INVENTORY AND GIS MAPPING OF LANDSLIDES IN NORTH EAST WEST AND SOUTH SIKKIM & IT'S MITIGATION

सत्यमेव जयते

UNDP

NATIONAL DISASTER MANAGEMENT AUTHORITY • INDIA •

Published by
Sikkim State Disaster Management Authority,
Land Revenue & Disaster Management Department
Government of Sikkim

INVENTORY AND GIS MAPPING OF LANDSLIDES IN NORTH EAST WEST AND SOUTH SIKKIM & IT'S MITIGATION

Published by
Sikkim State Disaster Management Authority,
Land Revenue & Disaster Management Department
Government of Sikkim

Pawan Chamling
(Honoris Causa)
Chief Minister of Sikkim

03592-202575(O)
03592-202304®

Tashiling
Gangtok - 737102
Sikkim

MESSAGE

I am happy to know that Land Revenue & Disaster Management Department is bringing out publication on Inventory and GIS Mapping of Landslides in North, East, West and South Sikkim & its mitigation. The book, I am sure, will highlight the physiological aspect of our Landmass, terrain and land variation and define them in the light of new findings based on the GIS aided studies carried out by the Department.

As a mountainous State, Sikkim has to cope up with natural calamity which is often hazardous to life and property of people. Occurrence of landslides, earthquake, flash-floods, thunderstorms & blizzards etc. requires that we conceive developmental programs through proper and scientific planning duly taking care of unique geographical environment of the State. And publication of this book provide us with that road map of long term development planning which is environmentally sustainable.

Let me congratulate the Secretary and his entire team for bringing out this scientifically tenable document offering control measures and also mitigation process and provide a sense of security to our citizens in all the Districts.

(Pawan Chamling)

Karma Gyatsa, IAS
CHIEF SECRETARY

Tshiling Secretariat
Government of Sikkim
Gangtok - 737101
Sikkim

MESSAGE

Sikkim experiences events of landslides year after year especially during the monsoons and in periods of intense rainfall which cause damages to life and properties.

Various studies and researches have been conducted for study and mitigation of landslides. However, it has not been possible to control the forces of nature. The land - process activities have further been increased due to anthropogenic activities. It is felt, that pre-disaster preparedness for such hazards is called for. A multi-disciplinary approach needs to be adopted.

I am happy to learn that the Sikkim State Disaster Management Authority of land Revenue & Disaster Management Department has conducted a study on "Inventory and GIS Mapping of Landslides in North, East, West & South Sikkim and its Mitigation" recommending probable mitigation measures. These recommendations need to be applied as pre-disaster risk mitigation programme for treatment of landslides in Sikkim.

This courageous effort of the Sikkim Disaster Management Authority of Land Revenue & Disaster Management Department is appreciable, and I hope that such programmes are taken up in future also.

(Karma Gyastso) IAS

03592-202575(O)
03592-202304®

Tashiling
Gangtok - 737102
Sikkim

LAND REVENUE & DISASTER MANAGEMENT DEPARTMENT
GOVERNMENT OF SIKKIM

FOREWORD

Sikkim Himalayas are young and folded mountain chain, originated by the continent to continent collision of the Indian and the Eurasian (Tibetan) plate during late Miocense geological period. The process of collision is still continuing causing the landmass an episodic uplift known as thrusting. Sikkim Himalayas are the origin of two main river systems, Tista and Rangit, flowing north to south with many tributaries joining them on their course. These rivers are the main natural resource for the State, most important being the renewable hydro-power resource. These resources are being tapped for making sustainable development of the State. Tourism, Agriculture & Horticulture are the other perspectives that bring the State on the economic forefront. Many infrastructure projects of tourism importance are being developed in the State. Sikkim is bestowed with pristine natural beauty.

Sikkim, being located over the growing mountain chain and number of deep seated lineaments within, has been rated to fall under zone IV/V of the seismic zonation map of India. The North Eastern Himalayas including Sikkim fall under one of the six most seismically active regions of the world with expected PGA value of grater than 400 gal. If a higher intensity earthquake with magnitude greater than eight strikes, it would have a catastrophic impact in the area and may cause colossal loss of life and property in the region. The recent earthquake of 18th September 2011 with 6.8 magnitude has been an eye opener to us.

Landslides are another major event occurring in Sikkim Himalayas causing loss of life and property on a number of occasions earlier. The occurrence of landslides in Sikkim Himalayas is basically due to its evolutionary process and geographical location. The dominant factors of instability can be attributed to a week geological and slope condition, surface and sub-surface water activity, earthquake tremors, landuse pattern and other human induced factors.

