek up-to-date, reliable and detailed information and media will play key role to provide the correct information.

It is also central to check that a communication network between different disaster agencies should be ensured for effective co-ordination of procedures and operations for preparedness, response and recovery plan. Additionally, dissemination of relevant information to enhance community information and preparedness is necessary for mitigating the potential impact of a disaster upon the community.

Spatial variation is the variation across the landscape that is normally associated with populations. Factors causing geographic variation include geologic differences that affect the soil type, and thus habitat and weather patterns, e.g. differences in rainfall across the landscape. Or it can be said that spatial variation in geography means pertaining to space on the earth's surface. Whereas Temporal Variation is the function of time and which varies from year to year or decade like coastline erosion or depletion of natural resources.

This chapter deals with these two variations i.e. over time and space. How one area differs from other over space and over different time period is being discussed below over 15years of duration. These data were collected from the daily local Newspaper i.e. 'Sikkim Now' from the year 1999 to 2013.

Spatial Variability occurs when a quantity that is measured at different spatial locations exhibits values that differ across the locations.

Chapter - IV

Temporal and Spatial Variability of Landslides in Sikkim

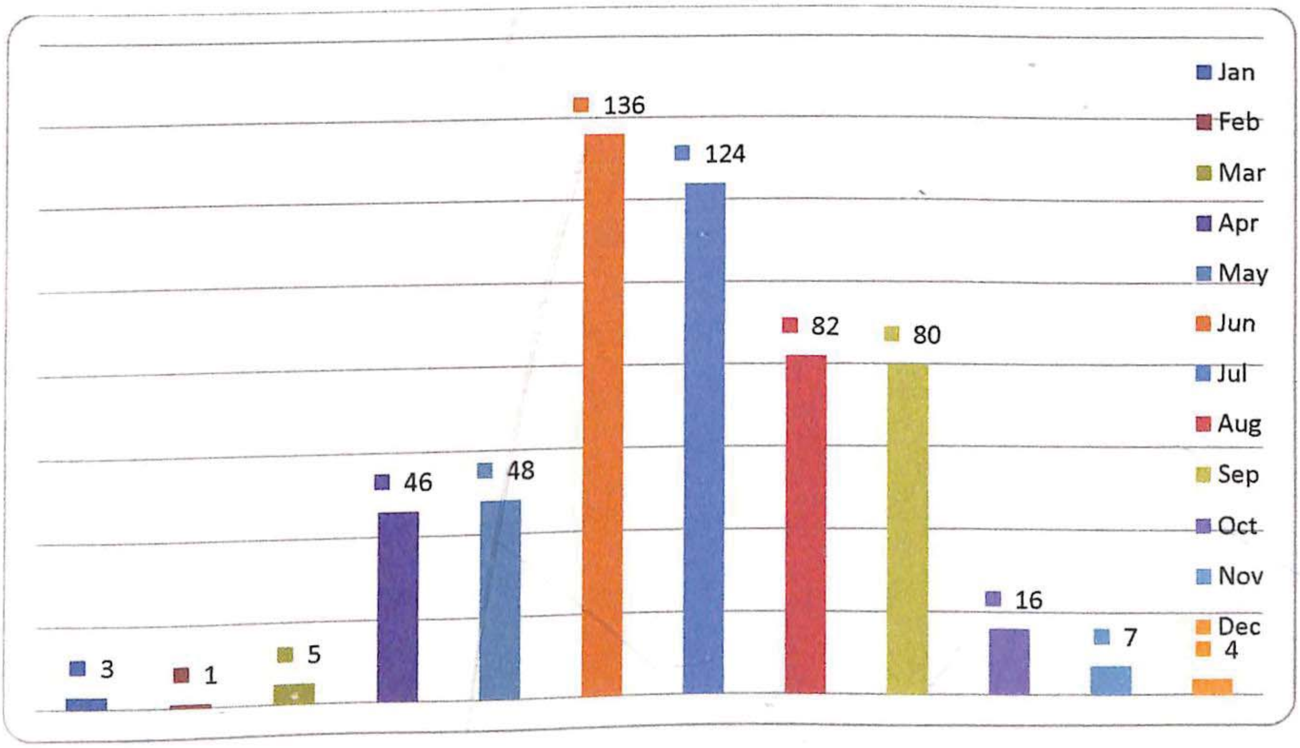
4.1: TEMPORAL VARIABILITY:

Table: 4.1.1: Monthly distribution of cases of reported landslides in 15 years (1999-2013) in Sikkim

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cases of Landslides	3	1	5	46	48	136	124	82	80	16	7	4
In %	0.54	0.18	0.91	8.33	8.70	24.64	22.46	14.86	14.49	2.90	1.27	0.72

(**Source**: Sikkim Now, 1999-2013)

FIGURE: 4.1.1- Monthly distribution of cases of reported landslides in 15 years (1999-2013) in Sikkim



From the table (4.1.1) it noticed that highest percentage of cases of reported landslide in last 15years is recorded in the month of June (24.64%) followed by the month of July (22.46%) and lowest in the month of February (0.18%) which shows huge gap of 24.46% between the two months in the cases of landslides during last fifteen years. Monthly distribution of cases of reported landslides from 1999 to 2013 in Sikkim clearly reveals that maximum cases of landslides occurs in the month of June and July and minimum cases are reported in the month of January, February, March, November and December. Figure 4.1.1 shows that cases of landslides, during less raining period viz. January, February, and March, are very-very less and it starts increasing with the increase in rainfall in the month of April and May. With the start of monsoon in the month of June, cases of landslides are sharply increased and reached up to the maximum level. In the month of July, cases are again very high. Even it starts decreasing in the month of August and September but the cases are significantly at higher end. There is a sharp decline in the cases of reported landslides during post monsoonal period i.e. October, November and December.

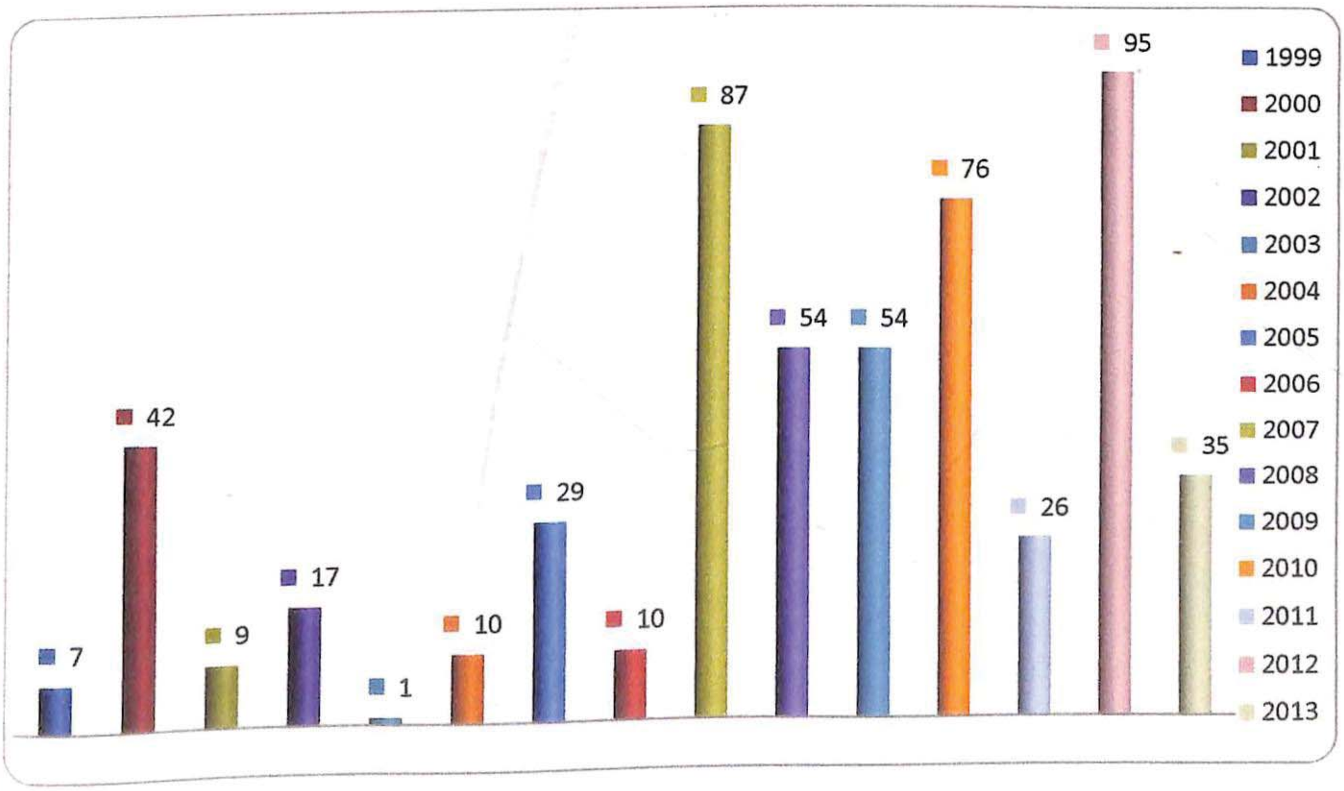
Table: 4.1.2- Total reported landslides in Sikkim, 1999-2013

Year	1999	2000	2001	2002	2003	2004	2005
No. Of slides	7	42	9	17	1	10	29
In %	1.27	7.61	1.63	3.08	0.18	1.81	5.25

Year	2006	2007	2008	2009	2010	2011	2012	2013
No. Of slides	10	87	54	54	76	26	95	35
In %	1.81	15.76	9.78	9.78	13.77	4.71	17.21	6.34

(**Source**: Sikkim Now, 1999-2013)

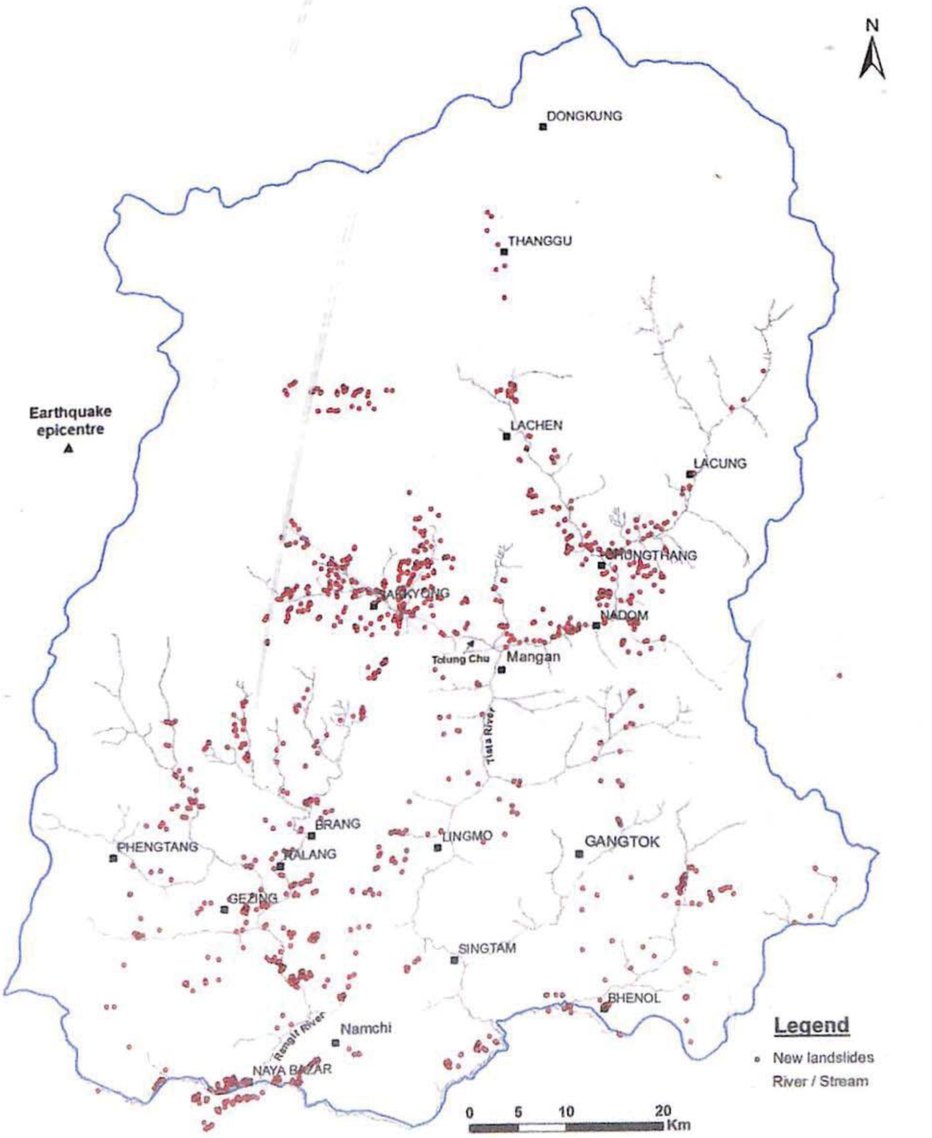
Figure: 4.1.2- Total reported landslides in Sikkim



From the table 4.1.2 it is clear that the year 2012 (17.21%) has the highest record of landslide in the Sikkim in the last fifteen years and least is reported in the year 2003 (0.18%). The year 2012 reported highest landslide may be due to the after effects of earthquake in the year

2011. The temporal variation of landslides in Sikkim (Figure 4.1.1) reveals that there was a sharp increase of reported cases of landslides in Sikkim from the year 2007 onwards. Around 87 cases of landslides have been reported in the state in 2007 in comparison to 10 in 2006. Maximum cases of landslides were reported in 2012 and minimum were reported in 2003. Reported cases of landslides in 2011 were only 26. It is pertinent to mention here that Sikkim witnessed a major earthquake of 6.8 on Richter Scale on 18th September 2011. Immediately after the earthquake, massive number of landslides has been reported (http://bhuvan-noeda.nrsc.gov.in/disaster/disaster/disaster.php#). NRSC analysed 123 image scenes from eight satellites covering an area of 4105 km^2 and mapped 1196 new landslides in Sikkim out of these, a total 354 new landslides were mapped in and around Teesta valley in Sikkim. The distribution of the landslides followed by earthquake has been shown in Map 4.1.1.

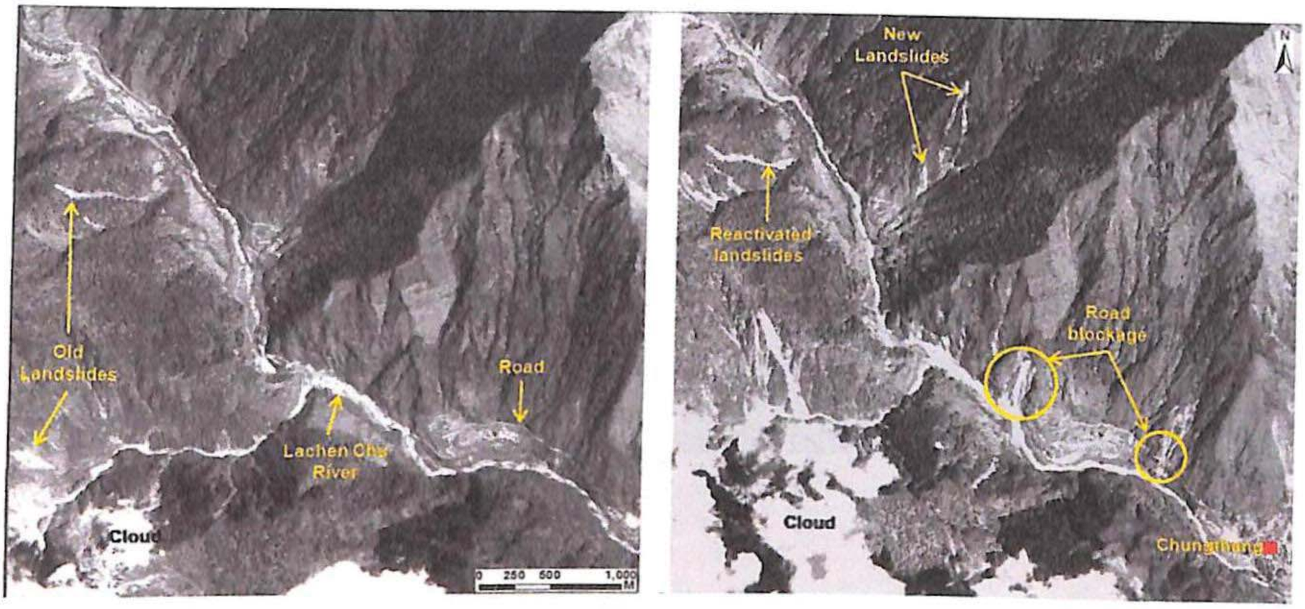
Map 4.1.1: Showing Distribution of Landslides after 18th Sept. 2011 earthquake



(SOURCE: NRSC, 2011)

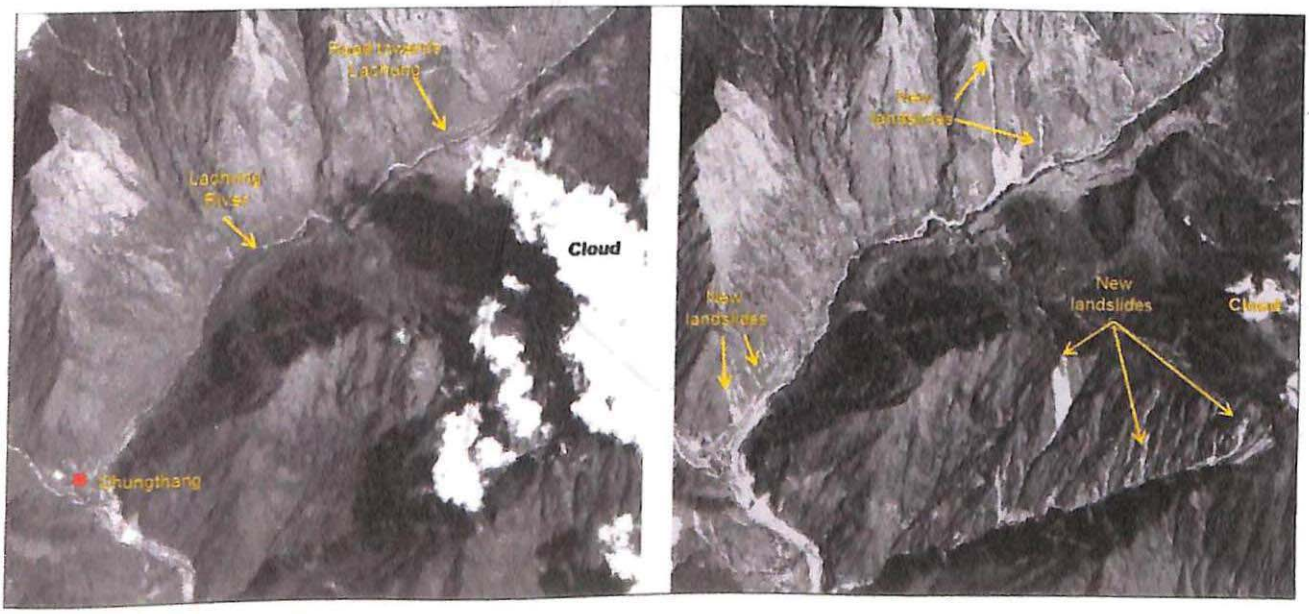
These landslides created major devastations along the roads in Sikkim especially in north Sikkim. Roads were blocked for several days.

