

VIDYASAGAR UNIVERSITY

Report On
Landslide and Its Causes, Consequennces & Management :
A Study in Some Parts of Sikkim Himalayas



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SEMESTER - VI

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for partial fulfilment of the syllabus prescribed by Vidyasagar University. The report has been prepared under the supervision of Miss Arpita Majumder and may be placed before examiner for evaluation.

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Place: Ranjiniapur, Amdabad

Date: 10.08.2023

Moumita Giri
signature

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**REPORT ON
LANDSLIDE and its Causes,
Consequence & Management:
A Study in Some Parts
of Sikkim Himalayas**

[1.0] INTRODUCTION:

[1.1] Introduction:—

Disaster and natural hazards are common and occur not only in India but all over the world. India has been prone to natural disasters on account of geo-climatic conditions; disasters such as floods, earthquakes, droughts, cyclones and landslides have been major within the country. (Kapur, R., 2018). A hazard may be defined as the perilous conditions or events that are threatening or have the potential for causing injury to life, property or the environment (Dey & Singh, 2006). Hazards are of two kinds, natural and manmade; natural hazards are the ones that take place as a result of natural phenomena, these can be meteorological, biological and geological such as cyclones, Tsunamis, earthquakes, landslides, floods, drought and volcanic eruptions. On the other hand, manmade hazards are the ones that occur due to human negligence; these are associated with industries or energy generation power plants and include explosions, leakage of toxic wastes, pollution, dam failure, wars or civil strife or occurrence of fires (Dey & Singh, 2006).

Landslide is also called as semi or quasi natural hazard as it originates due to natural phenomena.

men and also by human activities. Landslide is the common disaster in different parts of Sikkim. The high steep slope, making of the houses or constructional works in the hilly slope etc. causes are responsible for landslides in Sikkim. In the present project paper it is discussed about the causes, effects and management of Landslide Disaster in West and South Sikkim along with an overview of physical and socio-economic status of Sikkim as landslide is also triggered by human activities along with natural phenomena.

[1.2] Study Area:-

Sikkim is a small, extremely mountainous state in the Himalayas with sharply defined and extremely deep watershed. The state is situated between $27^{\circ}04'N$ to $28^{\circ}07'N$ to $28^{\circ}07'N$ and $88^{\circ}01'E$ to $27^{\circ}06'E$. It is bounded by Nepal in the West by the vast stretches of Tibetan Plateau in the North and by Bhutan and Chumbi Valley of Tibet in the East. Darjeeling district of West Bengal stretches along its southern boundary. The state has a total area of 7096 sq. km. Sikkim is divided into four districts - East, West, North and South.

The state lies between very high and ~~low~~ high landslide vulnerable zone on the basis of intensity of the controlling factors of landslide. Though north and east Sikkim are in very risk zone of landslide, South

LOCATION MAP



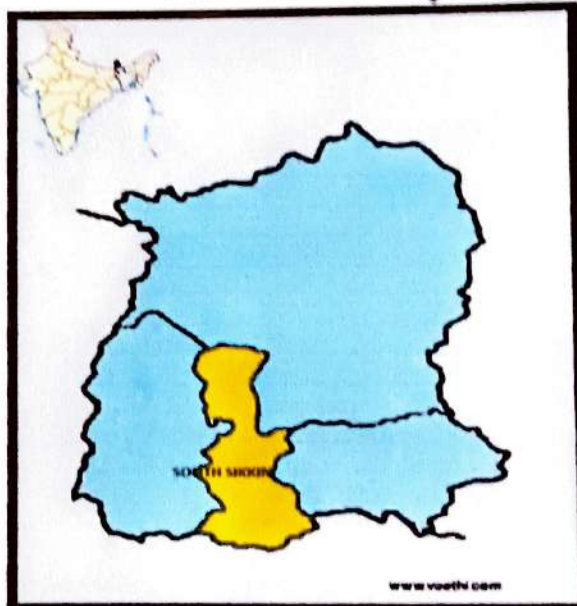
1. INDIA



2. SIKKIM



4. WEST SIKKIM



3. SOUTH SIKKIM

and West districts of Sikkim are also in high risk zone of landslide. South and West districts of Sikkim are also in high risk zone of landslide prone areas. West and South district of Sikkim lie at an altitude of more or less 400 meters to 2500 meters with unique countryside escape of endless waves of agricultural fields and the terraced slopes, intersected by spring riched forests. Tourism development, road construction, increasing rate settlement triggering the rate of landslide every year. Hence, in the present study South Sikkim and West Sikkim has been taken as special consideration in the study area to show the general scenario of the landslide with its causes, consequences and management.