This publication titled **'Inventory and GIS Mapping of Landslide in North, East, West and South Sikkim & its Mitigation"** provides meaningful information on the major landslide locations of the State and the probable solution for their arrest and mitigation. The information incorporated here has been obtained through a series of comprehensive field studies and other relevant data procured from various State and Central Governmental organizations.

The information provided in this publication would be useful for further research and development works on the subject.

(ARVIND KUMAR)
SECRETARY

CONTENTS

PART ONE

PART TWO

PREPARATION OF VULNERABILITY INDEX REPORT OF THE STATE

PART THREE

STATE LEVEL CONSULTATION ON LANDSLIDES MITIGATION PROGRAM

PART FOUR

GIS MAPPING OF LANDSLIDE VULNERABLE AREAS OF NORTH SIKKIM

PART FIVE

GIS MAPPING OF LANDSLIDE VULNERABLE AREAS OF EAST SIKKIM

PART SIX

GIS MAPPING OF LANDSLIDE VULNERABLE AREAS OF WEST SIKKIM

PART SEVEN

GIS MAPPING OF LANDSLIDE VULNERABLE AREAS OF SOUTH SIKKIM

PART ONE

Abstract

In the quest for better living, man has been for decades exploiting the non-renewable resources, which many a times is synonymous with the developmental activity. This pursuit is ever increasing with the development of mankind, industrialization and technological revolutions etc., and the gap between the supply and demand has not been bridged. This development has been at the cost of disturbing the ecosystems of the planet Earth. Certain terrains of the land are highly vulnerable to natural disasters. If we add to natural hazards, the increasing vulnerability caused by human activity, such as industrialization, uncontrolled urbanization, and the deterioration of the environment, we see a dramatic increase in frequency and effects of disasters. Disasters follow a cycle that includes the stage prior to impact, response to the disaster, and reconstruction and rehabilitation activities. The costs of reconstruction consume a major portion of available assets, reduce the resources for new investment, and can delay the development process.

The Himalayas, where we live in, are young lofty mountain chains and is believed to have originated by the continent-to-continent collision in the late Miocene period and the process is still continuing. The architecture of this episodic uplift is known as thrusting. Himalayas are sources of natural resources most important being the renewable hydro power resource. The Himalayas are further the origin of major river systems, which are mainly snow fed. Now, with global warming and with many other reasons, the glaciers, which are the sources of rivers, are retreating. Also a point is to be noted here that the Himalayas are rated to fall under higher zonation on seismicity and landslides. Hence, earthquakes are to make an impact to the environment if it is to strike with higher magnitude.

Therefore, with resources provided by the Himalayas, the natural hazards associated with the mountain chain has to be contended with while initiating developmental activities. For sustainable development, a balance has to be maintained; otherwise, the environmental degradation brought about might outweigh the advantages of developmental activity. To understand about the balance between the development and environmental degradation, one has to understand the problems and hazards scientifically and adopt to manage and mitigate the effects of natural disasters. Sometimes, it is also seen that projects are environment friendly and has proved to be protecting the environment.

Landslide, constitute the major natural hazard which accounts for considerable loss of life, property and damage to communication networks, human settlements, agricultural and forest land in Sikkim. As yet, management of this type of hazard is confined to post disaster relief and rehabilitation and that too on a temporarily basis. There is an urgent need to take up this hazard to be studied systematically and on priority basis at pre-hazard state.

Sikkim, as we all know, is situated in the Himalayan mountain system. She has been bestowed with natural resources and to take advantage of it depends upon how the human can balance the development and the environment as the development would cost a major stake if environment is not protected. We can tap these resources through proper planning with total scientific reasoning. Sikkim is plagued by various types of mass movement. The triggering factors are invariably excessive water, geological condition, earthquakes, etc. Hence, study and monitoring has become imperative to safeguard against the destruction of the failing slopes.

In brief, human society and the natural environment have become increasingly vulnerable to natural hazards such as earthquakes, landslides, hurricanes, droughts, and flooding, etc. The situation is particularly not always occurring in Sikkim, but it is situated in the very high zone in regard to earthquake and high zone with regards to landslides, which is one of the most disaster-prone regions of India according to multi hazard map of UNDP (Map no 03).