PLATE 2: Landslides along the roads and Fault Scarps in North Sikkim



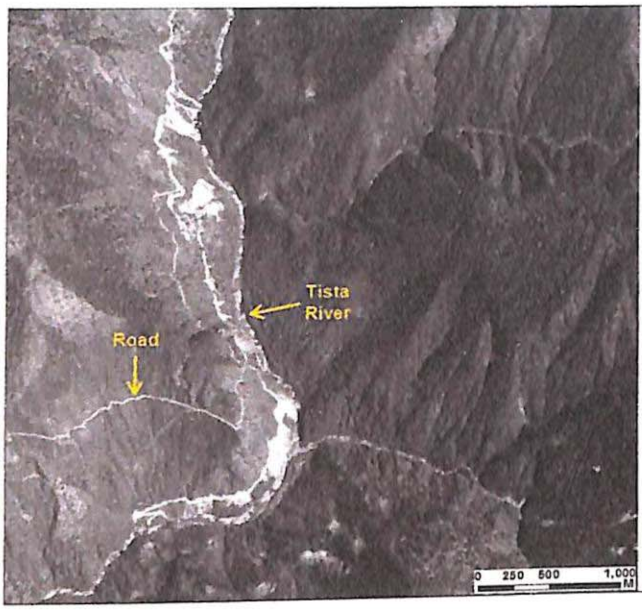
(**SOURCE**: NRSC, 2011)

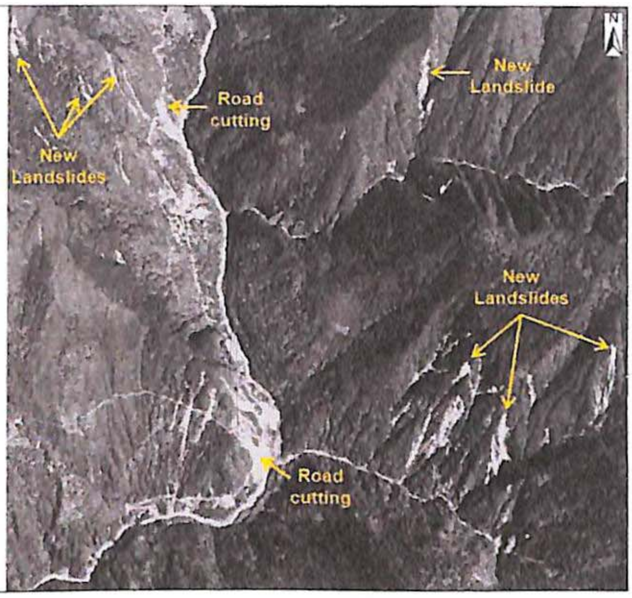
PLATE 4: Showing New Landslides after last earthquake along the Roads and River Beds



(**SOURCE**: NRSC, 2011)

PLATE 5: Showing New Landslides after last earthquake along the Roads and River Beds





(**SOURCE**: NRSC, 2011)

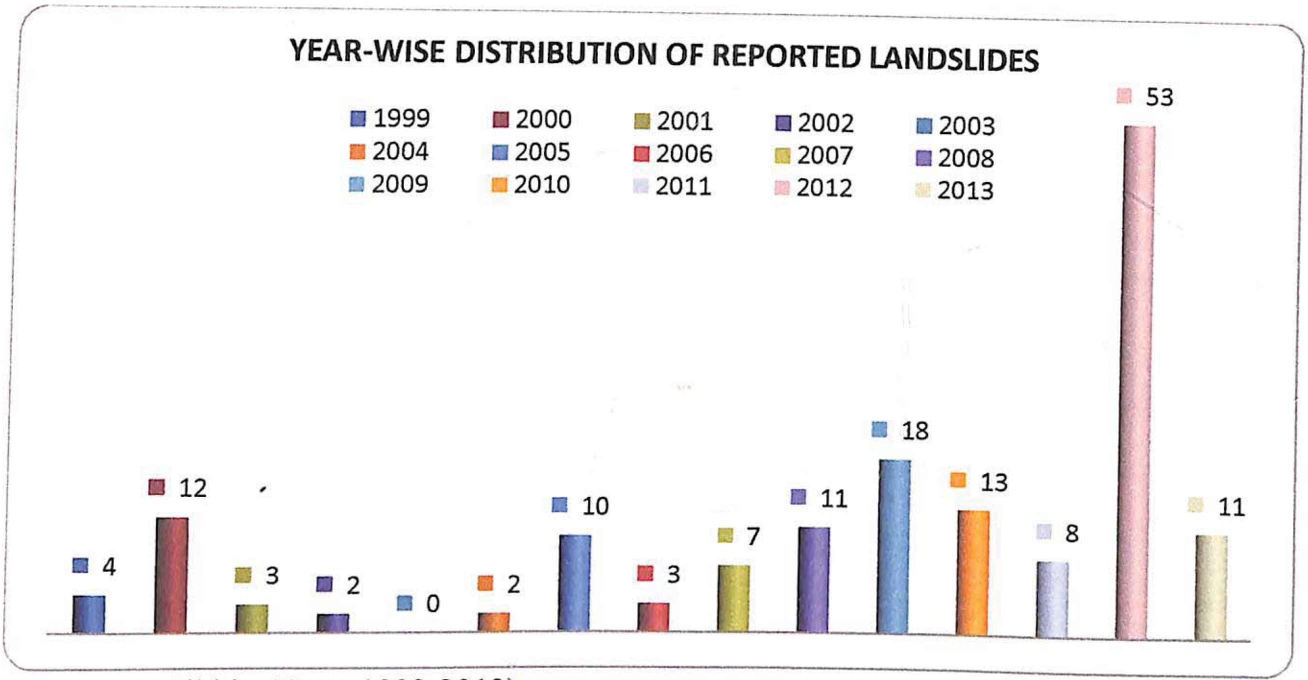
New landslides mapped from Cartosat-1 image in an area east of Mangan (bottom) and near Chungthang (top). Pre- and post-earthquake images are shown in left and right, respectively. Road cuttings can be seen in both images

Parts of road completely destroyed by landslides triggered due to the earthquake near Chungthang area in north Sikkim. Pre- and post-earthquake Cartosat-1 images are shown in left and right, respectively.

The data shown in the Figure 4.1.1 does not include the cases of landslide that occurred followed by earthquake. At the day of earthquake around 1200 cases of landslides has been reported by the National Remote Sensing Centre (NRSC). The significant increase in the reported landslides after 2006 may be attributed to human intervention and infrastructure development.

4.1.1: TEMPORAL VARIABILITY IN NORTH DISTRICT OF SIKKIM:

FIG 4.1.1.1: Distribution of Landslides in North District

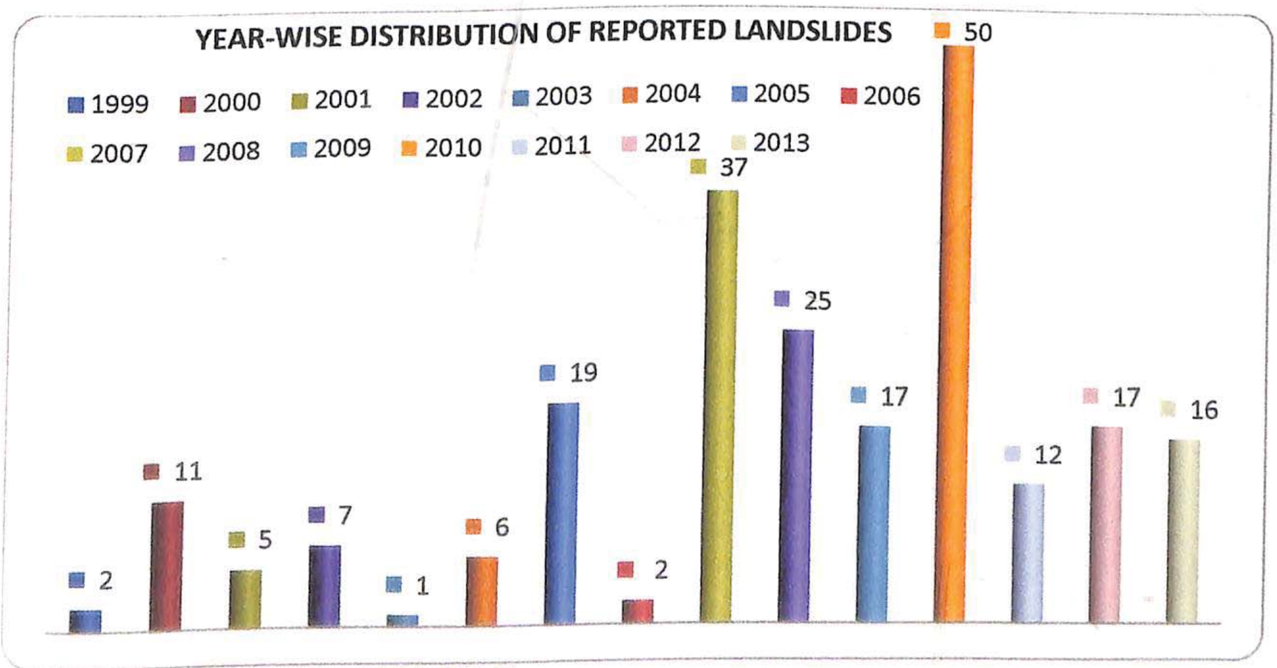


(**SOURCE**: Sikkim Now, 1999-2013)

North district experienced highest landslide in the year 2012 (53 cases) and the lowest has been reported in the year 2001 and 2004, 2 each, in last 15 years (Figure. 4.1.3). In the year 2003 no landslide has been reported in the North district.

4.1.2: TEMPORAL VARIABILITY IN EAST DISTRICT OF SIKKIM

FIG 4.1.2: Distribution of Landslides in East District

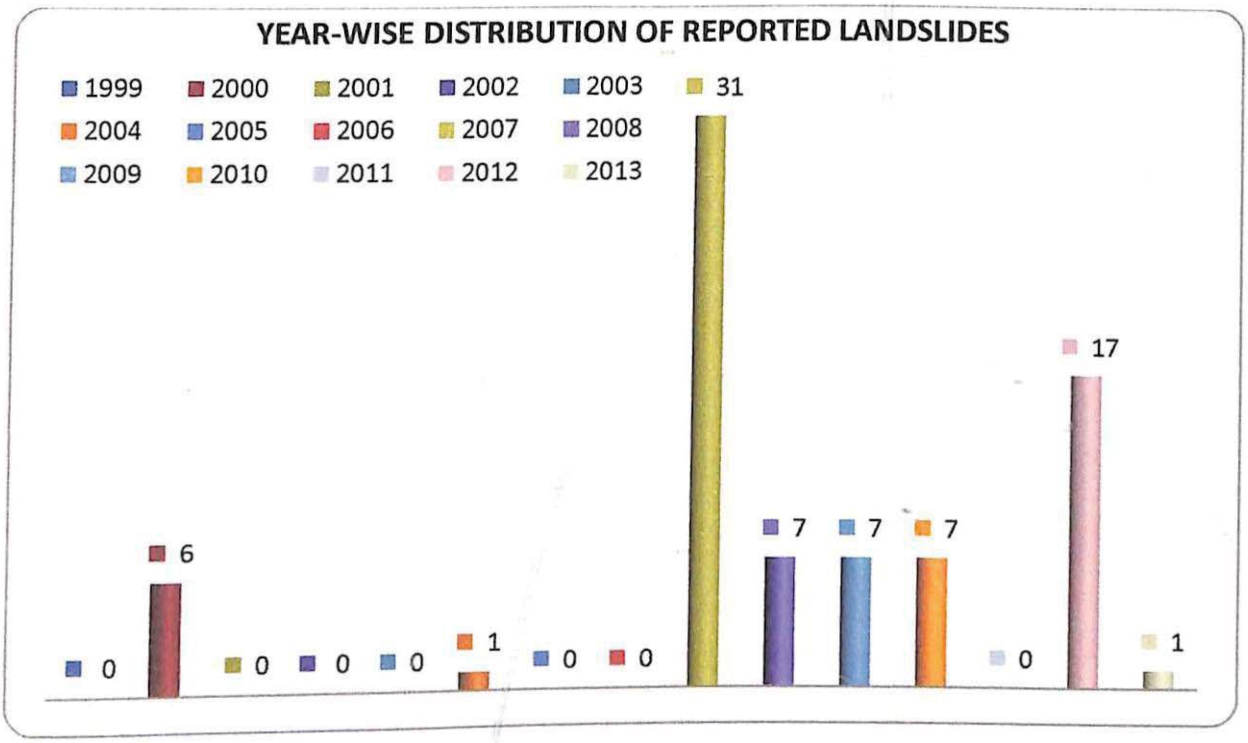


(**SOURCE**: Sikkim Now, 1999-2013)

The nature of temporal variation of reported landslides is quite different in East district as compared to the North district. The highest number of cases has been reported in the year of 2010, 50 cases, and the lowest had been reported in the year 2003. Year of 2007 also witnessed noticeable number of reported landslides as compared to rest of the years.

4.1.3: TEMPORAL VARIABILITY IN SOUTH DISTRICT OF SIKKIM

FIG 4.1.3.1: Distribution of Landslides in South District

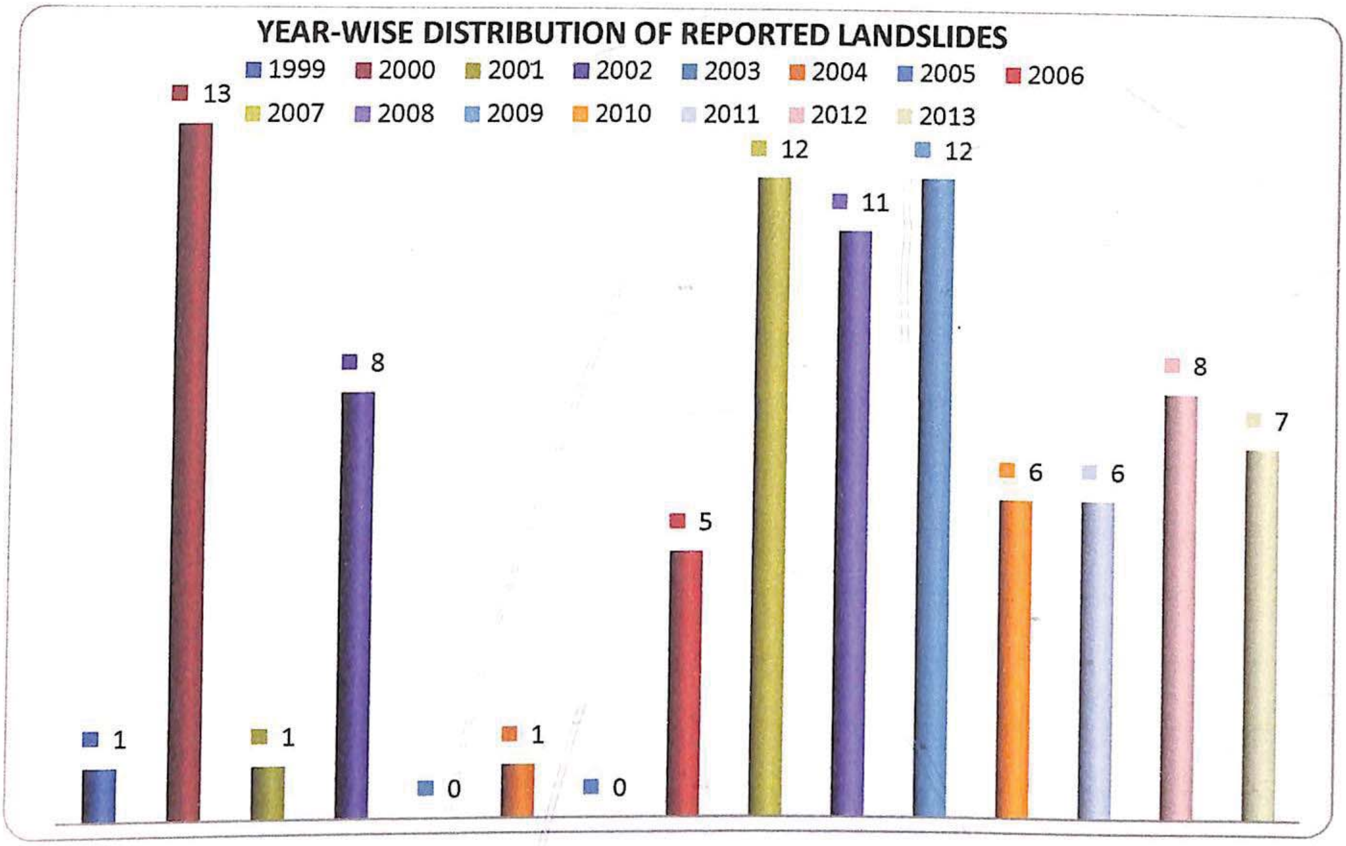


(**SOURCE:** Sikkim Now, 1999-2013)

It has been noted that very few landslides have been reported till 2006 and there is a sharp increase in the frequency of reported landslides in 2007 onwards in the Southern district of Sikkim. Highest numbers of landslides were reported in 2007 followed by the year of 2012. No landslides were reported in the years of 1999, 2001, 2002, 2003, 2005, 2006 & 2011.

4.1.4: TEMPORAL VARIABILITY IN WEST DISTRICT OF SIKKIM

FIG 4.1.4.1: Distribution of Landslides in West

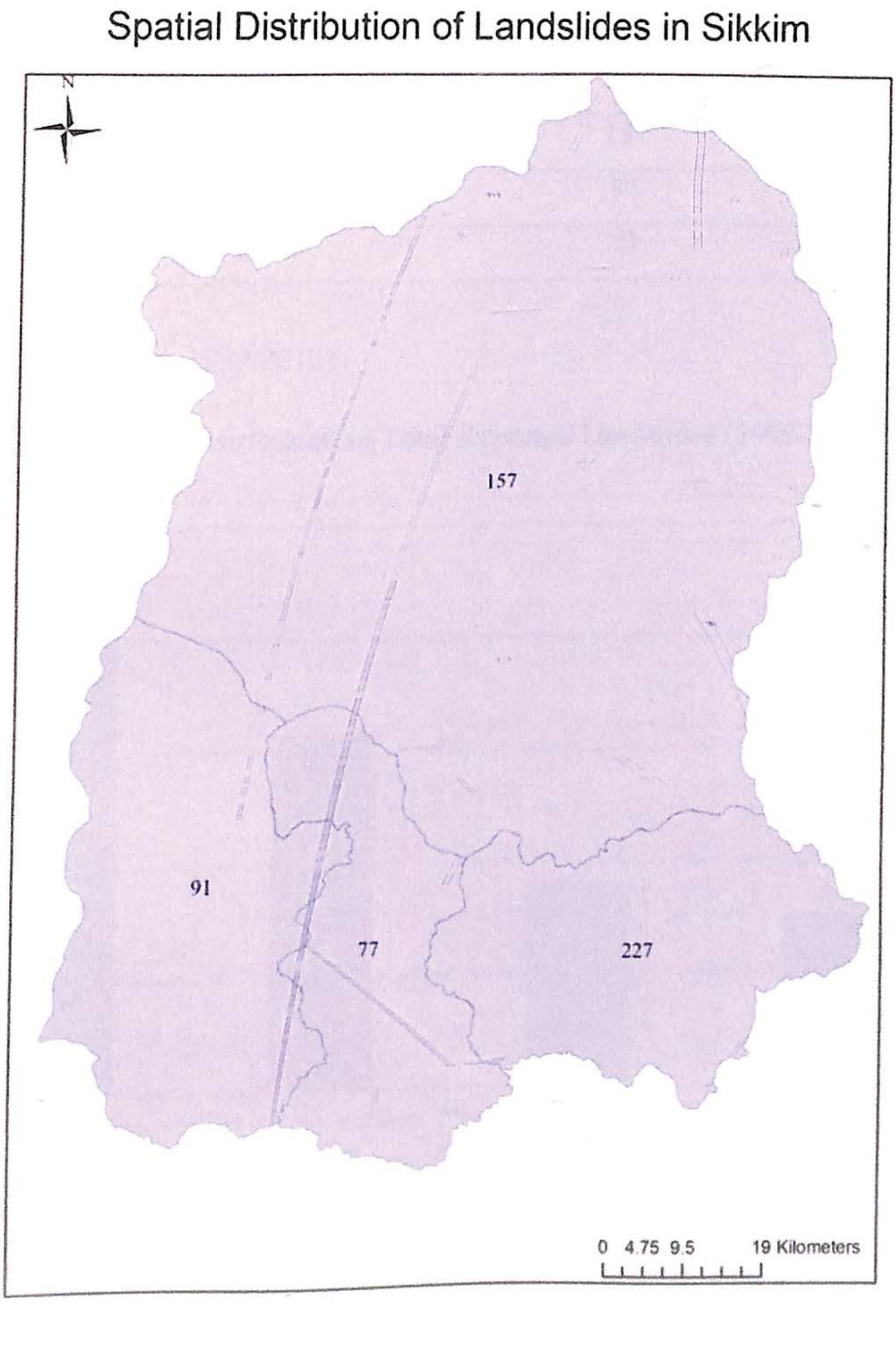


(**SOURCE:** Sikkim Now, 1999-2013)

Although the number of reported landslides in West district of Sikkim is comparatively less but the frequency of landslides has been increased after 2006 (Figure: 4.1.6). The highest numbers of cases have been reported in the year 2000 and the lowest in 2003 & 2005.