[1.3] Objectives:-

The present project paper on landslide has been initiated to fulfill some basic objectives which are as follows:

- To study the general overview physical and economic, socio-cultural environment of the study area as both are very much related to landslide.
- To identify the major causes of landslide and its consequences in the study area specially in West and South Sikkim.
- To assess the effective landslide management techniques and to give some suggestive measures to prevent landslide in the study area.

[1.4] Research Question:—

- (i) What is the nature of landslide in west and south sikkim?
- (ii) What are the main causes of landslide?
- (iii) What are the effects of landslide on the lives of the local people?
- (iv) What measures have been taken to prevent landslides from government?

[1.5] Data base and Methodology:—

→ The data has been collected from two sources — Primary and Secondary. The primary data has been collected from hotel manager, car driver, local people and seller of souvenir shop. The secondary data were collected from — various article, book, different link from website, journal etc.

→ We collected data from hotel manager, car driver, local people and seller of souvenir shop through interview method, and we gain an understanding of landslides through the observation method while traveling near landslide prone area.

→ Different cartographic techniques have been chosen to represent the data properly. We used to bar and line graph to show rainfall and temperature. To represent demography and literacy we have use pie and bar diagram.

[1.6] Limitation of the Study:-

Due to the limited time period surveyor were not able to collect data properly. Besides this some other problem such as poor financial condition, communication gap between respondent and surveyor due to different language etc. which was prevailed in that area. Hence the study was not dealt properly.

[2.0] A general overview on physical and socio-economic environment of Sikkim:-

As landslide is called as semi or quasi natural hazard, it is originated by natural phenomena and triggered by human activities. Sikkim is one of the vulnerable state in India due to landslide. Geology, relief structure, nature of slope, type of rock and its resistance power to erosion, soil, climatic nature (specially rainfall), vegetation cover etc. all are the controlling factors of landslide. Apart from these, human activities such as, economic activities, developmental works also affect on landslide. On the other hand, physical and socio-economic environment of the region can be devastated due to landslide.

Hence, a brief introduction on physical and socio-economic environment of Sikkim should in thought to know the causes and consequences of landslide in the study area.

[2.1] Physical Environment

▣ Physiography :

Situated in the Himalayan mountains, the state of Sikkim is characterised by mountainous terrain. Almost the entire state is hilly. With an elevation ranging from 80 meters (262 ft.) in the south at the border with West Bengal to 8586 meters (28,169 ft.) in the south at the border with West northern peaks near Nepal and Tibet. The summit of Kanchenjunga, the world's third highest peak, is the state's highest point, situated on the border between Sikkim and Nepal. For the most part, the land is unfit for agriculture because of the rocky, precipitous slopes. However, some hill slopes have been converted into terrace farms.

[2.1] Physical Environment

▣ Physiography:

[2.1.1] Drainage:—

Sikkim is drained by large number of perennial rivers, which merge into two prominent rivers, the Teesta and the Rangpoet. Rest of other stream eventually joining one or the other. Rangpoet also joining the Teesta just near the boundary between Sikkim and West Bengal.

The Rangpoet river and its tributaries originate in the Talung glacier in West Sikkim and after flowing for about 60 km., joining Teesta below Malvi near the border of Sikkim with West Bengal. River Rangpoet is a major tributary of River Teesta from the western Sikkim. Major tributaries of Rangpoet are Rimbi Khola, Rathangchhu, Kaley Khola, Ramam Khola and the little Rangpoet.