As Sikkim's population have been effected by many landslides and earthquakes in the past (Table No 7), this study particularly describes human vulnerability to natural disasters in Sikkim and the case study addresses one of the pioneering efforts of Geographic Information Systems (GIS) applications in human vulnerability due to Landslides. It is becoming increasingly recognized that computer methods such as models and GIS can be valuable tools for analyzing a geographical area in terms of its hazard vulnerability. Certainly as long as society insists on occupying hazardous land, a good understanding of the risk involved makes sense. The introduction of computerized assessments (in this study using of GIS), which are designed to provide and analyse detailed information about natural disaster patterns and potential Landslides-related impacts and human vulnerability in Sikkim particularly South Sikkim, have become a welcome addition to the State's long-standing battle against nature's fury.

INTRODUCTION

The Himalayas are known to be young-fold mountains, because these have been formed relatively recently in the earth's history, compared to the older mountain rangers like the Aravallis in India and the Appalachian in the USA. They are known as Fold Mountains because the mountains extend for 2500 km in length in a series of parallel ridges or folds.

The accepted theory about the formation of the Himalayas started to take shape in the year 1912 when German meteorologist Alfred Wegener developed his Theory of Continental Drift. The theory picks up the story about 250 million years ago, during which time, all the earth's land was a single super continent called Pangea surrounded by a large ocean.

Around 200 million years ago (also known as the Middle Permian Period), an extensive sea named Tethys stretched along the latitudinal area presently occupied by the Himalayas. Around this period, the super continent Pangea began to gradually split into different land masses and move apart in different directions. Resultantly, rivers from both the northern Eurasian land mass called Angara and the southern Indian land mass called Gondwana started depositing large amounts of sediments into the shallow sea i.e., Tethys. The two landmasses, the Eurasian and the Gondwana moved closer and closer and during the Upper Cretaceous period around 70 million years ago, these two land masses began to collide with each other. As a result, the already shallow Tethys seabed rapidly folded raised into longitudinal ridges and valleys.

During the Upper Eocene Period, about 65 million years ago, the bed of the Tethys started rising again, the sea retreated, and the seabed was elevated into high mountain ranges. This was the second phase of mountain building. Later, about 25 million years ago during the Middle Miocene period, another phase of mountain building took place, which led to the formation of the low Shivalik ranges.

The periodic process of mountain building is an ongoing-continuous process. Although the major upheaval of the Himalayas has passed, yet the Himalayas are still rising. The Indian plate is continuously moving north at the rate of about 2 cm/year, as a result the Himalayas are rising at the rate of 5 mm/year. This indicates that the Himalayas are still geologically active and structurally unstable characterized by the frequent occurrence of earthquakes in the entire Himalayan region. The detection of movement of the plates and uplifting of the Himalayas is, thus, explained by the Continental Drift Theory and is measured by the modern technology called Global Positioning System (GPS).

Due to such movements, various kinds of tectonic activities are ongoing processes. The Himalayan Stratigraphical Sequence is folded, faulted and thrusted due to which the normal stratigraphy is reversed. Himalayas are, thus, vulnerable to both natural and man-made processes. Apart from the natural processes, man has been responsible, to a large extent, for some of the environmental problems faced by the mountains. The strive for modernization, industrialization, globalization and the so-called higher standard of living, has distributed the fragile ecosystem of the Himalayas into many parts. Human exploration in terms of development of tourism, intricate network of roads, hydro power projects urbanization, infrastructural development etc., needs to be executed in an environmental friendly and systematic manner.

Natural Disasters Overview in context to India and World

In the 1970s and the 80s, droughts and famines were the biggest killers in India, the situation stands altered today. It is probably a combination of factors like better reservoir management and food security measures that has greatly reduced the deaths caused by droughts and famines. Floods, high winds and earthquakes dominate (98%) the reported injuries, with ever increasing numbers in the last ten years. The period from 1973 to 1997 has been associated with a large number of earthquakes in Asia, which have a relatively high injury- to death ratio.