4.2: SPATIAL VARIABILITY:

MAP 4.2.1: Showing Distribution of reported Landslides in Sikkim



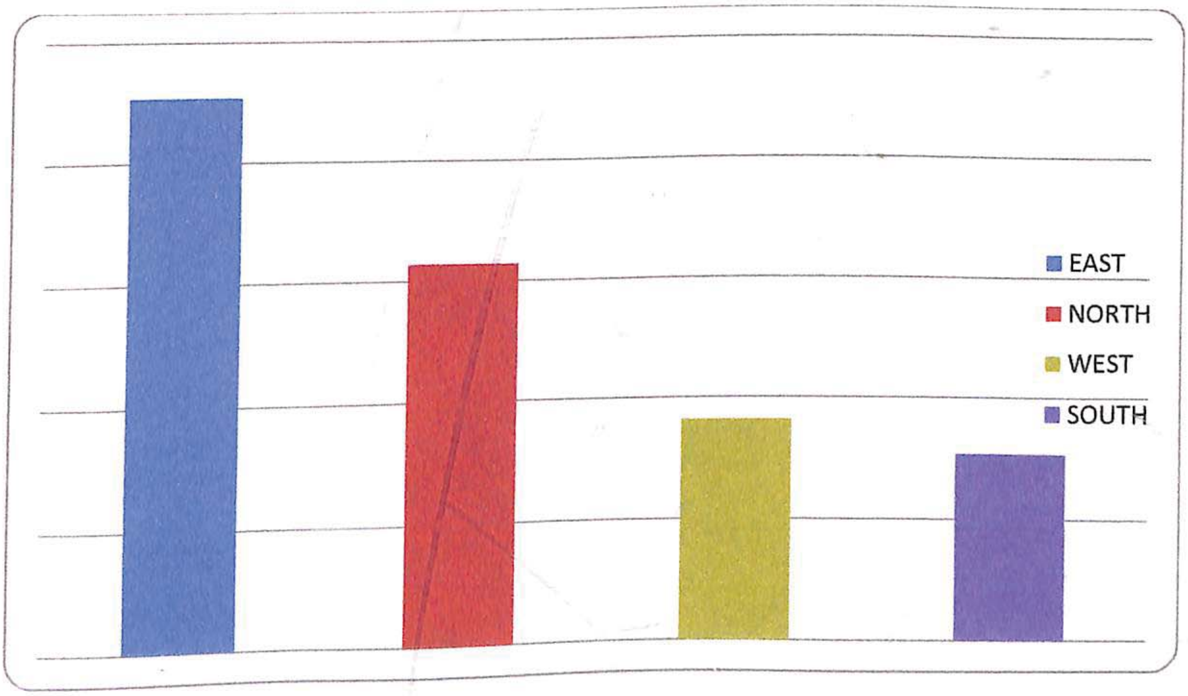
Huge variations in spatial distribution of landslides were reported in Sikkim in last 15 years (Figure 4.2.1).

TABLE 4.2.1: Total Reported Landslides in Sikkim (1999-2013)

DISTRICT	TOTAL NO. OF LANDSLIDES
EAST	227
NORTH	157
WEST	91
SOUTH	77

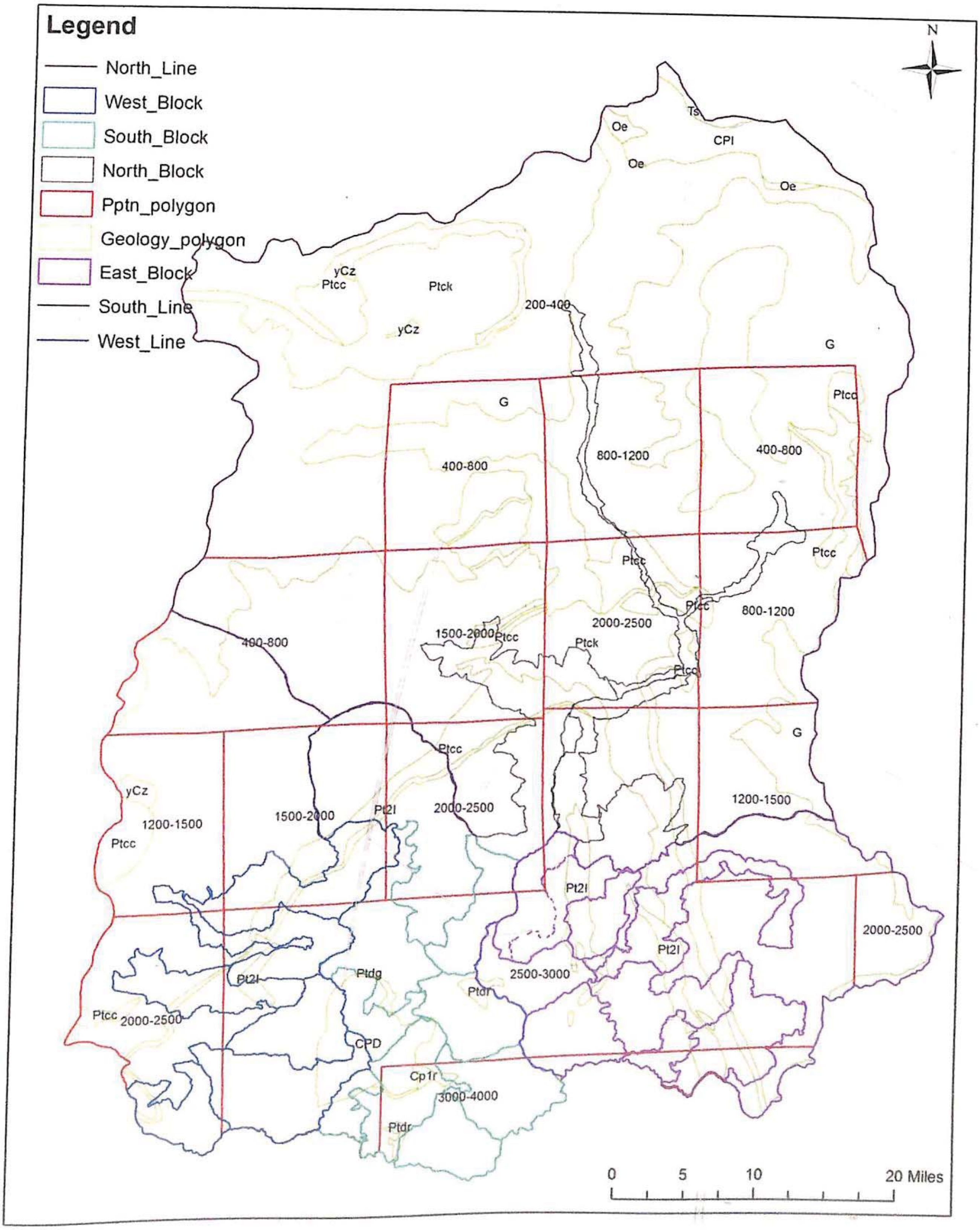
(**SOURCE:** Sikkim Now, 1999-2013)

FIG 4.2.1: District-Wise Distribution of Total Reported Landslides (1999-2013)



The maximum numbers of landslides were reported in East district followed by North, west and south district. The number varies from 227 in the East (highest) to 77 in the South (lowest)

MAP 4.2.2: Overlay Map showing District & Block-Wise distribution of Geology & Precipitation



From the above map it is clear that East district of Sikkim lies in high rainfall zone (2500-3000 mm) and geological lies in the vicinity of the MCT zone and the dominant litho-units in the area are Lingtse granite gneiss that may trigger the landslides is east district.

4.2.1: SPATIAL VARIABILITY IN EAST SIKKIM

MAP 4.2.1.1: Block-Wise distribution of Landslides

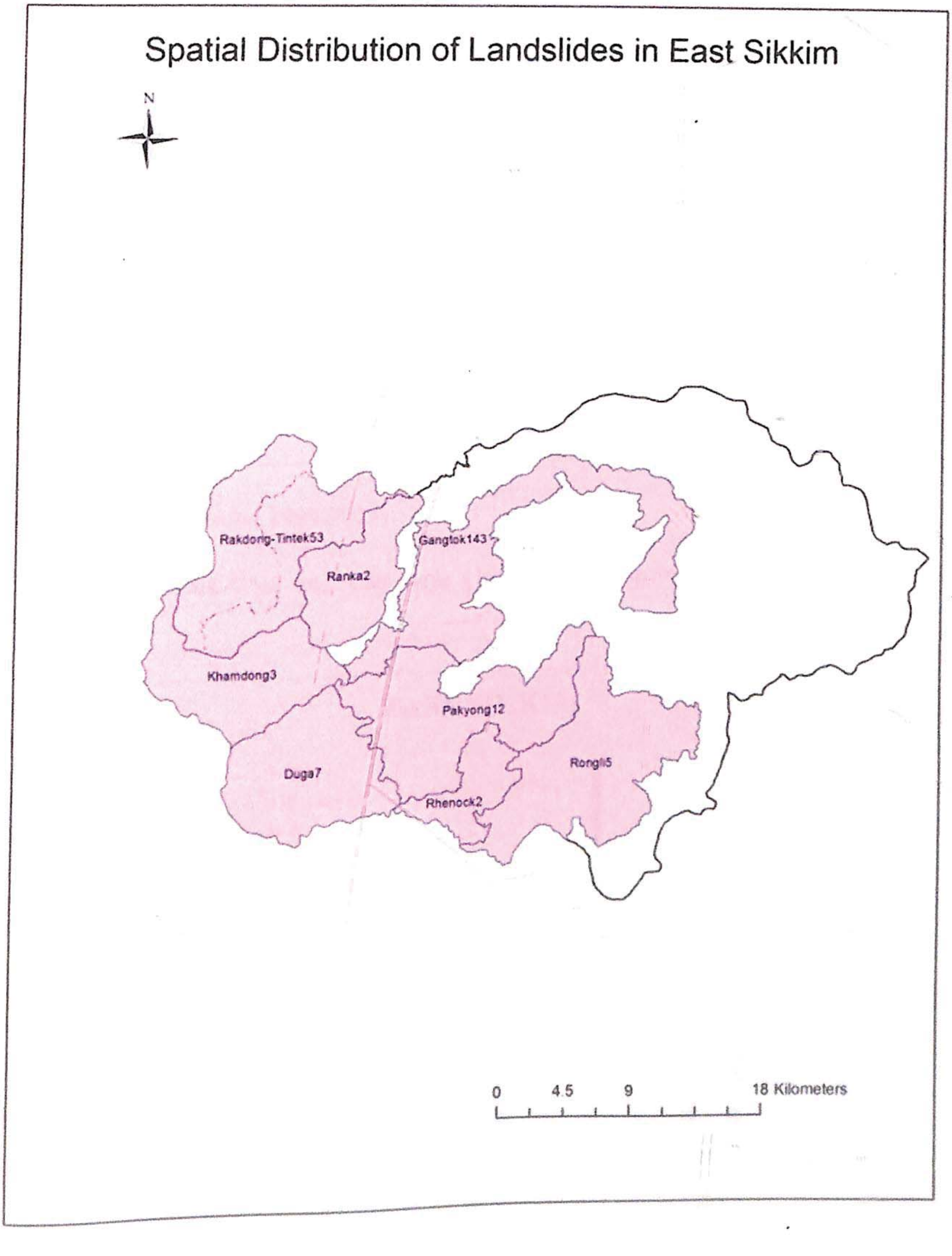
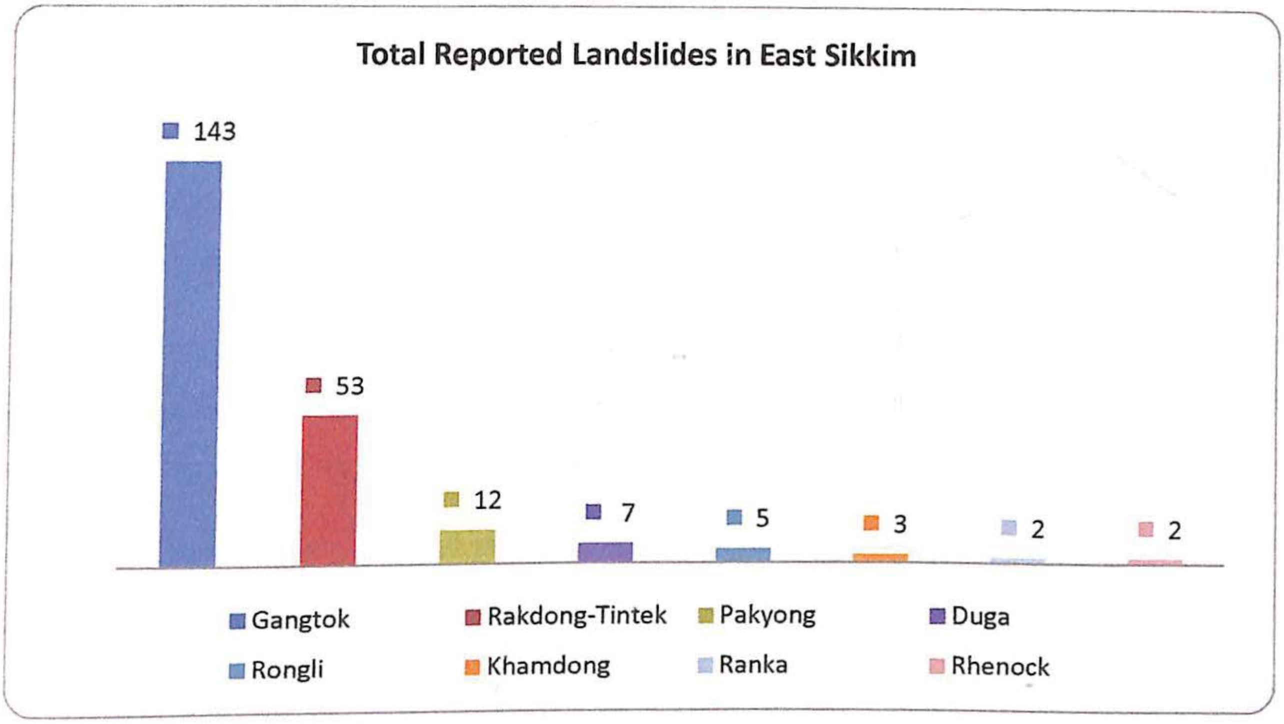
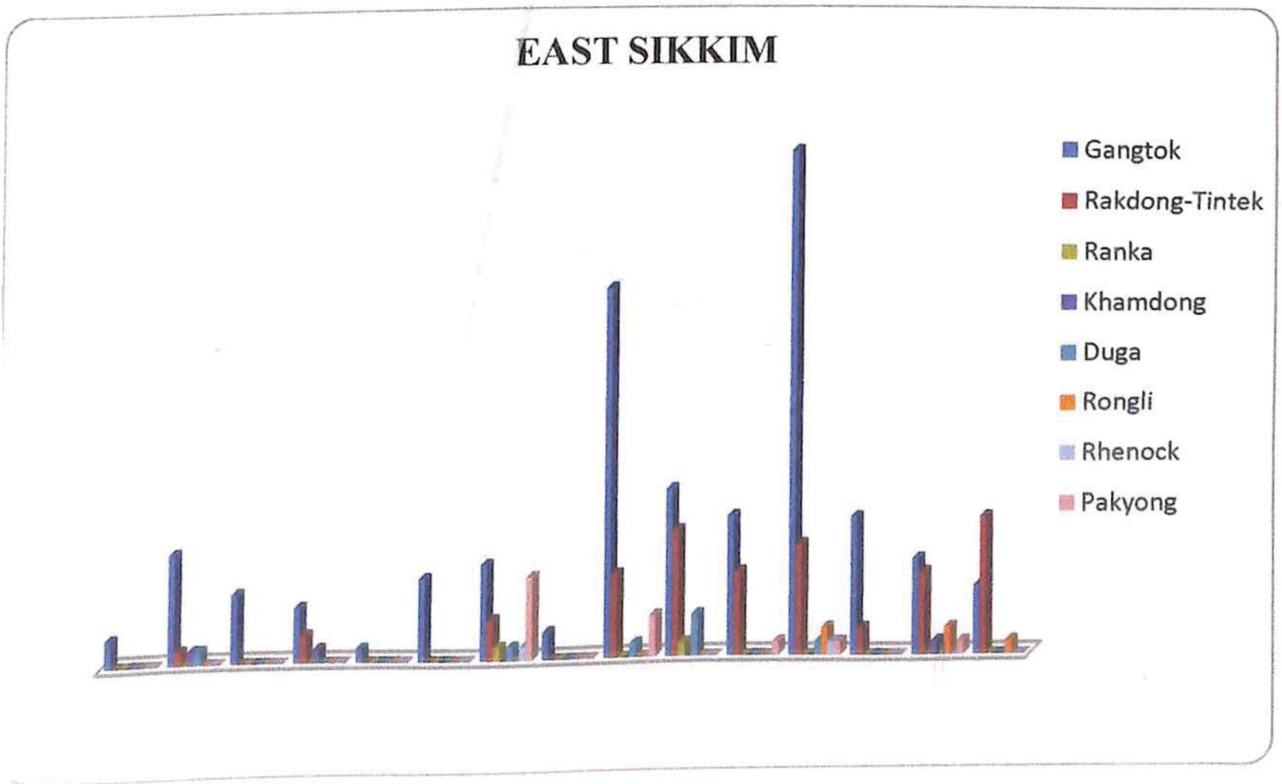


FIG 4.2.1.1: Block-Wise distribution of Landslides in East Sikkim



(**SOURCE**: Sikkim Now, 1999-2013)

FIG 4.2.1.2: Block-Wise and year wise (1999-2013) distribution of Landslides in East Sikkim



SOURCE: Sikkim Now, 1999-2013)

In East Sikkim, the maximum numbers of landslides were reported in Gangtok UFS block, followed by Rakdong-Tintek block, Pakyong, Duga, Rongli, Khamdong & Rhenock and Ranka respectively.

Geologically Gangtok lies in the vicinity of the MCT zone and the dominant lithounits in the area are Lingtse granite gneiss and Lesser Himalayan meta-sedimentary rocks. This may be one of the factor for higher incidence of landslides in and around Gangtok.

Other reason attributed for the highest occurrence of landslides may be the high urbanization around Gangtok. It is important to note that, being capital of the state there is huge population pressure and more focus on the infrastructure development around city of Gangtok.

It is also important to note that majority of the landslides cases are duly reported, while in other part of the state this may not be the case.

Rakdong-Tintek block has witnessed second highest reported cases of landslides in east district and the reason may be attributed to construction of Hydro power projects in the area.

The people residing near Dikchu, one of the GPU in Rakdong-Tintek block also has this perception. During Focused Group Discussion (FGD) in lower Rakdong area, People has opinion that cases of landslide have been increased in this area after the beginning of the developmental activities like hydro projects. They consider construction of Hydro power project as the main reason for the frequent occurrence of landslides in and around the area.