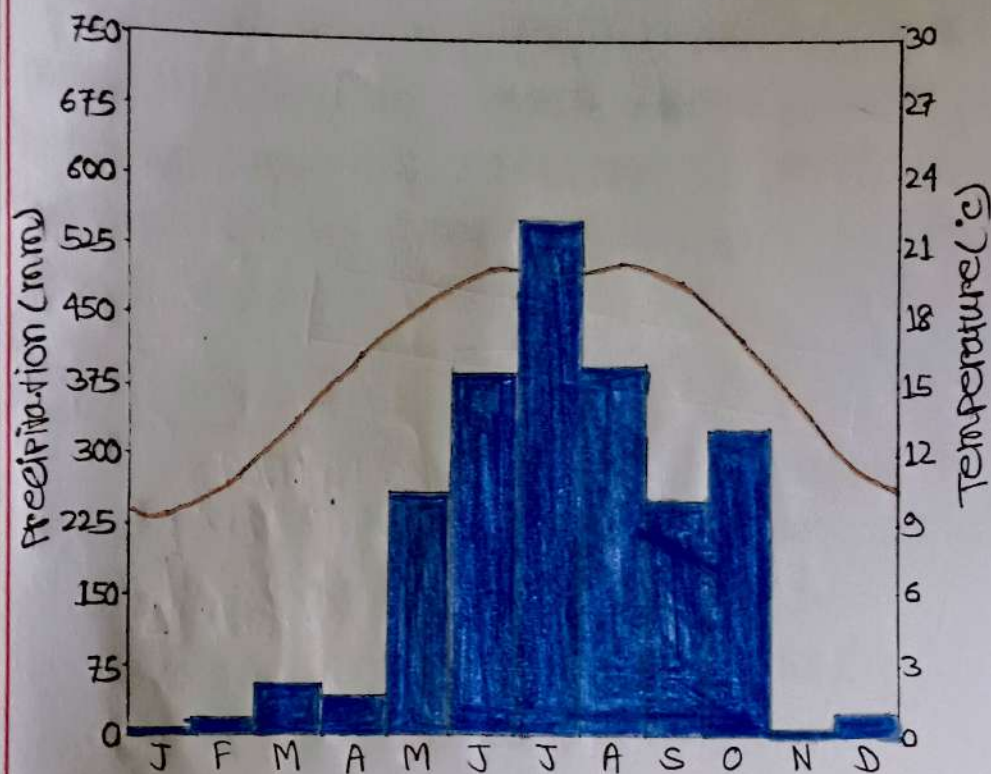
[2.1.2] Soil:—

The hills of Sikkim mainly consist of gneiss and schist, which weather to produce generally shallow brown clay soils. The rock consists of phyllites and schists.

[2.1.3] Climate:—

The state has five seasons - Winter, summer, spring, Autumn and Monsoon season. Most of the inhabited regions of Sikkim experience a temper-

CLIMATE GRAPH FOR SIKKIM



SCALE

Precipitation	1 cm to 75 mm
Temperature	1 cm to 3°C

LEGEND

Precipitation	
Temperature	

rate climate, with temperatures seldom exceeding 28°C in summer. The average annual temperature for most of Sikkim is around 18°C . During the Monsoon, heavy rains increase the risk of landslides. The record for the longest period of continuous rain in Sikkim is 11 days. Fog affects many parts of the state during winter and the Monsoons, making transportation perilous. Temperatures in the mountain can drop to as low as 4°C in winter.

[2.1.4] Flora and Fauna:—

Sikkim is situated in an ecological hotspot of the lower Himalayas, one of only three among the ecoregions of India. To its altitudinal gradation, the state has a wide variety of plants. From tropical species to temperate, alpine and tundra ones. Noble orchid is Sikkim's state flower. Rhododendron is its state tree; about 40 species of Rhododendron bloom late April - mid May across the state.

Sikkim is home to around 5000 species of flowering plants. 515 rare orchids, 60 Primula species, 11 oak varieties, 23 bamboo varieties, 16 conifer species, 362 types of ferns and fern allies, 8 tree ferns and over 900 medicinal plants. A relative of the Poinsettia, locally known as 'Christmas Flower', can be found in abundance

in the mountainous state.

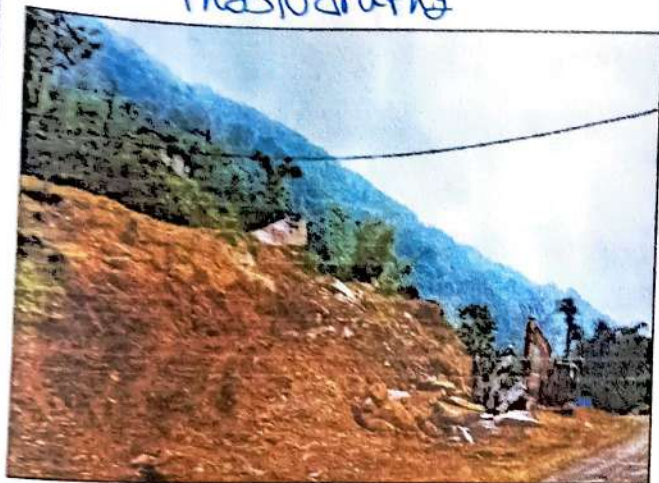
The Fauna of Sikkim include the snow leopard, musk deer, Himalayan tahr, red panda, Himalayan marmot, Himalayan serow, Himalayan goral, muntjac, common langur, Asian black bear, Clouded leopard, marbled cat, leopard cat shole, Tibetan wolf, hog badger, binturong and Himalayan jungle cat. Among the animals more commonly found in the Alpine zone are yaks, mainly reared for their milk, meat and as a beast of burden. Sikkim has more than 550 species of birds. Some of which have been declared endangered. The red panda is the state animal of Sikkim.