Floods, droughts, cyclones, earthquakes, landslides and avalanches are some of the major natural disasters that repeatedly and increasingly affect India. (World Disasters Report-1999, International Federation of Red Cross and Red Crescent Societies) in the last two decades, over 3 million people have been killed in natural disasters worldwide. According to statistical evidence, there have been three times as many losses resulting from disaster events in the past ten years than was the case in the 1960s. As a consequence, economic losses have been nine times greater during this decade, currently exceeding US $90 billion a year. In 1998 alone, natural calamities claimed the lives of more than 50,000 people worldwide (Extracted from CRED 2000). In many parts of the world, disasters caused by natural hazards such as earthquakes, floods, landslides, drought, wildfires, tropical cyclones and associated storm surges, and volcanic eruptions have exacted a heavy toll in terms of the loss of human lives and the destruction of economic and social infrastructure, not to mention their negative impact on already fragile ecosystems. Indeed, the period between 1960 and 2007, witnessed an exponential increase in the occurrence, severity and intensity of disasters, especially during the 1990s. This trend poses a major threat to the planet and therefore, needs to be addressed by the state, national, international community with a sense of urgency. While natural hazards will continue to occur, human action can either increase or reduce the vulnerability of societies to these hazards and related technological and environmental disasters by focusing on socio-economic factors determining such vulnerability. For example, population growth as well as changing demographic and economic patterns, which have led to uncontrolled urbanization, together with widespread poverty has forced large numbers of people to live in disaster-prone areas and sub-optimal shelters, thus increasing vulnerability. On the other hand, there is considerable scope for the reduction of risk through the application of disaster prevention and mitigation efforts based, for instance, on modern forecasting technology in terms of the development of early warning systems as well as improved land use settlements plans and building practices, provided that societies ensure the application of these practices in a manner consistent with the needs of sustainable development.

Sikkim is among the India's most vulnerable regions 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 (Map no 03) not only that Sikkim is one of the developing state. A tough mesh of rampant and unplanned urbanization is coming up in the state; unsafe buildings compound the risks. The four seasons arrive and depart in tandem with four major kinds of natural disasters: windstorm accompanied by heavy rainfall, earthquakes, landslides, flashflood and hailstorm. Other catastrophic events such as avalanches, blizzards, coldwave and fires occur less frequently and threaten fewer people. We know that human communities will always have to face natural hazards, whether windstorm, landslides, flashflood hailstorms or earthquakes. But today's disasters owe as

much too human activities as to the forces of nature. Indeed, the term natural is an increasingly misleading.

What we have witnessed over the past decades, however, is not nature's variation but a clear upward trend caused by human activities. There were three times as many great natural disasters in the 1990s as in the 1960s, while disaster costs increased more than nine fold in the same period. The facts are startling. The costs of weather-related disasters in 1998 exceeded the costs of all such disasters in the decade of the 1980s. Tens of thousands of mostly poor people died during the year, tens of millions have been temporarily or permanently displaced. We know why the trend is upward. Ninety per cent of disaster victims worldwide live in developing countries, where poverty and population pressures force growing numbers of poor people to live in harm's way- on flood plains, in earthquake-prone zones and on unstable hillsides. The vulnerability of those living in risk-prone areas is perhaps the single most important cause of disaster casualties and damage. We know that unsound development and environmental practices exacerbate the problem. Massive logging operations and the destruction of wetlands reduce the soils ability to absorb heavy rainfall, making erosion and flooding more likely. It is not just the costs of natural disasters that are exacerbated by human action. Many scientists believe that the recent upsurge of weather-related natural disasters is the product of increased global warming, much of which is probably caused by human activity. Given that the pressures of poverty and population growth continue to increase, the disaster trend is likely to worsen if we do not take disaster prevention more seriously (UNEP GEO 3 Report 2001).

Above all, we must never forget that it is poverty, not choice, that drives people to live in risk-prone areas. Equitable and sustainable economic development is not only a good in its own right, but also one of the best forms of disaster insurance.

Justification/rational of the study

In many areas, science can identify the physical hazards; it tells how many people are likely to be affected by each one, what are the various mitigations measures. One can rank risks and remedies and put things in perspective. But normally, policies are based more on fear rather than fact. By definition, fear is more emotional than rational. People have more fear about something emotional than rational. The society should be more rational with their thinking because of limited resources. So how do people make policy making more rational? How can people get political leaders and government agencies to make wiser choices and protect people better? Sikkim is situated at one of the most disaster prone areas in India. Many property, roads and lives of people are destroyed every year due to disasters mainly heavy rainfall, rainstorms, earthquakes, landslides, flashflood, thunder lightning, hailstorm, fire. In this report, an attempt will be made to find out the human vulnerabilities due to landslide in Sikkim. The case study of this report will also facilitate GIS analysis for human vulnerability due to Landslides in Sikkim and landslides Mitigation program for state. A Geographic Information System (GIS) offers a valuable suit of tools and techniques for identifying and measuring the hazard and assessing its spatial manifestation. For example, spatial data of different types such as remotely sensed imagery, aerial photography, and digitized maps could be easily incorporated and analyzed in the GIS for hazard assessment. Here, an attempt will be made to demonstrate the use of GIS in capturing the uncertainty associated with human vulnerability assessment. This is an important subject for further research by scholars and practitioners given that uncertainty is a pervasive characteristic of

hazard assessment. GIS is the only tool to calculate vulnerable population in the geo-spatial domain. However, calculating human vulnerability using GIS with natural hazards is a challenge for decision makers.