4.2.2: SPATIAL VARIABILITY IN NORTH SIKKIM

MAP 4.2.2.1: Block-Wise distribution of Landslides

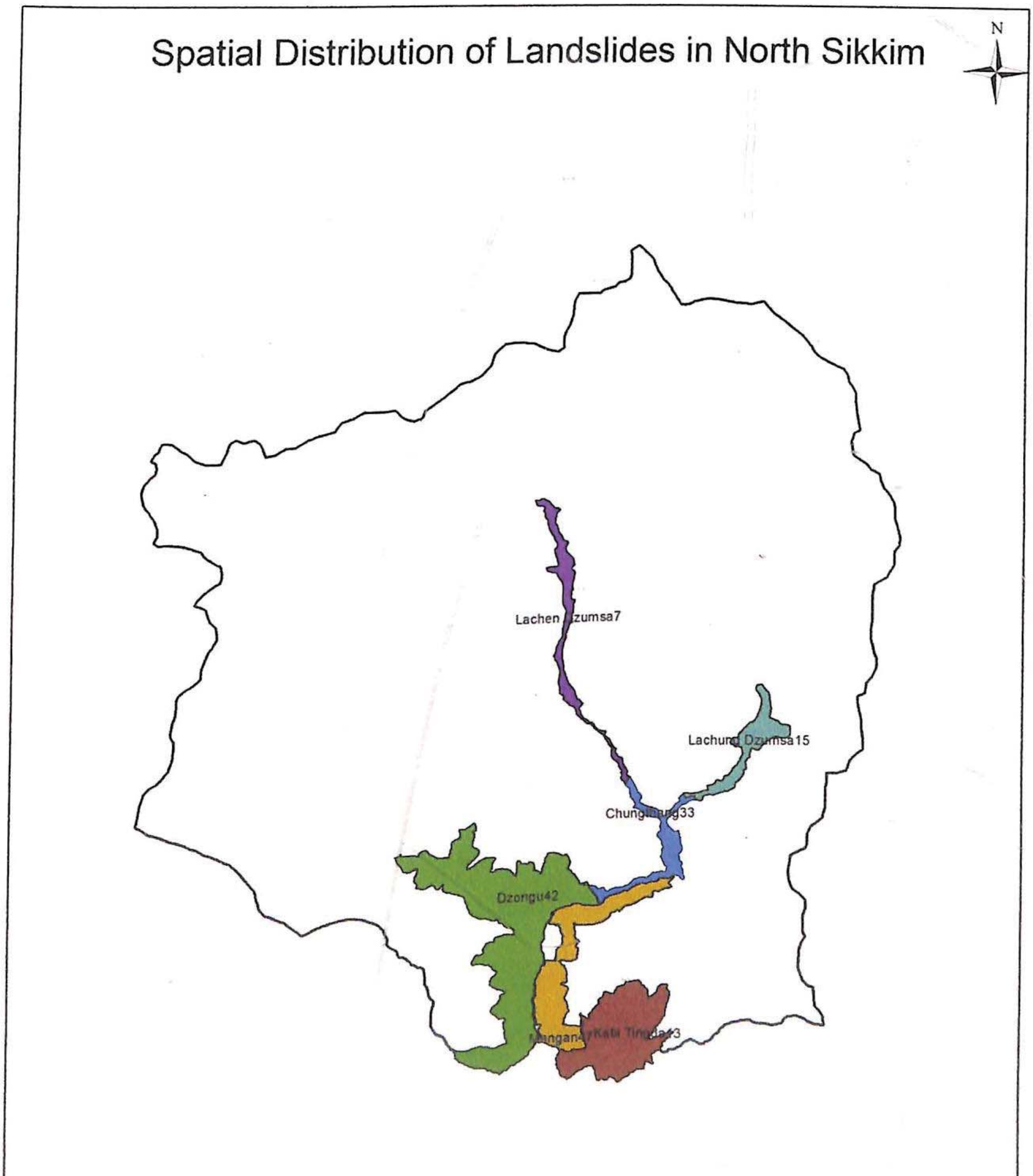
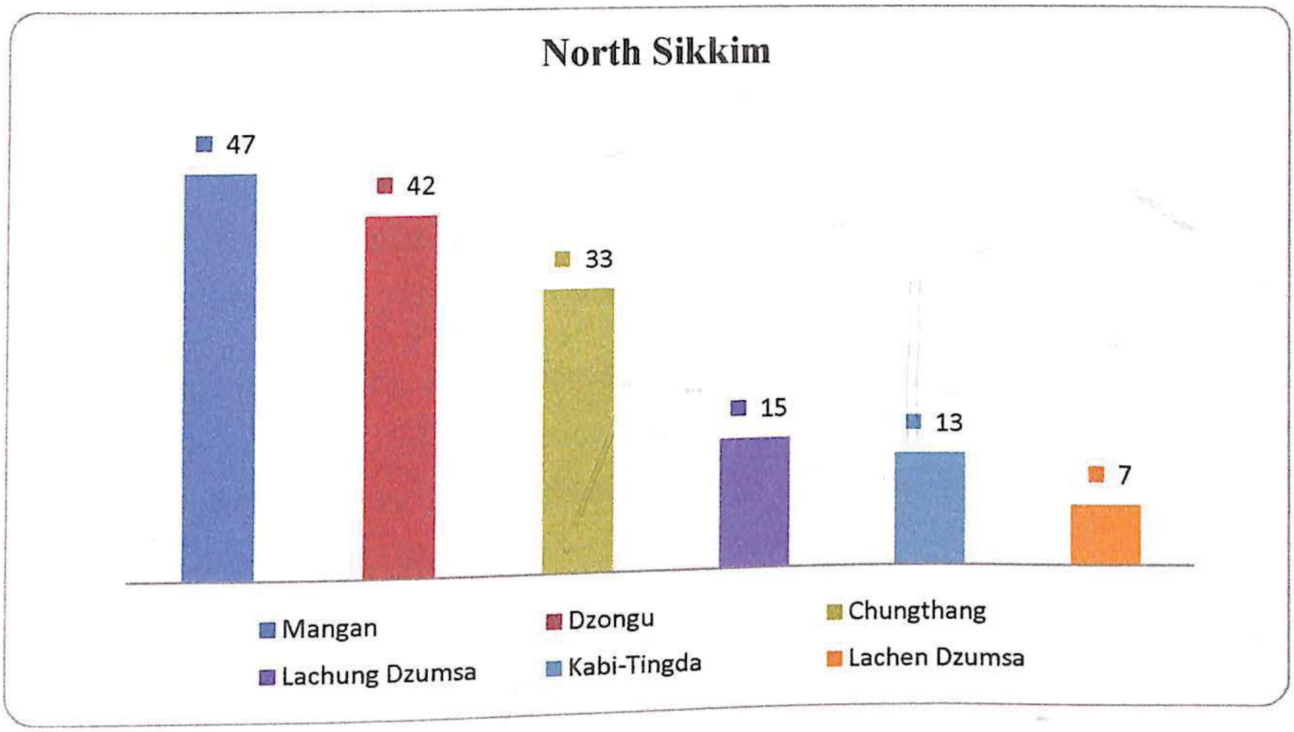
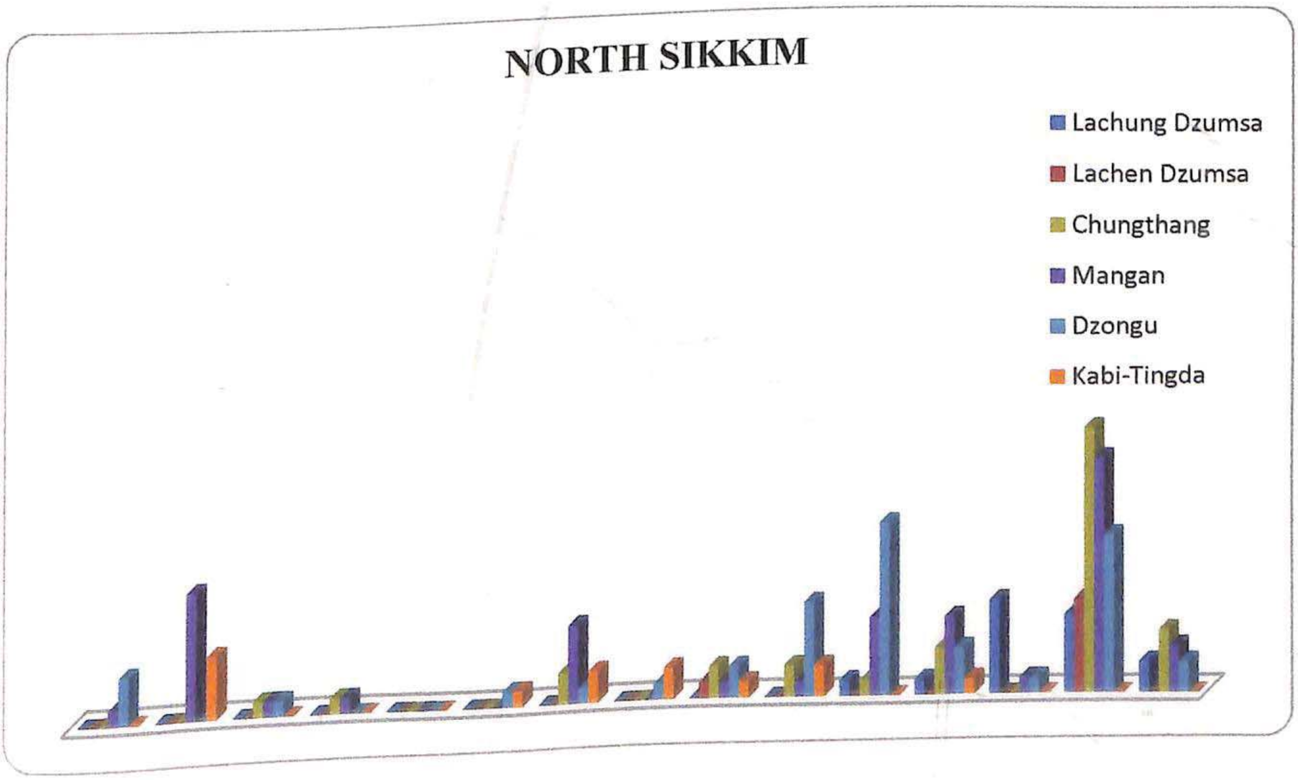


FIG 4.2.2.1: Block-Wise distribution of Landslides in North Sikkim



(**SOURCE:** Sikkim Now, 1999-2013)

FIG 4.2.2.2: Block-Wise and year wise (1999-2013) distribution of Landslides in North Sikkim



(**SOURCE:** Sikkim Now, 1999-2013)

In North Sikkim, the maximum numbers of landslides were reported in Mangan followed by Dzongu, Chungthang, Lachung Dzumsa, Kabi-Tingda & Lachen Dzumsa respectively.

It is to be noted that Mangan Dzongu and Chungthang lie in Main Central Thrust (MCT) region. One of the reason for higher cases of landslides may be this geological thrust zone.

The other reason for higher incidents of landslides in Mangan Dzongu and Chungthang region is very high developmental activities e.g construction of roads, dams and tunnels etc.

It is also important to note that construction of biggest Hydel power project of 1200 MW (Teesta III) is in process in Chhungthang. During FGD in Chungthang, people blames this construction for the increased cases of landslides and other problems like shortage of water both for drinking and irrigation purpose.

During FGD in Lachung, Dzongu, Mangan and Chungthang; it has been observed that residents of these regions blamed construction of hydro power projects, blasting and tunnelling for increase in the occurrence of landslides.

4.2.3: SPATIAL VARIABILITY IN WEST SIKKIM:

MAP 4.2.3.1: Block-Wise distribution of Landslides

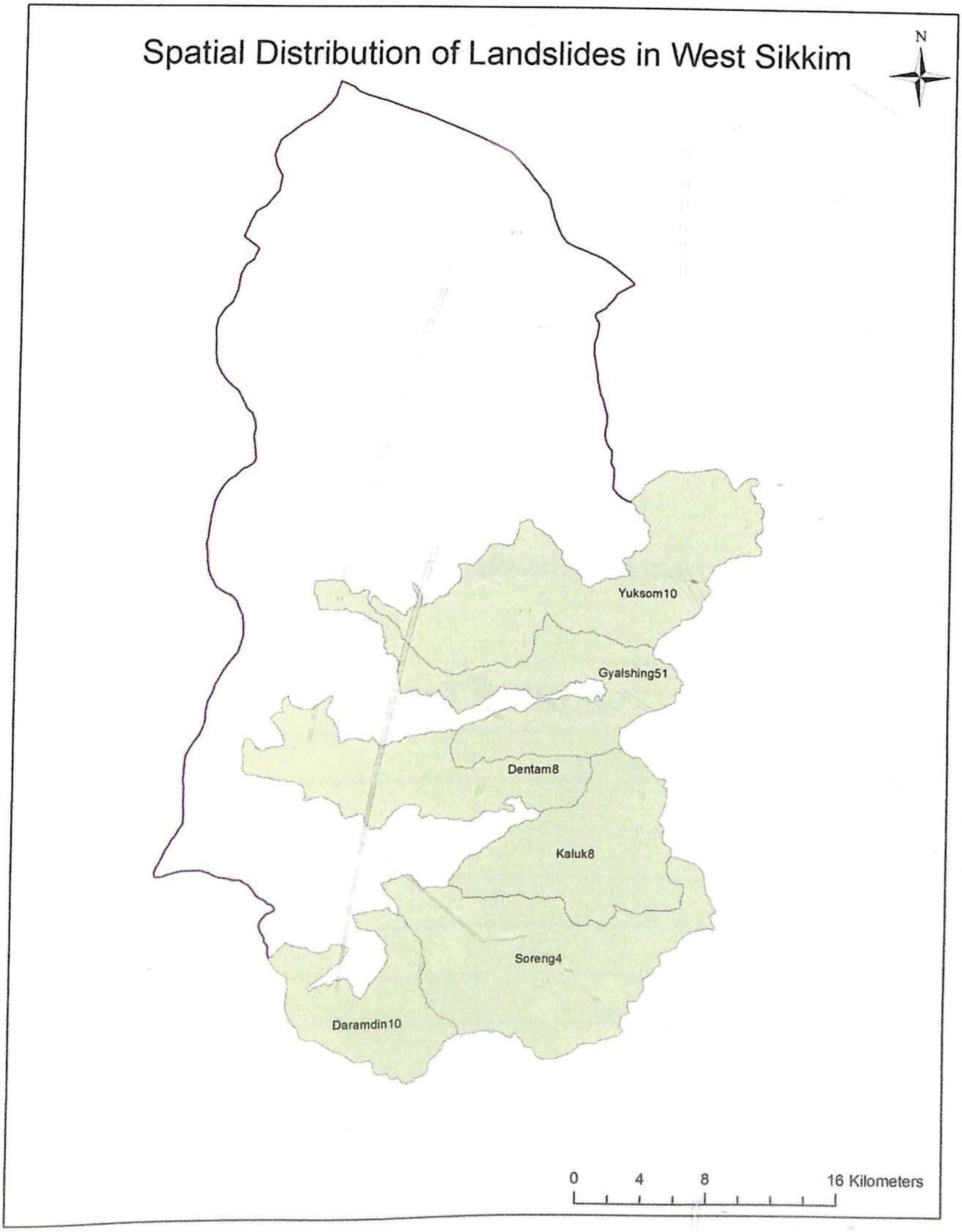
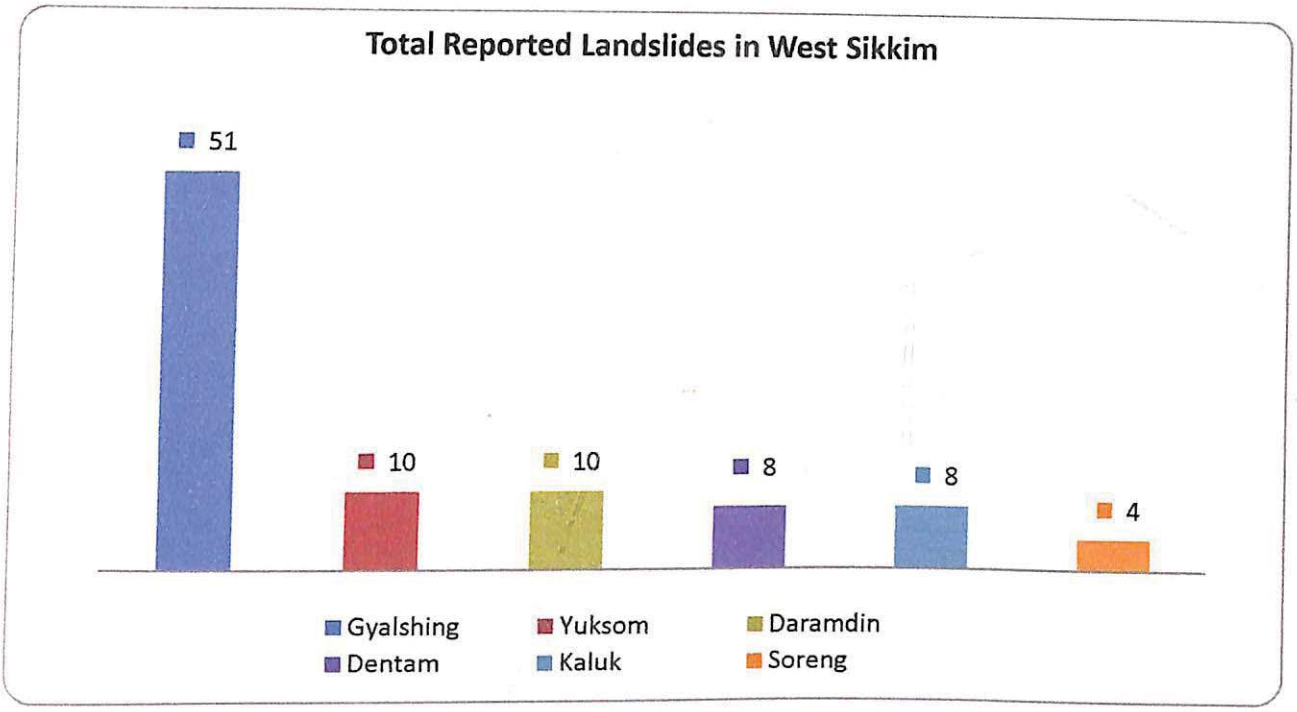
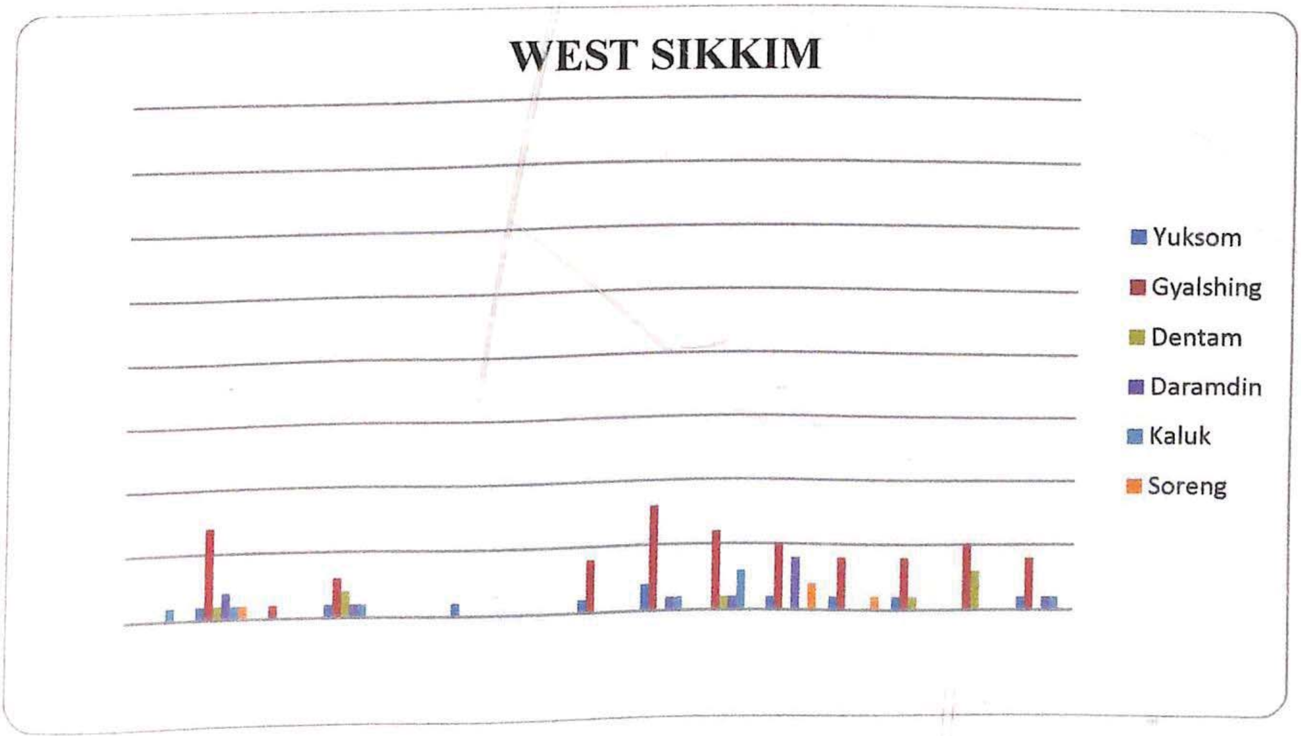


FIG 4.2.3.1: Block-Wise distribution of Landslides in West Sikkim



(**SOURCE**: Sikkim Now, 1999-2013)

FIG 4.2.3.2: Block-Wise and year wise (1999-2013) distribution of Landslides in West Sikkim



(**SOURCE:** Sikkim Now, 1999-2013)

In West district of Sikkim maximum numbers of landslides, in last 15 years, were reported in Gyalshing revenue block followed by Yuksom and Daramdin, Dentam & Kaluk and Soreng, respectively. It is important to mention here that Gyalshing is also district headquarter of West District and witnesses highest urbanisation. High human intervention in Gyalshing may be the reason for the highest cases of landslides here.

4.2.4: SPATIAL VARIABILITY IN SOUTH SIKKIM

MAP 4.2.4.1: Block-Wise distribution of Landslides

Spatial Distribution of Landslides in North Sikkim

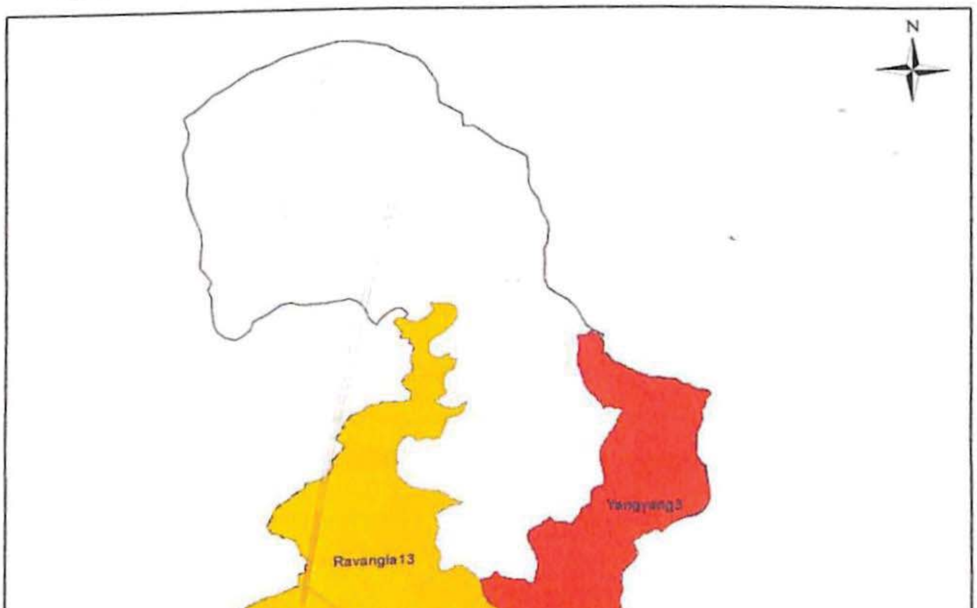
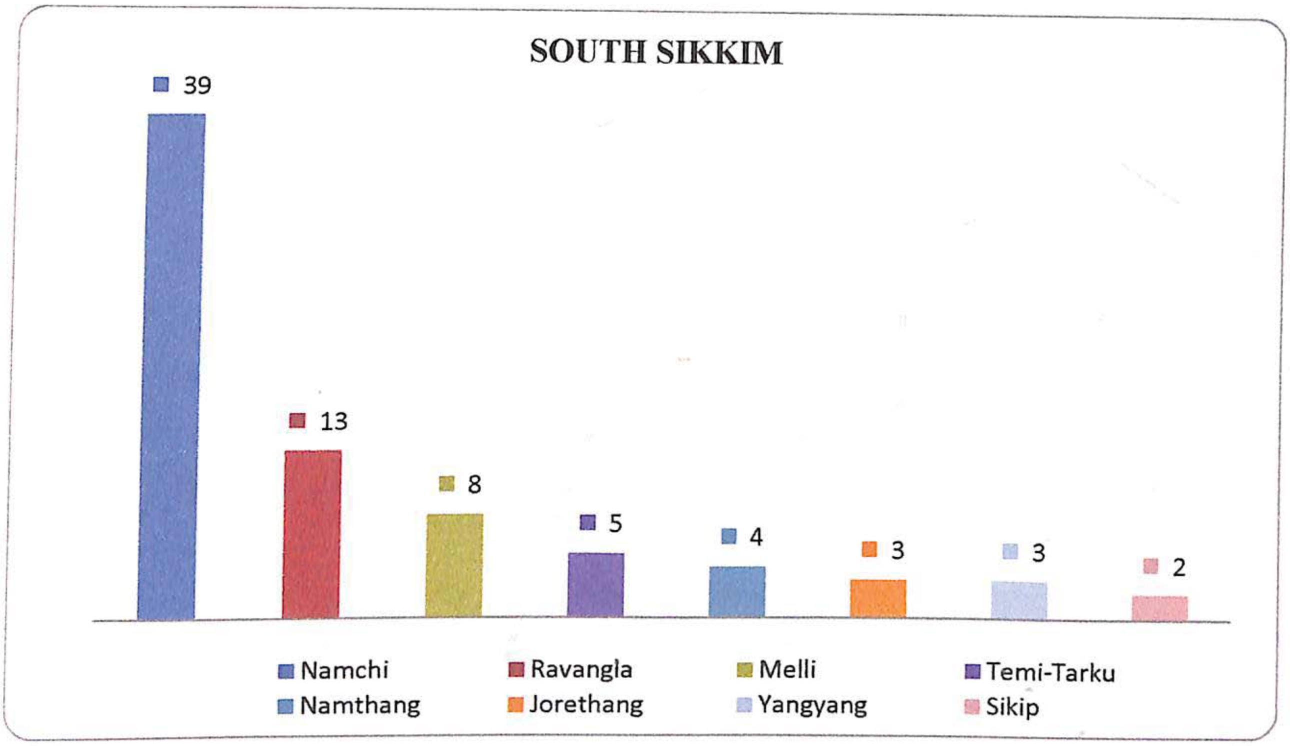
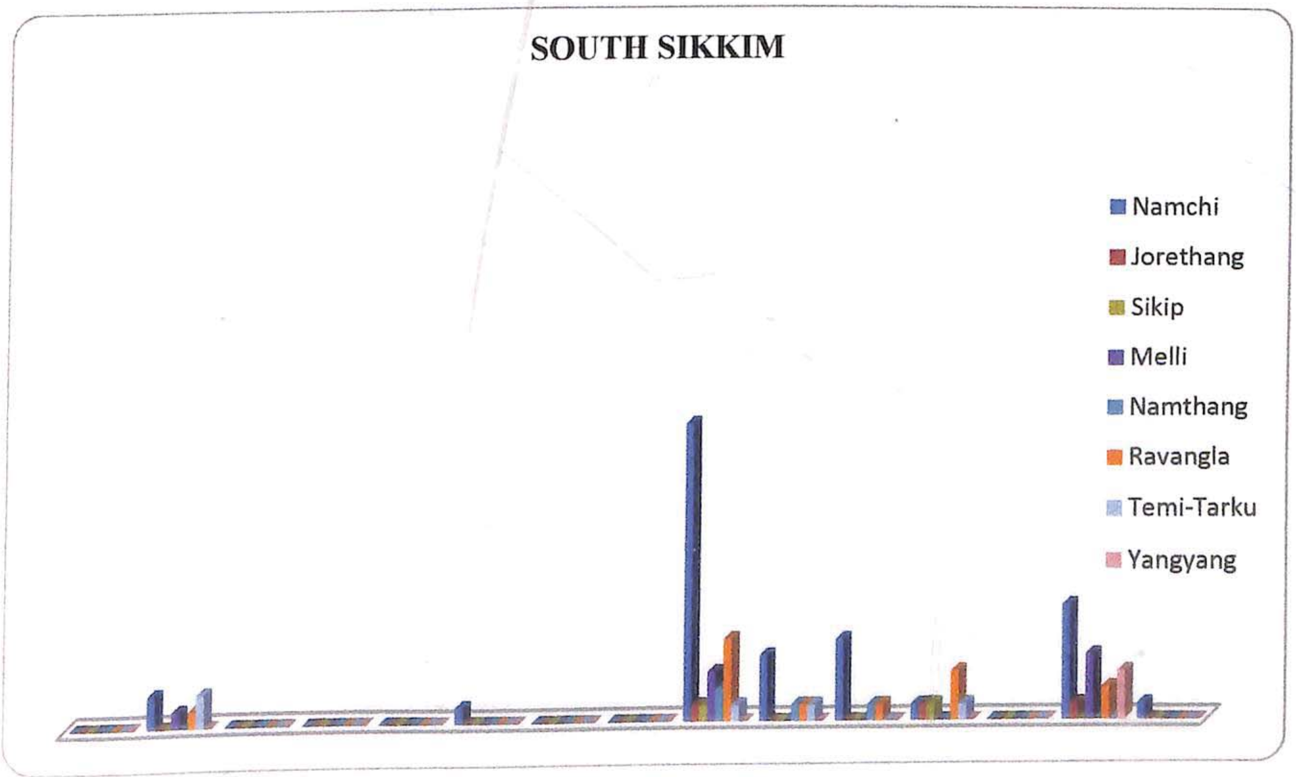


FIG. 4.2.4.1: Block-Wise distribution of Landslides in Sikkim



(**SOURCE:** Sikkim Now, 1999-2013)

FIG 4.2.4.2: Block-Wise and year wise (1999-2013) distribution of Landslides in West Sikkim



(**SOURCE:** Sikkim Now, 1999-2013)

Spatial distribution of reported landslides in South Sikkim reveals that most of the cases of landslides were concentrated in Namchi followed by Ravangla, Melli, Temi-Tarku, Namthang, Yangyang & Jorethang and Sikip. Again Namchi is the district headquarter of the soth Sikkim and second most urban city after Gangtok. It is pertinent to mention that Ravangla represents MCT on the surface and this may be attributed to the reasons for landslides in this area.

At the end it can be concluded that distribution of landslides, Temporally and Spatially varies from one block to another and the highest numbers of cases are mostly observed in the main district headquarters of all the Districts of Sikkim. It is clear from the map and the figure below (4.3.1) that district headquarters has witnessed maximum number of reported landslide in last 15 years.

MAP 4.3.1: Digitized map of Sikkim showing Block-wise distribution of reported Landslides (Last 15 Years)

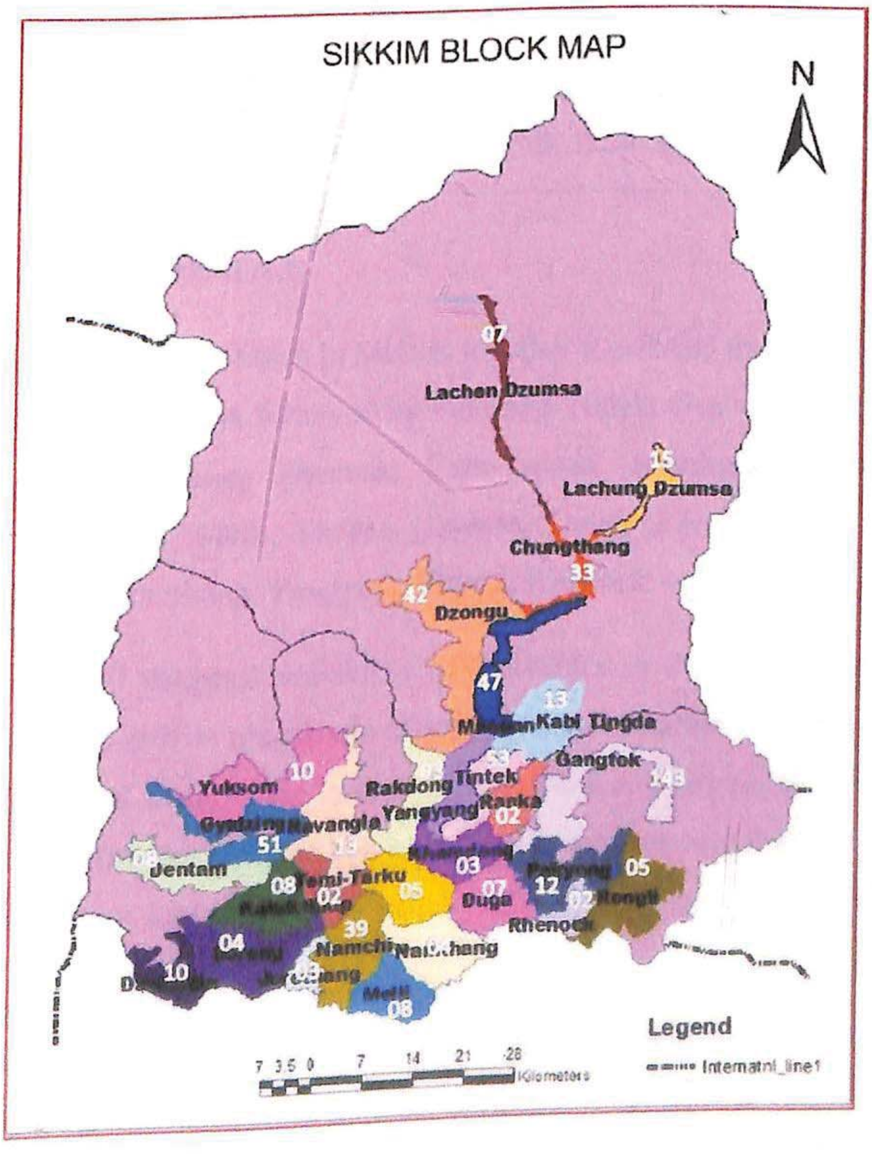
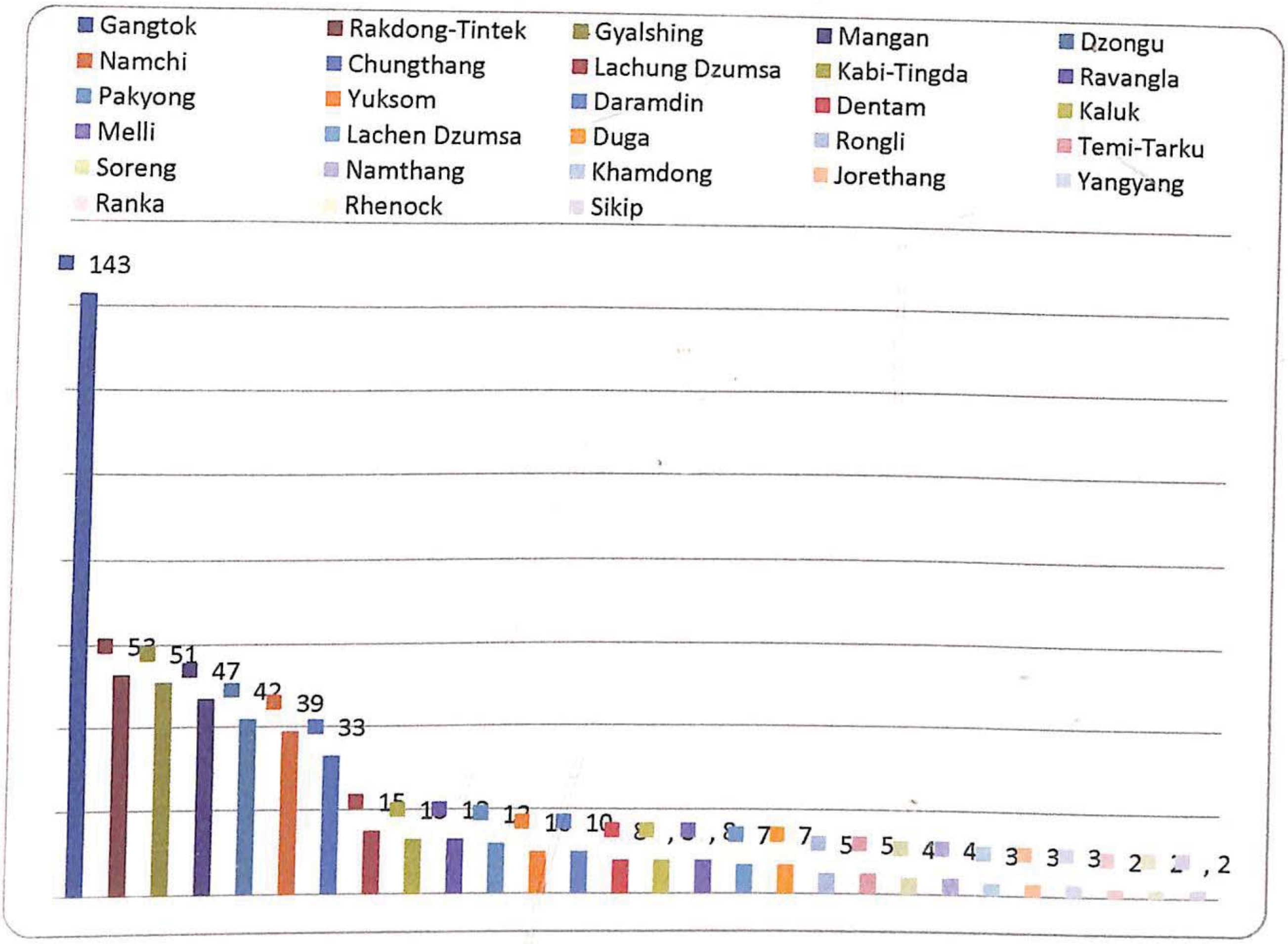


FIG. 4.3.1: Year-Wise Distribution of Reported Landslides in all the Blocks of Sikkim



(**SOURCE:** Sikkim Now, 1999-2013)

If we consider the total revenue block in Sikkim together it is found that maximum number of landslides is reported in Gangtok followed by Rakdong-Tintek, Gyalshing, Mangan, Dzongu, Namchi, Chungthang, Lachung Dzumsa, Kabi-Tingda, Ravangla, Pakyong, Yuksom, Daramdin, Dentam, Kaluk, Melli, Lachen Dzumsa, Duga, ,Rongli, Temi-Tarku, Soreng, Namthang, Khamdong, Jorethang, Yangyang, Ranka, Rhenock, and Sikip.

High spatial and temporal variability of landslides in Sikkim may be attributed to lithological variation as well as magnitude of structural deformation in form of various large and small scale structural features viz., thrust, faults, small and large scale folds. Apart from these factors attitude of planar features like joint planes, schistosity and axial planar cleavage are some of the important geological factors controlling the incidence of landslides.

Apart from the above mentioned predisposing geological factors in the area, high rainfall, steep topographical slope and relatively high weathering rate of the litho-units are also major causative factors for the landslide incidence.

Major anthropogenic factors causing landslides include loss of vegetative cover and slope modification for construction of various structures like roads, tunnels, buildings etc. In this regard presence of numerous hydroelectric power projects in the Sikkim may be considered as crucial factor as the large scale construction activities not only involves removal of vast amounts of rock mass from the slopes but it also significantly interferes with the ground water and surface water conditions in the area.

Chapter - V

Social Vulnerability Assessment and Case Studies

5.1 VULNERABILITY TO NATURAL DISASTERS:

Vulnerability in the context of natural disasters is the capacity to anticipate, to cope with, resist and recover from the impact of a natural disasters (Adger, 1999). High levels of Vulnerability and low adaptive capacity have been linked to a range of factors that include access and distribution of resources, technology, information and wealth, risk perceptions, social capitals and community structure and the existing formalized institutional framework which organize warning planning and other services (Dolan & Walker, 2003). When disaster hits, some individuals are less affected, or may even benefit, while other individuals may suffer significant or even catastrophic losses depending on where they are settled (Cutter, Mitchell, & Scott, 2000).

Although the highest magnitude of economic damage is often born by wealthier populations, due to possessions of higher value, the relative impact is generally greater for low income groups. For people who cannot afford the cost of repair, reconstruction, or relocations, it may take years to recover from the aftermath of disasters. In addition the effect of a disaster may persist to the next generation because of a lack of a resource to recover (Adger W. , 1996)

Watts & Bohle (1993), Blaikie et al. (1994), Kelly & Adger (2000) argue that people vulnerability to natural hazards is determined not os much by the event itself but rather is the function of social conditions and historical circumstances. Thus protection from the social forces that create inequitable exposure to risk becomes just as important than protection from natural hazards (Hewitt, 1983).

It will not be wrong to say that the ability to repond and cope with the bearings of natural disasters is a function of socio-economic as well as bio-physical factors. Lack of access to economic or human resources or knowledge can limit the knack to some socio-economic groups to respond amply to a disaster. Groups who conventionally experience low socio-economic status include minorities, women headed houseolds, the elderly, the unemployed, the illiterate or uneducated, the ill or handicapped. Housing status, whether renting or owing property can also limit an individual's propensity to repond to natural disaster.According to Bullard and Wright (2005), home ownership is a cushion against inflation, the cornerstone of economic wealth creation and a long term asset that can secure advantage and transfer across generations of material wealth and security. Low income households tend to rent rather than own their homes. The potential for damage is also affected by the type and quality of housing in the hazard prone area. Mobile or poor constructed or maintained homes are genrally occupied by low income people and which are easily destroyed in the event of a natural disaster.