Objectives of the study

The main objectives of the study are:

1. 'Inventory and GIS mapping of District wise landslides of Sikkim.

2. Study of landslide and its Mitigation consisting of different measures specific to Sikkim Himalayas.

Methodology of the study

Before start of the study, a working concept was drawn. Data for the study were collected from two sources; primary and secondary sources. Both primary and secondary data sources were carefully analysed to take advantage of the strengths of both types of data and to minimize their respective weaknesses. Secondary data of this study mainly included records available in different Government Departments and organization of Sikkim and India. The Mines Minerals and Geology Department's field survey data were used for case studies. Primary data were collected from some selected areas with field observation. To make the study more comprehensive, additional data sources as below were taken into consideration;

1. Literature review:

This approach assesses the concepts of vulnerability, terms of events, and effects on humans due to natural disasters. Review of existing literature on disaster was necessary to understand the underlying concepts of naturals disaster within different geo environmental settings and to use the terms or definition to describe a natural event.

2. Quantitative (survey, census data, secondary data, Meta analysis using regression etc.):

This part describes the nature, area-wise distribution and also the trend of affected people in Sikkim due to natural disasters. In this part, mainly the last twenty-five year data were used from the following Government Department - District Collector, Land Revenue and Disaster Management Department, Department of Forest, Department of Science & Technology, Department of Urban Development & Housing, Department of PHE, Department of Irrigation, Department of Agriculture, Department of Economics, Statistics, Monitoring & Evaluation, Department of Mines, Minerals & Geology database, Sikkim State Disaster Management Authority.

3. GIS techniques (use of GIS system; geo-referenced data):

This part of the report showed one case study; analyzed human vulnerability due to a single hazard i.e., Landslides with GIS aid. For the case study, a Geographic Information

System (GIS) was focused in a historical data approach and a GIS based mapping approach. The database of the case study was collected by Field Officers of Disha Services through Field Surveys and from the Department of Mines Minerals & Geology and Land Revenue and Disaster Management Department, Government of Sikkim.

4. Historical data approach:

In this approach different historical data were explored to show the Landslides and human vulnerability trends.

GIS based mapping approach

Geographic Information System (GIS) tools help to answer questions like who is vulnerable, where they are and why they are vulnerable? GIS was used to identify vulnerable areas using statistical tools. Although the data generated are usually integrated in the form of tables, graphs and/or charts, maps have the advantage of presenting data in an easily accessible, readily visible and eye-catching manner. The resulting maps combine information from different sectors to provide an immediately comprehensive picture of the geographical distribution of vulnerable groups at state level. By providing a visual overview of the major issues affecting Landslides and vulnerability, the maps highlight gaps and shortfalls in information and those areas needing attention. A GIS based approach is helpful for highly disaggregated data; it can easily perform statistical analysis as well as graphic presentation. Within the GIS analysis of this paper, we first modeled district wise geographic distribution of Landslides prone areas in Sikkim. Using available field surveys from Mines, Minerals and Geological Department, Land and Revenue Department, UNDP, State Disaster Management Authority, Government of Sikkim and our Fields Officers, we developed various types of Maps like Slop Morphometry Map, Geological/Lithological Map, Soil Type Map, Hydrological Map, Soil Thickness Map, Landslide Inventory Map, Relative Relief Map, Land Use/Land Cover Map, Rainfall Map, Drainage Density. Which were extensively analysesed with the help of GIS Software to form District wise landslide vulnerable areas of Sikkim.

Limitation of the Studies

The study was conducted under very limited resource in terms of time, past data and funds. Therefore, we could not engage latest technology like Landslides Monitoring Stations, Satellite Maps, Geographical Scanners, Geotechnical studies and Ariel Photo for our studies. In this regard, we would like to request the concern authorities to facilitate more funds for this types of study, so that new and latest technology could be incorporated in the study thereby making it more accurate and scientifically correct. This could help the Government to evaluate the hazard related with the Landslides and make the community safer.