Table 5.1.1: Population Characteristics Influencing Social Vulnerability

POPULATION CHARACTERISTICS	DESCRIPTION	INCREASES (+), DECREASES (-) SOCIAL VULNERABILITY
Socio-economic status (income, political power, prestige)	Wealth enables individual to absorb and recover from loses more quickly using insurance, social safety nets and entitlements programs.	High status (+/-) Low Income or status (+)
Gender	Women often have more difficult time during recovery than men because of lower wages and family care responsibilities	Gender (+)
Race and Ethnicity	These factors impose language or cultural barriers and affect access to post-disaster funding and occupation of high hazard areas.	Non-white (+) Non-Anglo (+)
Age	Extreme of age affects the movement out of harm's way. The elderly may have mobility constraints or concerns that increase the burden of care and lack of resilience.	Elderly (+) Children (+)
Residential Property	The value, quality and density of residential construction affect potential loses and recovery. Expensive homes are costly to replace, mobile homes are easily destroyed and less resilient to hazards	Mobile homes (+)
Renters	People rent because they transients, do not have the financial resources for homeownership, or do not want the responsibility of homeownership. They often lack access to information about financial aid during recovery. In extreme cases renters lack sufficient shelter options when lodging becomes uninhabitable or too costly to afford.	Renters (+)
Education	Education is linked to socio-economic status in that higher educational attainment affects lifetime earnings, and limited education constrains the ability to understand warning information and access recovery information.	Little Education (+) Highly Educated (-)
Health Status	People with pre-existing illnesses may be at risk for death/illness/injury in disaster setting. Additionally lack of access to adequate health or health insurance would increase vulnerability to natural disasters.	Major Health problems (+) Minor or No Health

		problems (-)
Social Dependence	People who are totally dependent on social services for survival are already economically and socially marginalized and require additional support in the post-disaster period.	High dependence (+) Low dependence (-)
Special-needs Population	Special-needs populations (infirm, institutionalized, transient and homeless) are difficult to identify, let alone measure and monitor. Yet it is this segment of society that invariably is left out of recovery efforts, largely because of this invisibility in communities.	Large number of special needs (+) Small number of special needs (-)
Other facilities / or Services	In a hazard like landslides, services (water supply, electricity, and drainage systems, may be close or open or having no drainage system in the area) have a role to play. Cut-off from this kind of services is vulnerable for the population and difficult for them to adjust.	Closed drainage (-) Open drainage (+) Cut-off Electricity & Water supply (+)

[SOURCE: Cutter et al. (2001)**]**

As a result of the cobination of all these factors, low income households and communities are more vulnerable to natural disasters than wealthier ones, they tend to live in a more hazardous places, have less protection and have fewer reserves or insurance and alternatives. People living in poverty or with inadequate resources may be less likely to perform necessary actions to mitigate the effects of hazardous agents because of a lack of a sense of personal control over potential outcomes (Vaughan, 1995). Community level factors such as urban versus rural setting, infrastructure, medical services, and available social services also affect hazard vulnerability (Cutter et al., 2001).

5.2 VULNERABILITY ASSESSMENT:

*"**A vulnerability assessment** is the process of identifying, quantifying, and prioritizing (or ranking) the vulnerabilities in a system. Vulnerability from the perspective of disaster management means assessing the threats from potential hazards to the population and to infrastructure. It may be conducted in the political, social, economic or environmental fields."*

However, social vulnerability is a pre-existing condition that affects a society's ability to prepare for and recover from a disruptive event.

*"**Social Vulnerability** is the dimension of vulnerability to multiple stressors and shocks, including abuse, social exclusion and natural hazards. Social vulnerability refers to the inability of people, organizations, and societies to endure adverse sways from numerous stressors to which they are exposed".*

These impacts are due in part to characteristics inherent in social interactions, institutions, and systems of cultural values. Because it is most apparent when calamity occurs, many studies of social vulnerability are found in risk management literature (Peacock and Ragsdale 1997; Anderson and Woodrow 1998; Alwang, Siegel et al. 2001; Conway. T & Norton. A 2002)

5.3 BUILDING SOCIAL VULNERABILITY INDICES

5.3.1 PRINCIPAL COMPONENT ANALYSIS:

Some broad indicators of vulnerability appear repeatedly in the vulnerability assessment in literatures, although different variables may be chosen to represent each indicator depending upon such factors as availability of data. The main indicators are age, disability, education, medical facilities, water supply, drainage, and electricity, Ownership status. These indicators have been further subcategorized according to the Census of India 2011 division to make it easier and reliable for study work, so that the analysis of these factors becomes much more sophisticated. Income factor has been analyzed separately. To capture these indicators, fifty one variables were chosen for inclusion in a principal component analysis of social vulnerability. All variables were derived from the 2011 Census of India and were analyzed at the district level. The basic aim of a principal components analysis is to reduce a complex set of many correlated variables into a set of fewer, uncorrelated components.

The variables were entered into a correlation matrix and a Varimax orthogonal rotation with Kaiser Normalization was applied to the solution (George and Mallery, 2003). This approach generated thirteen components accounted for 80 % of the variance in the dataset, however, with such a large number of components, each component were extracted for analysis. After examining a scree plot, only three components accounted for 55% of the variance in the dataset.

All the 51 indicators which have been used for PCA analysis has been shown in table 5.3.1.1 below:

TABLE 5.3.1.1: 51 Indicators for PCA Analysis

S.No.	INDICATORS	S.No.	INDICATORS
1.	population under age group of 0-6 years	22.	Number of hospitals
2.	population above 60 years	23.	total number of Primary Health Centres
3.	Per capita income	24.	Total number of Primary health sub-centers
4.	Average number of people per household	25.	population living in urban areas
5.	persons living in poverty	26.	population with disability
6.	renter occupied housing units	27.	Total population growth
7.	housing units per sq. mile	28.	people dependent on Tap water from treated sources
8.	female work participation rate	29.	people dependent on Tap water from untreated sources
9.	Female population	30.	people dependent on covered well
10.	employed in primary industry	31	people dependent on uncovered well
11.	employed in transportation, communication & other public utilities	32.	of people dependent on Springs
12.	employed in service occupation	33.	people dependent on other sources
13.	Average family income	34.	people dependent on electricity
14.	Percentage of population change	35.	people having no electricity
15.	population density per sq. km	36.	people dependent on other sources
16.	Female literacy rate	37.	people having closed drainage
17.	Number of physicians per 100000 population	38.	people having open drainage
18.	permanent census houses	39.	people having no drainage
19.	semi-permanent census houses	40.	people dependent on Fire-wood for cooking
20.	semi-permanent census houses	41.	people dependent on electricity for

			cooking
21.	Nepali speaking population	42.	people dependent on LPG for cooking
43.	Bhutia speaking population	48.	Total literacy rate
44.	Lepcha speaking population	49.	Kutcha house
45.	Other languages	50.	Pucca house
46.	houses in good condition	51.	household in livable condition
47.	household in dilapidated condition		

All the above indicators have been used for analysis so that the vast number of indicators can be organized in a proper and concise way. After the factor analysis 24 indicators have been found for the calculation of SVI with Eigen 0.5 to 1. These 24 indicators have been shown with its absolute value below in the table 5.3.1.

5.3.2 CACULATION OF SOCIAL VULNERABILITY INDEX:

Here Cutter's method (1997) of calculating Social Vulnerability Index has been followed for fulfilling the objective of the chapter. Social vulnerability here is determined by calculating the percentage of every variable for each district where the absolute values has been collected from Census of India. The percentages are than normalized to determine every variable's Social Vulnerability (SV) for each district and after that the SV's for each district are combined to create the Social Vulnerability Index (SVI). The first calculation in the process finds out the percentage of each variable and the calculation used to find out the 1st step result is expressed as:

$$[X=a/b]$$

Where "a" represents the value of the variable for the districts and "b" represents the total value of the variable for the entire state. For example, from a state of four districts, one district has a female population of 18841 (a) and the entire state has population of 286027 females (b) then the percentage (X) of females in that particular district would be 6.587.

The next step is calculating the SV, which is expressed as:

$$[SV= X/X_{max.}]$$

Where, X represents a district individual variable for any of the district in the state. This normalizes the percentage to yield an indicator score between 0 and 1. Based on previous sum and continuing the same 6.587 represent the X. if the greatest value or $X_{max.}$ for the female variable is 43.504, the SV for this particular district would be 0.144.

So on the method of calculation is continued for each variable in every district. Finally after calculating the social vulnerability scores for each district, the scores are summed to form a final Social Vulnerability Index (SVI):

$$SVI = SV_1 + SV_2 + SV_3 + \ldots\ldots SV_n$$

Mapping these index scores illustrates social vulnerability across the state and its district, highlighting the location of high and low scores areas, where social groups are most and least vulnerable to hazard, respectively.

The result, after calculating Social Vulnerability Index (SVI), shows that East district is much more vulnerable than that of other districts in every term. Below is the table which shows the complete vulnerability Index and ranking of the districts in terms of its vulnerability to hazards of any kind.

Table 5.3.1: Showing 24 Selected Indicators of Social Vulnerability with its Absolute value

DISTRICT	pop 0_6 (1)	H_owned (2)	Renter (3)	pop_density (4)	Fe_Literacy (5)	pop_disability (6)
SIKKIM	61077	82619	39144	86	67107	18187
NORTH	4479	5566	2501	10	8819	1343
WEST	14957	23013	3943	117	17614	3905
SOUTH	15070	21582	7532	196	13134	5375
EAST	26571	32458	25168	295	27540	7564

DISTRICT	HH_tap_treated (7)	HH_tap_untreated (8)	HH_Springs (9)	Electricity (10)	No_electricity (11)	Closed_drain (12)
SIKKIM	37410	71858	14163	118578	650	18737
NORTH	565	5837	2228	7826	58	682
WEST	3714	19589	2840	25272	147	1565
SOUTH	24824	27139	7107	27587	123	1777
EAST	8307	19293	1988	57893	322	14713

DISTRICT	Open_drain (13)	No_drain (14)	Wood_cooking (15)	Elec_cooking (16)	LPG_cooking (17)	Nepali Pop. (18)
SIKKIM	48826	60568	67310	333	52871	338606
NORTH	3586	4635	5710	14	2343	9198
WEST	8461	17834	21361	117	35170	72974
SOUTH	10815	17654	18714	191	10021	96160
EAST	25964	20445	21525	11	5337	160274

DISTRICT	Bhutia Pop. (19)	Lepcha Pop. (20)	Others Lang. (21)	H_G_cndt (22)	H_liv_cndt (23)	Dilp_cndt (24)
SIKKIM	41852	35728	117931	72442	48739	6950
NORTH	6418	12628	11881	4791	3798	314
WEST	6703	8524	34737	11707	13973	2180
SOUTH	5594	5146	23180	16438	12258	1550
EAST	23110	9430	48133	39506	18710	2906

(**Source:** Census of India, 2011)

These absolute are than normalized or standardized to change it to zero to one scale (0-1) and social vulnerability has been calculated and then summed up to find the Social vulnerability Index.

Table 5.3.2: Values of Social Vulnerability after Standardization

DISTRICT	pop 0_6 (1)	H_owned (2)	Renter (3)	pop_density (4)	Fe_Literacy (5)	pop_disability (6)
NORTH	0.169	0.171	0.099	0.034	0.320	0.178
WEST	0.563	0.709	0.157	0.397	0.640	0.516
SOUTH	0.567	0.665	0.299	0.664	0.477	0.711
EAST	1.000	1.000	1.000	1.000	1.000	1.000

DISTRICT	HH_tap_treated (7)	HH_tap_untreated (8)	HH_Springs (9)	Electricity (10)	No_electricity (11)	Closed_drain (12)
NORTH	0.023	0.215	0.313	0.135	0.180	0.046
WEST	0.150	0.722	0.400	0.437	0.457	0.106
SOUTH	1.000	1.000	1.000	0.477	0.382	0.121
EAST	0.335	0.711	0.280	1.000	1.000	1.000

DISTRICT	Open_drain (13)	No_drain (14)	Wood_cooking (15)	Elec_cooking (16)	LPG_cooking (17)	Nepali Pop. (18)
NORTH	0.138	0.227	0.265	0.073	0.067	0.057
WEST	0.326	0.872	0.992	0.613	1.000	0.455
SOUTH	0.417	0.863	0.869	1.000	0.285	0.600
EAST	1.000	1.000	1.000	0.058	0.152	1.000

DISTRICT	Bhutia Pop. (19)	Lepcha Pop. (20)	Others Lang. (21)	H_G_cndt (22)	H_liv_cndt (23)	Dilp_cndt (24)
NORTH	0.278	1.000	0.247	0.121	0.203	0.108
WEST	0.290	0.675	0.722	0.296	0.747	0.750
SOUTH	0.242	0.408	0.482	0.416	0.655	0.533
EAST	1.000	0.747	1.000	1.000	1.000	1.000

Final calculation of SVI for the district has been analyzed on the basis of the values came while going through different steps. Below is the table which shows the values and ranking status in terms of vulnerability.

Table 5.3.3: Social Vulnerability Index

DISTRICT	SVI
NORTH	4.668
WEST	12.990
SOUTH	14.133
EAST	20.281

The overall result of the Social Vulnerability Index shows that East district is more vulnerable as compared to other districts. Population density in this district is highest and so the amount of property damage and all other loses will also be higher. The value shows that East has the highest score followed by South, West and North but it may is varying on the ground when the field study has been done. East has the highest the highest vulnerability to hazard but North doesn't have the least value. At ground level North is socially more vulnerable in rural areas.

5.3.3 CASE STUDY:

Total of 330 samples has been collected from all the four districts covering different blocks and villages of Sikkim. In North Mangan (urban), Toong-Naga (rural area under Kabi Tingda block) & Lachung Dzumsa has been considered for study where total 90 samples were collected from all the three areas. Similarly, Gyalshing (Urban) & Dentam (Rural) in West, total of 80 samples from this part, Namchi (Urban) & Temi-Tarku (Rural) in South from where 60 samples and Singtam (Urban) & Rakdong-Tintek (Rural) block in the East from where 100 samples has been collected for studies. S.S here represents the total number of sample sizes in different area which has been represented in the form of percentage of one indicator from the total sample size.

TABLE 5.3.3.1: Showing 24 Indicators in selected Rural Areas of Sikkim

RURAL AREAS (%)						
DISTRICT	**pop 0_6 (1)**	**H_owned (2)**	**Renter (3)**	**pop_density (per sq.km) (4)**	**Fe_Literacy (5)**	**pop_disability (6)**
NORTH (Lachung Dzumsa)	05	80	20	09	30	02
WEST (Dentam)	03	75	25	50	45	04
SOUTH (Temi-Tarku)	02	80	20	55	55	02
EAST (Rakdong Tintek)	05	70	30	30	30	02

RURAL AREAS (%)						
DISTRICT	**HH_tap_treated (7)**	**HH_tap_untreated (8)**	**HH_Springs (9)**	**Electricity (10)**	**No_electricity (11)**	**Closed_drain (12)**
NORTH (Lachung Dzumsa)	50	30	20	70	30	10
WEST (Dentam)	25	30	45	65	35	25
SOUTH (Temi-Tarku)	20	20	60	65	35	10
EAST (Rakdong Tintek)	51	48	01	85	15	20

RURAL AREAS (%)						
DISTRICT	**Open_drain (13)**	**No_drain (14)**	**Wood_cooking (15)**	**Elec_cooking (16)**	**LPG_cookng (17)**	**Nepali Pop. (18)**
NORTH (Lachung Dzumsa)	55	35	40	25	35	10
WEST (Dentam)	40	35	45	20	35	70
SOUTH (Temi-Tarku)	65	25	52	12	36	75
EAST (Rakdong Tintek)	45	35	25	25	50	50

5.3.3 CASE STUDY:

Total of 330 samples has been collected from all the four districts covering different blocks and villages of Sikkim. In North Mangan (urban), Toong-Naga (rural area under Kabi Tingda block) & Lachung Dzumsa has been considered for study where total 90 samples were collected from all the three areas. Similarly, Gyalshing (Urban) & Dentam (Rural) in West, total of 80 samples from this part, Namchi (Urban) & Temi-Tarku (Rural) in South from where 60 samples and Singtam (Urban) & Rakdong-Tintek (Rural) block in the East from where 100 samples has been collected for studies. S.S here represents the total number of sample sizes in different area which has been represented in the form of percentage of one indicator from the total sample size.

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NORTH (Lachung Dzumsa)	05	80	20	09	30	02
WEST (Dentam)	03	75	25	50	45	04
SOUTH (Temi-Tarku)	02	80	20	55	55	02
EAST (Rakdong Tintek)	05	70	30	30	30	02

RURAL AREAS (%)						
DISTRICT	**HH_tap_treated (7)**	**HH_tap_untreated (8)**	**HH_Springs (9)**	**Electricity (10)**	**No_electricity (11)**	**Closed_drain (12)**
NORTH (Lachung Dzumsa)	50	30	20	70	30	10
WEST (Dentam)	25	30	45	65	35	25
SOUTH (Temi-Tarku)	20	20	60	65	35	10
EAST (Rakdong Tintek)	51	48	01	85	15	20

RURAL AREAS (%)						
DISTRICT	**Open_drain (13)**	**No_drain (14)**	**Wood_cooking (15)**	**Elec_cooking (16)**	**LPG_cookng (17)**	**Nepali Pop. (18)**
NORTH (Lachung Dzumsa)	55	35	40	25	35	10
WEST (Dentam)	40	35	45	20	35	70
SOUTH (Temi-Tarku)	65	25	52	12	36	75
EAST (Rakdong Tintek)	45	35	25	25	50	50

RURAL AREAS (%)						
DISTRICT	**Bhutia Pop. (19)**	**Lepcha Pop. (20)**	**Others Lang. (21)**	**H_G_cndt (22)**	**H_liv_cndt (23)**	**Dilp_cndt (24)**
NORTH (Lachung Dzumsa)	45	35	10	35	30	35
WEST (Dentam)	05	05	20	35	35	30
SOUTH (Temi-Tarku)	05	05	15	30	35	35
EAST (Rakdong Tintek)	05	05	40	45	45	10

(**SOURCE:** Field Survey, 2014)

The above table (5.3.3.1) shows that in rural areas North district has the higher population in the age-group of 0-6 years and also higher in ownership of households including South district also i.e. people having their own house are vary in percentage because these areas are villages where development and proper infrastructures are lacking behind. Almost 80% of the people have ownership of their own which also shows that they don't have much of their relatives outside that place and so these groups of people are much more vulnerable in time of hazards because of no other alternative options. In case of renter's East district has the highest percentage of households living in rent, following this indicator the percentage of disabled population in the East is also higher compared to other districts.

Houses that are dependent on tap water governmental supply of water are much higher in East Sikkim i.e. in Rakdong-Tintek (51%) of the total sample size in this particular rural area whereas houses that are dependent on springs are higher in rural areas Temi-Tarku (60%), South district. Households having electricity supplies also show highest record in East district. It can be said that Water supply and electricity's are the two things which is affected by the occurrence of landslides. Talking about the drainage system in rural areas it is noticed that it is not that developed and so open drains are higher in percentage in south district and west has the highest percentage record in the households having no drainage system. In managing cooking system North district has the highest value of wooden cooking. Rakdong-Tintek in East has the highest values of LPG cooking facilities which clearly show that North is much more vulnerable to landslide because of more use of woods for cooking purposes and due to which people will be much more dependent on forest for fulfilling their needs.

Due to less number of people or households speaking other languages mostly Nepali and Lepcha speaking population are higher in number and highest percentage of households speaking these languages are much higher in North Sikkim, where condition of Dilapidated houses are also much more higher and houses which are in good and livable condition is high in East Sikkim. From above analysis it is clear that in rural areas Northern part of Sikkim is much more vulnerable to hazards than that of other districts.

TABLE 5.3.3.2: Showing 24 Indicators in selected Urban Areas of Sikkim

URBAN AREAS (%)						
DISTRICT	**pop 0_6 (1)**	**H_owned (2)**	**Renter (3)**	**pop_density (per sq.km) (4)**	**Fe_Literacy (5)**	**pop_disability (6)**
NORTH (Mangan)	10	75	25	10	25	05
WEST (Gyalshing)	04	69	31	65	20	05
SOUTH (Namchi)	05	55	45	105	45	05
EAST (Singtam)	15	40	60	100	65	05

URBAN AREAS (%)						
DISTRICT	**HH_tap_treated (7)**	**HH_tap_untreated (8)**	**HH_Springs (9)**	**Electricity (10)**	**No_electricity (11)**	**Closed_drain (12)**
NORTH (Mangan)	20	55	25	77	23	15
WEST (Gyalshing)	40	35	25	55	45	20
SOUTH (Namchi)	50	30	20	80	20	20
EAST (Singtam)	55	25	20	90	10	25

URBAN AREAS (%)						
DISTRICT	**Open_drain (13)**	**No_drain (14)**	**Wood_cooking (15)**	**Elec_cooking (16)**	**LPG_cokng (17)**	**Nepali Pop. (18)**
NORTH (Mangan)	51	34	20	35	45	40
WEST (Gyalshing)	50	30	40	05	55	55
SOUTH (Namchi)	45	35	15	30	55	55
EAST (Singtam)	55	20	10	35	55	35

URBAN AREAS (%)						
DISTRICT	**Bhutia Pop. (19)**	**Lepcha Pop. (20)**	**Others Lang. (21)**	**H_G_cndt (22)**	**H_liv_cndt (23)**	**Dilp_cndt (24)**
NORTH (Mangan)	30	20	10	25	55	20
WEST (Gyalshing)	10	05	30	40	35	25
SOUTH (Namchi)	10	10	25	55	30	15
EAST (Singtam)	10	05	50	50	40	10

(**SOURCE:** Field Survey, 2014)

Talking about the urban areas of Sikkim, the above Table (5.3.3.2) shows that population of people under age group of 0-6 years is much higher (15%), in Singtam, East, this also indicates that this group is much vulnerable during hazards. In Ownership status North has the highest percentage of households holding their own houses whereas the renter population is higher in East district which shows that Singtam, East Sikkim has high ongoing developmental activities & infrastructure development and due to which the percentage of other languages speaking people are much more higher in Singtam which also indicates in one way that income status or income generating opportunities are much more higher in this part of state where most of the people are middle incomer.

Though literacy rate of females is much higher as compared to other blocks in urban areas but awareness about the hazard is not that high in any of the block. The disability among the people is also very high (06%) in Singtam (East) and so it is more vulnerable to landslips. Again East has the highest percentage of people using Government water supplies from taps and percentage of using spring waters are higher (25%) in Mangan & Gyalshing (North & West), respectively.

Electricity supplies are also higher (90 & 80%) in Singtam followed by Namchi, East & South respectively, making it more vulnerable during hazards because it is very much affected when landslides occur which harms the electric poles and supplies. Drainage system in the urban areas is more systematic than that of rural areas but still East reports the higher percentage of households who have open drainage system and which makes it vulnerable to landslides because drainage is one of the factor which leads to increase in cases of landslides.

The condition of houses are much more better and in Good condition in East district which also indicates towards that if any incidents takes place if the building is affected or knocked out than it may harm or affect the surrounding buildings in the areas making it vulnerable during an hazard.

Overall it can be said that if compared to the Vulnerability Index among overall districts East is more vulnerable and Urban areas also East district is much vulnerable to hazards but in rural areas it signs towards the Northern part of Sikkim which is more affected during an hazard occurrence or during an case of landslides.

Social Vulnerability Index of Sikkim shows that East district is the most vulnerable part of Sikkim and case studies in selected blocks from each district also reveals that blocks which falls under East district is much more vulnerable as compared to other blocks. But the result varies in terms of rural and urban areas vulnerability position. Though according to study and data gathered from field Eastern part is more vulnerable to landslides but it is only for Urban areas including the all four districts whereas in rural areas blocks which falls in North Sikkim are much more vulnerable to these kind of disaster. This may be because in rural areas people have less awareness about the event itself and accessibility of facilities or basic needs are not that developed and they are dependent on the urban and more developed areas.

The analysis also indicates that if any sort of incident takes place in urban areas, the rural villages are always cut-off because of transportation and communication gaps. It has been noticed that urban area is more vulnerable also because of its developmental activities and huge and haphazard infrastructural development in the study area, owing people more prone to the disasters which takes the form of hazard for the settlements and creates havoc for them and can give it a worse shape in near future.

PLATE 6: Loss of road connectivity for about a month

(**Source:** Field Survey 2014)

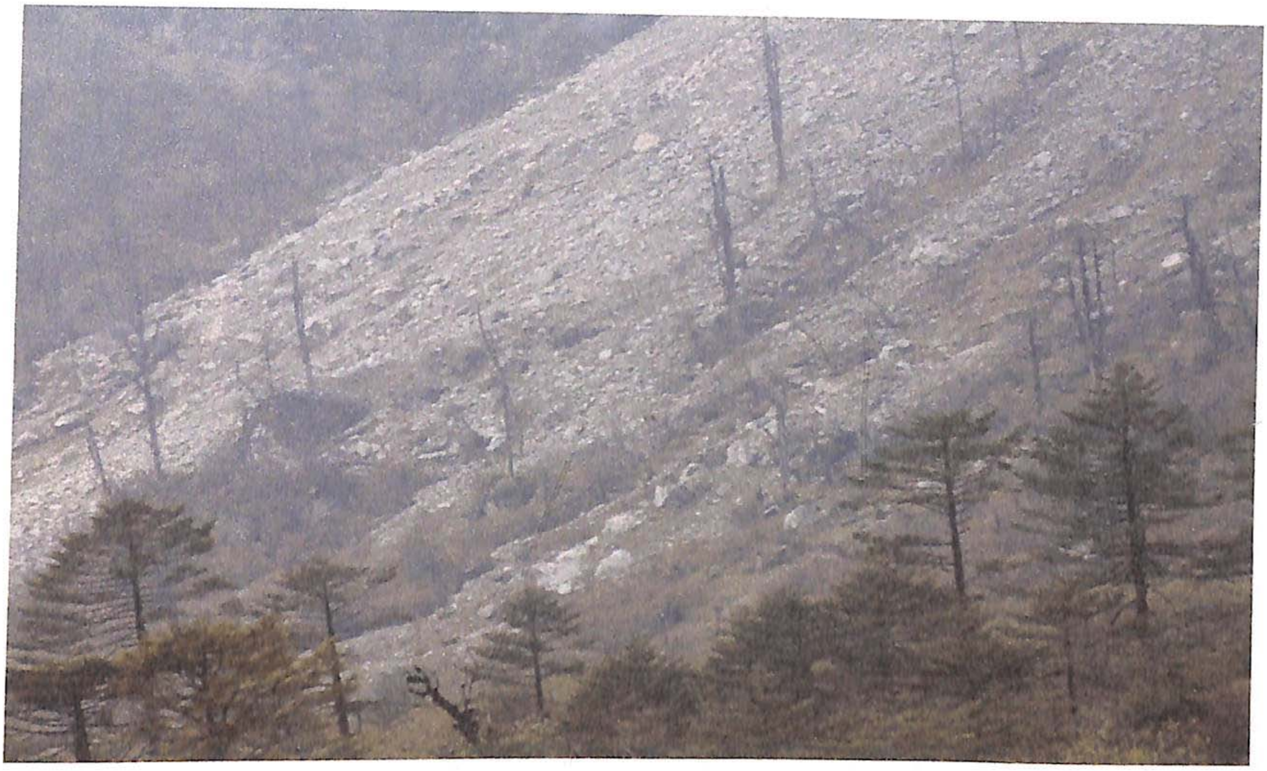
PLATE 7: Poor road connectivity due to Landslides

(**Source:** Field Survey 2014)

PLATE 8: Apple agriculture completely destroyed due to huge landslide in Lachung

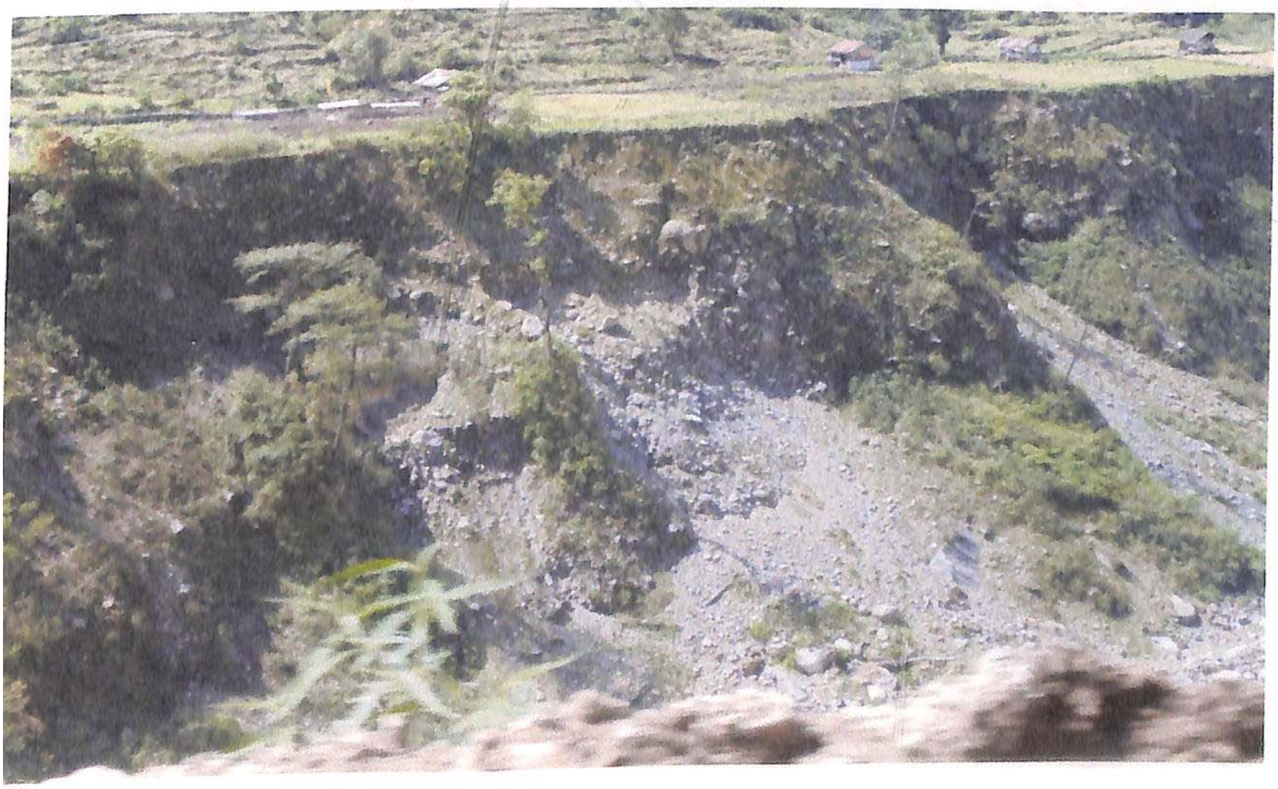
(**Source:** Field Survey 2014)

PLATE 9: Agriculture production affected due to Landslides

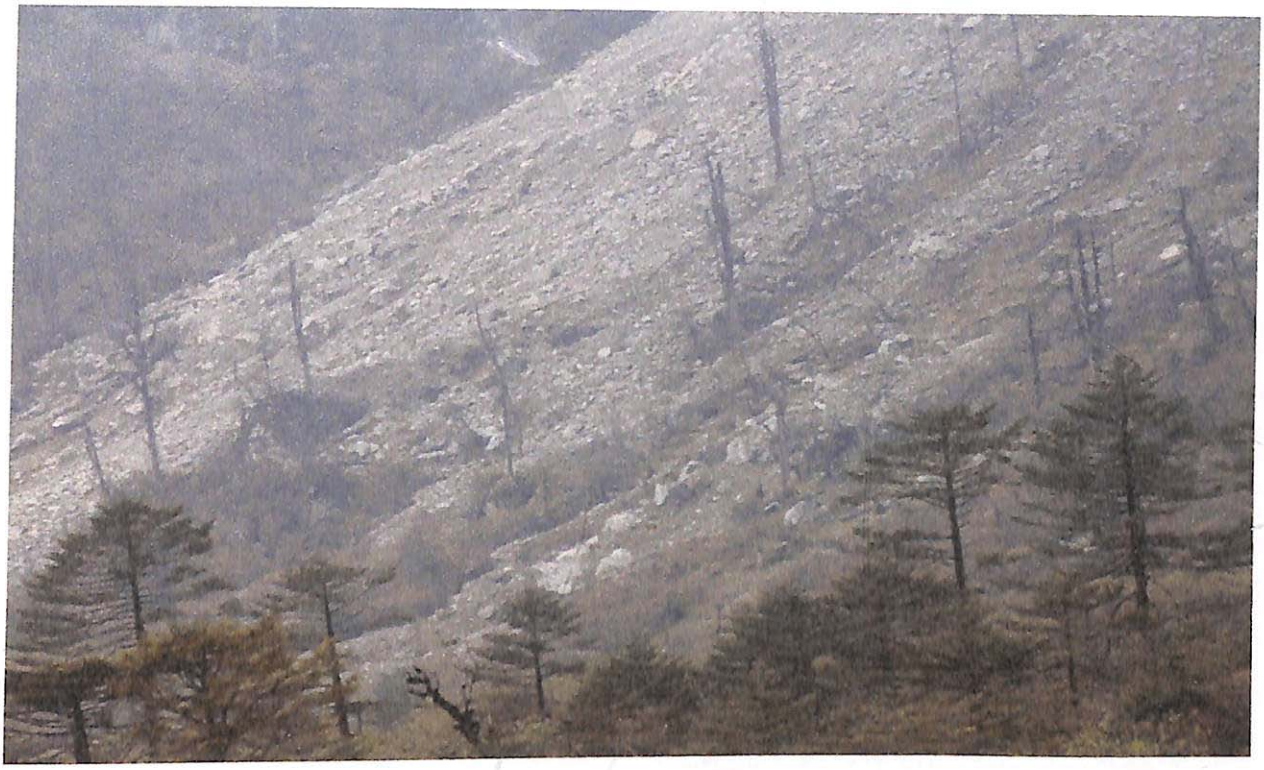


(**Source:** Field Survey 2014)

PLATE 10: Loss of Agricultural Land due to Sliding down

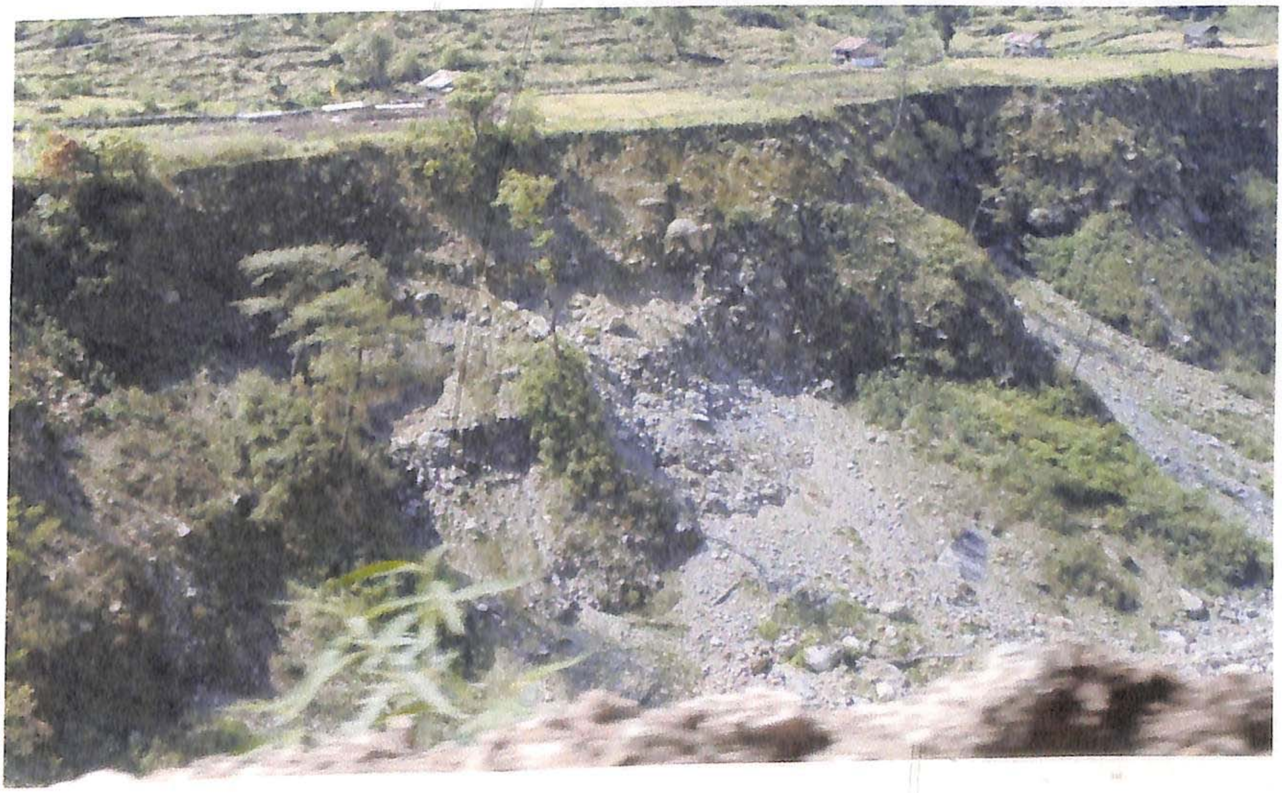


Source: Field Survey 2014)



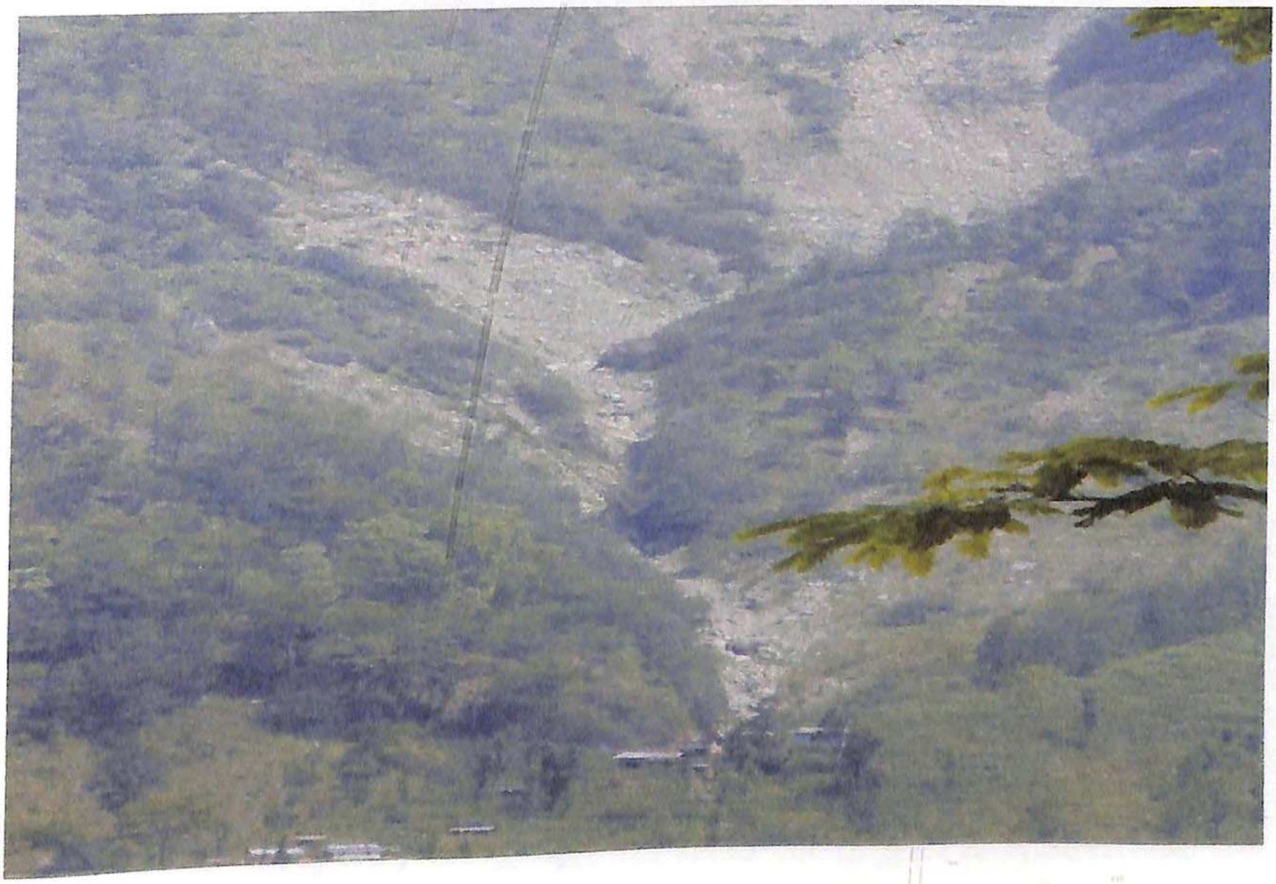
(**Source:** Field Survey 2014)

PLATE 10: Loss of Agricultural Land due to Sliding down



(**Source:** Field Survey 2014)

PLATE 11: House vulnerable due to slides and built under more active zone



(**Source:** Field Survey 2014)

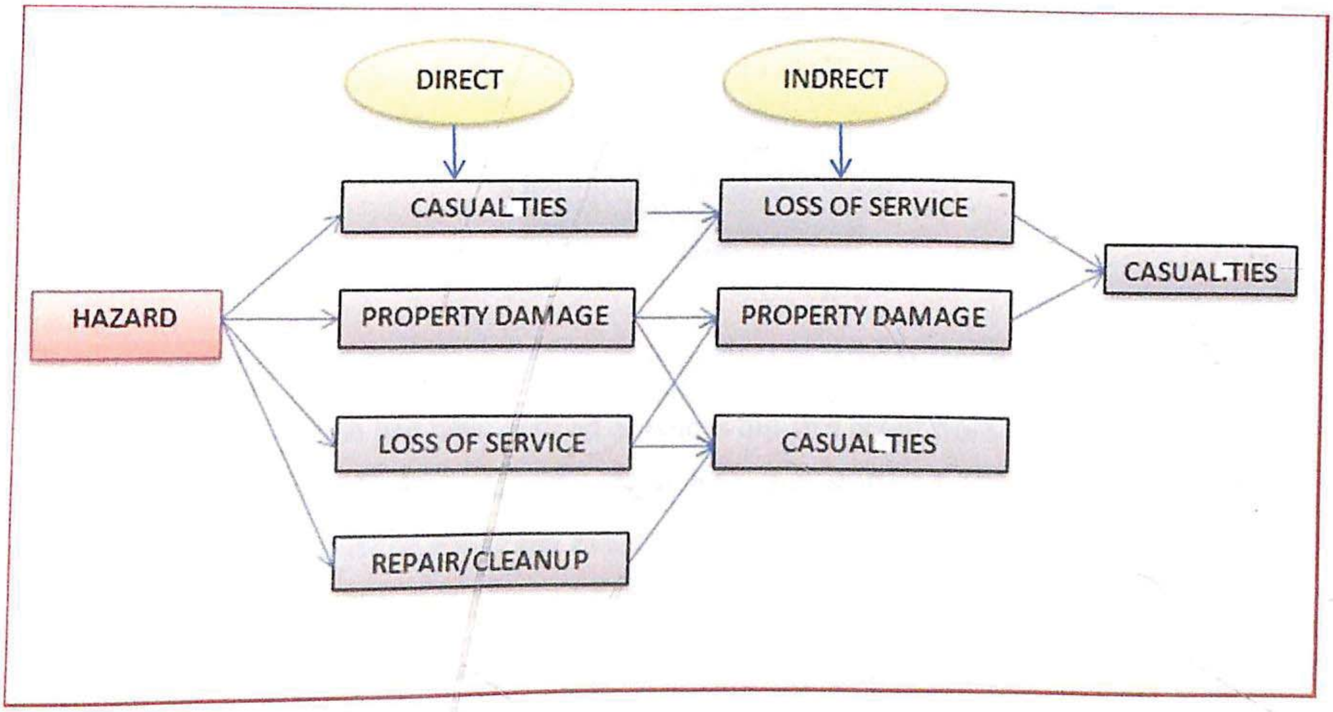
PLATE 12: House Knocked-Out by Landslide

(**Source:** Field Survey 2014)

The impact of a hazard may be direct and indirect both but the ultimate solution comes from the fact that how society or any community cope with it or adopt with the situation.

Direct impacts lead to casualties, property damage, loss of services to the general public and Indirect impacts leads to loss of service & casualties through property damage and casualties through property damage & repair works but the ultimate result of all these leads to the birth or increase of casualties. These consequences are inter-related to each other and one factor leads to the growth of other and vice-versa.

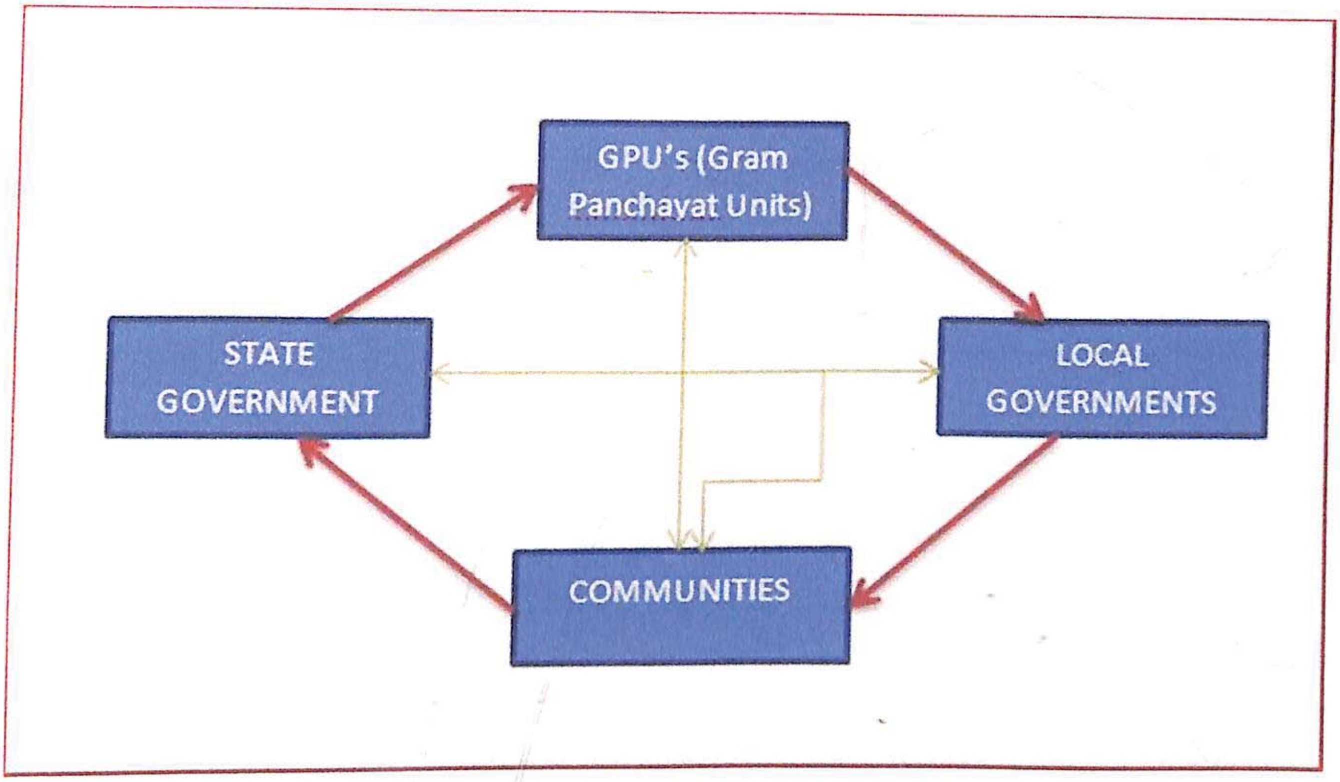
FIG. 5.3.1: Direct and Indirect consequences of landslides



During an interview in one of the block with the Panchayat it is being said that people do not take interest in awareness programs and do not become the part of it. According to them this will not help them and it is waste of time.

On the other hand talking with the residents it has been informed that they had never been called for such programs or had not been give any training about any kind of hazard. There is a gap between the officials of the village and the residents and it is very important for the government and the people both that this gap should be replaced by proper understanding and increasing knowledge among the residents.

FIG.5.3.2: Inter-Relationship between the all the Governmental Organizations and Local Communities



The impact which had been noticed or comes out as a result from this study is that in a society vulnerable people are generally those who are shattered by low incomes, poor facilities, and less knowledge about any event which can take place in that particular area or how to take precautions about any kind of hazards.

Circumstances generally forces people to take any sort of decision whether in their favor or not and that should be understood by each and every individual to overcome the impact of any kind of hazard and that can be done only through proper knowledge and awareness among the communities and societies.

Chapter - VI

Findings Recommendations and Conclusion

6.1 FINDINGS:

Social Vulnerability Index of Sikkim shows that East district in general is highly vulnerable to disasters and hazards and this may be because of high population increase in this district and development taking place at higher pace. The SVI values of each district shows a distinction in the vulnerability during a disaster where East district holds the highest value of 20.281. According to the value of SVI in overall index calculation North district is the least vulnerable to disasters and this may be because North district has the lowest contribution in the state's population and in other fields too.

North districts mostly lack in fulfilling basic facilities also and accessibility to this area is also very challenging and so during a disaster the area most of the time gets cut-off from the main land which makes them vulnerable in any disaster and hazard. Transport networks and communication is not up to the mark in villages of North district and that's why this area is very vulnerable to hazard.

The study shows difference in overall vulnerability index and field based vulnerability analysis. According to SVI East is more vulnerable but according to the ground study rural areas of North district is more vulnerable to landslide hazard, though in Urban areas again East district is much more vulnerable.

It is clear from the field study that the social condition is worst in the North district of Sikkim mainly in rural areas. There are some indicators which lead to increases in the cases of landslides and some factors which get affected by landslides. Factors like drainage system, type of area, & education leads to landslides whereas electricity, source of water, house type are affected by landslides. Out of total 330 samples, most of the households are affected whenever an incident of landslide takes place in terms of electricity supply and water supply. Water pipelines get damaged and electricity supplies get affected due to it. In East district water pipelines are affected most of the time because of the origin of pipelines in some of the areas whereas in North district roads and electricity gets damaged because of this hazard.

According to the survey in selected blocks from all the districts, East and North are the two districts which cover most of the landslide where East ranks top. In Rakdong-Tintek block one of the village called Dikchu, has always higher cases of landslides as compared to other blocks. Similarly, Singtam in the East, one of the sub-division of East District, has the highest cases of landslides and has high proportion of urban population and development taking place at high rate, arising new problems and creating havoc for the people to live their life peacefully. Natural hazards cannot be predicted to the extent that one can stop it or cannot be immobile but forcing or creating the situation which can increase its cases is on the hands of humans. Haphazard developments in this part have done havoc for the people and their living.

Field study clearly reveals that people from these areas are struggling highly due to incidents of landslides. From the study and above Index calculation it is clear that East district is highly vulnerable to landslides hazards and in Urban area also. East is the most vulnerable part leading to more number of landslides and this may be because of higher development and increase in construction works as well as massive population increase in this region. But even if the vulnerability is much higher in East district but if in terms of huge damage and losses it has been noticed that North district is more affected by landslides and it is also clear from the study of different rural areas that North is much more vulnerable in rural areas. In areas like Chungthang & Lachung in the Northern part of Sikkim, whenever any massive cases of landslide are noticed its after affects are much higher. One of the reason may be that each and every supply for fulfilling basic needs of life comes from main urban centres of Eastern part of Sikkim to the North and due to which even if any incident of landslide takes in the East which links the roadways from North is being more affected.

Landslide referred as one of the main hazard in the state of Sikkim and which also creates many problems for the local residents to live life with no trouble. It cannot be said that development should not take place but even if it's taking place it should be to the extent where the human security is not affected. Each and every type of development has positive and negative effects, positive in the sense that it helps the society to overcome its necessities and contributes in the areas overall development but at the same time it generates place for some sort of hazard to take place. It can be of any kind and may be big or small and generally this kind of hazard is named as "Human Induced Hazards".

If talked about the North district of Sikkim the intensity of landslide is much higher in this area but in terms of losses, people from this place mainly face the communication gap and road networks are very weak in these areas. Roads are blocked at regular basis due to landslides in these areas and people tend to face problems due to this. In a discussion with the residents of Lachung area, it has been noticed that the main problem of the people in this Dzumsa is losing the agricultural lands. Their basic complaint is that due to increase in the cases of landslides, their agricultural lands are much more affected. The area of the land is decreasing and crops also get affected due to it. The day-to-day life is affected when the road network is disturbed due to bigger cases of slides.

Many houses are also built on the verge of slides where new or old landslides are taking place or have taken place respectively. One reason comes in front through interviewing some of the locals individually that they do not have any alternatives to change their place and go or opt for other places, they are not that economically strong to construct their house again and again and whenever any sort of damages takes place they have to bear the damage or repair cost of their own which comes out as a big challenge for them.

6.2 RECOMMENDATIONS:

- If the outer rock is harder and there is presence of water in the inner part or it can be said that in loose soil due to presence of spring or high amount of water, incident of landslide is common. Similarly, if the rock is hard in nature but if its falling under MCT/MBT zone, which is susceptible to other disaster also than it is natural that landslide will take place and that's why it cannot be said that geology alone is the strong factor which lead to the occurrence of landslide in the area. Hence, a comprehensive study should be done to apprehend the involvement of these parameters or factors of landslide separately so that their nature and role can be better understood.
- People in the study areas are mainly blaming anthropogenic factors specifically Hydro-Power projects in the areas going on, which leads to damming and blasting process. So a further study can be done in this field that to what extent these factors are affecting or enhancing the event of landslide in the area.
- Traditional knowledge is considered as one of the valuable way of coping with or during a disaster and traditional people is very much aware of it. So exploration of this Traditional Ecological Knowledge in combating the other natural disasters and more added in respect to landslide hazards can be done & focussed further.
- A further study can be done in a more technical way by incorporation of Remote Sensing and GIS, including satellite images to verify the Spatial and Temporal variability of landslides.
- People's involvement in various types of awareness programmes and community based management programmes for managing different disasters should be focussed more and locals should be included in governmental organisations so that their knowledge can be incorporated to overcome the problems as well as human induced disasters.
- More research work and studies should be promoted in the governmental departments of the state, so that a better understanding of the villages can be done which will help in making and implementing policies and acts properly to the areas and in with each type of disaster in particular.
- Zonation mapping has been done by the state government but its use has not been implemented on the ground level. Susceptible and agricultural areas can be avoided

by the communities for the settlement and this should be implemented only through awareness programs through government and NGO's to the communities.

6.3 CONCLUSION:

Natural hazard is a threat of a naturally occurring event that will have a negative effect on the people or environment. A natural disaster is the effect of the earth's natural hazard. They can lead to financial, environmental or human losses and also may lead to mental loss and the resulting depends on the vulnerability of the affected population to resist the hazard.

Vulnerability assessment is the dimension through which inability of people, organizations and societies were known. Social vulnerability to a certain extent is the product of social inequalities, so it is not only registered by the exposure to hazards alone but also resides in the sensitivity and resilience of the system to prepare, cope and recover through these hazards. The ability of a system, community or individual to cope during disasters depends on their mental ability to resist after the incident of hazard or depends on the surrounding environments in which they are living.

Spatial and temporal variability of landslide basically means the variation of landslide with respect to space and time. Large variations are reported in the distribution of landslide in Sikkim from one place to another. It has also been reported that occurrences of landslides are not uniform over the time period. It has been found that cases of landslide is generally very high in the months of June to September during monsoon period in Sikkim and so there is an increase in the cases of landslides induced hazard during this periods.

It has been found that lithological variation as well as structural deformation in form of various large and small scale structural features mainly thrust, faults, small and large scale folds are geological controlling factor of the landslides in Sikkim. Some of the other important geological factors that controls landslides in Sikkim are joint planes, schistosity and axial planar cleavage In addition to these geological factors, high rainfall, steep topographical slope, and high weathering rate are other major contributory factors for the landslide prevalence.

Rainfall in Sikkim contributes a major role in generating landslides in different part of Sikkim. High intensity of rainfalls is related with debris flow & high amount rainfall & its duration are also responsible for deep rooted landslides. .Relief & elevation and slope has also important role in landslide generation. Relief and elevation are parallel to each other like relief is the topography of the area and elevation the height, if relief of the area is not good and elevation is high and it affects the slope. Similarly, slope gets destabilize by the presence of high level of fluids such as it fluidization of debris from earlier events and loss of suction forces in Silts materials which lead to shallow failures and undercutting of toe of the slope through river erosion.

One of the important things is the role of anthropogenic factors in generation of landslides in this region. Loss of vegetative cover, and slope modification for construction of various erections like roads & tunnels etc. is among the anthropogenic factors leading to high rate of landslide incident in Sikkim. Deforestation is considered as one of the important anthropogenic factors for increase in rate of landslide events and it is high in villages where wood is the primary source for cooking foods and for other uses.

In many of the places it is noticed that irrespective of being at the MCT or MBT zone & weak geological formations, the area is not prone to that much of landslides as other places are. Like Yuksom and Gyalshing (West Sikkim) lies on the same MCT belt but still Gyalshing is much more prone to landslide hazard than that of Yuksom. Similarly Khamdong and Ranka block falls under high precipitation zone but the incidences are much lesser than other blocks in East Sikkim. The reason other than the above mentioned factors is pointing towards the increase in population pressure of the region, and construction activities in the area and this human intervention for their comfort and development making it further copious vulnerable to landslides.

One of the recent incidents of landslide in Lachung witnesses the above problem of roads and communication. One of the bridge which connects the people of Lachung to Chungthang, from where small necessities is fulfilled for the people of Lachung and Lachen, was damaged completely due to landslide and the area was cut-off for vehicles for many weeks. Many people used to walk from Lachung to Chungthang if they did not get any vehicles for their respective destination.

As a result it can be said that the factors like geology & its formation type as well as the precipitation rate together may lead to higher rate of landslides in Sikkim making it more and more vulnerable to the natural disasters and with human interference it is getting worse.

It has been also found that the people of Sikkim are highly vulnerable to landslides and adapting to this phenomenon is very difficult for them. People do have their traditional ways for the management of landslides and owing to this they used many methods for taking precautions from natural hazards. Of course they cannot stop the occurrences of landslides but they can reduce the frequency and its effects. Communities in the villages used many traditional plants e.g. bamboo trees and Amliso (known as local broom) to overcome from the problem of landslips, basically those plants have soil binding properties. Amliso are generally preferred because of its dual use, one for soil binding and second as a broom which also helps people to get some profit out of selling it. Bamboo trees are also preferred because it is easy to grow and much effort is not needed for its growth.

It has also been found that people of Sikkim have strong faith on their culture and traditional practices to cope with the landslides and have opinion that planting trees can help in reducing the effect of landslides. They don't consider the building of retaining walls for preventing landslides as appropriate. The people has opinion that increase in landslide mostly effects their agricultural land and transportation. When a huge slide takes place in any of the area the local commuters do face the problems of connectivity/transportation and their day-to-day lives are ruined. The basic accesses to facilities are also blocked many times. People also reported the decrease in their agricultural land and productivity because of landslides.

The Lepcha people in the Dzongu region of Sikkim have strongly blamed human interference to the nature for increasing cases of all any natural these hazards. They believe that when nature is inhibited to the limit that it cannot resist their intervention than it gives havoc out of it which takes the form of disaster for them. The Lepcha's still practicing their own traditional way to mitigate the effect of natural hazards. They always used to follow their traditional knowledge which makes them unite at the time of disasters or hazard events. They have very strong belief in their culture, nature and traditions which according to them is always true to their knowledge.

High spatial and temporal variability of landslides in Sikkim may be attributed to lithological variation as well as magnitude of structural deformation in form of various large and small scale structural features viz., thrust, faults, small and large scale folds. Apart from these factors attitude of planar features like joint planes, schistosity and axial planar cleavage are some of the important geological factors controlling the incidence of landslides. The Spatial and Temporal variation also shows that frequency of landslides is higher in Easter part of Sikkim but the intensity of Landslide has been noticed higher in the Northern part of Sikkim.

The overall result of the Social Vulnerability Index shows that East district is more vulnerable as compared to other districts. Population density in this district is highest and so the amount of property damage and all other loses will also be higher. SVI of Sikkim shows that East district is the most vulnerable part of Sikkim and case studies in selected blocks from each district also reveals that blocks which falls under East district is much more vulnerable as compared to other blocks. But the result varies in terms of rural and urban areas vulnerability position. It has been noticed that urban area is more vulnerable also because of its developmental activities and huge and haphazard infrastructural development in the study area, owing people more prone to the disasters which takes the form of hazard for the settlements and creates havoc for them and can give it a worse shape in near future.

So better understanding of the disasters at all the level is very necessary so that it can be managed and proper help can be given to the communities at the time of emergency. Awareness at all the levels can help in proper management and this awareness should be carried forward to the communities in the villages. Governments initiatives for managing disaster in Sikkim includes many plans and acts but it has been lacking in the field of Implementation on the ground level which can be improved by proper communication between every levels of managing committee.

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