Physiography



Teesta River



Brown clay soil



Rhododendron Tree



Red Panda, State animal of Sikkim

[2.2] Socio-Economic Environment

[2.2.1] Demography:—

As per census of India, 2011, total population of Sikkim was 6.11 lakhs. Sikkim is the least populated state of India where percentage of male was 52.27% and female percentage was 47.05%.

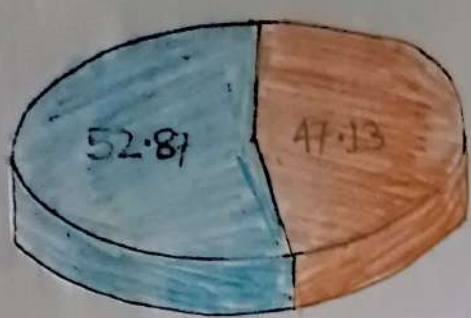
[2.2.2] Literacy:—

Literacy rate in Sikkim stood was at 81.42%, where male literacy rate was at 86.55% and female literacy rate was 76.04% according to census of India, 2011.

[2.2.3] Culture:—

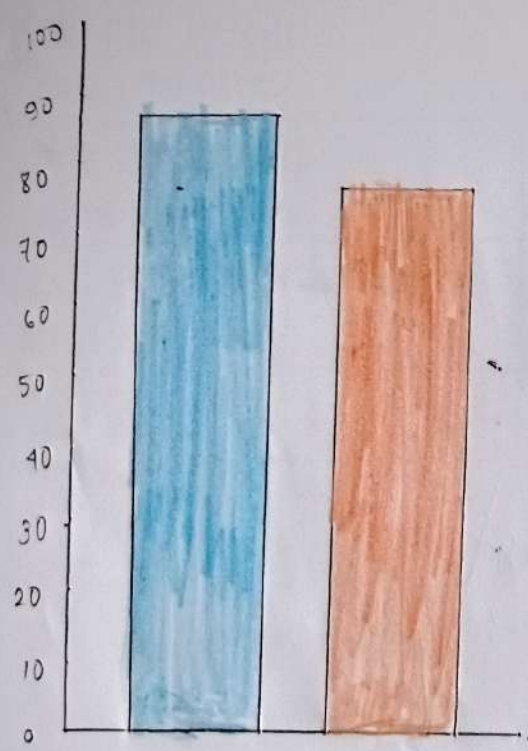
In Sikkim the leading communities are the Lepchas, Bhutias and Nepalese. The official languages of the state are English, Nepali, Sikkimese and Lepcha. The Sikkimese are highly devout people and religions play major role in Sikkim. There are major two religions Buddhism and Hinduism. Sikkim is multi-lingual state where people of many communities beside harmoniously.

POPULATION COMPOSITION



LEGEND	
Male	
Female	

LITERACY RATE OF SIKKIM, 2011



LEGEND	
Male	
Female	

[2.2.4] Health:-

There are few hospitals, health centres, clinics and health facilities across the state of Sikkim. These medical facilities provide treatment both to the local patients and other patients from neighbouring places as

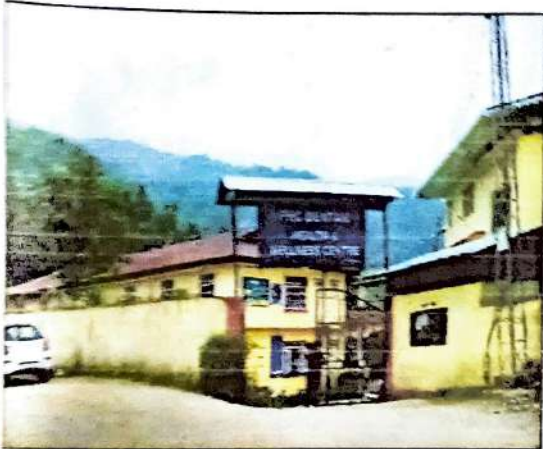
SL.No.	HEALTH INSTITUTION	EAST	WEST	NORTH	SOUTH	STATE
1.	State Referral Hospital/ St m. Hospital	1	.	.	.	1
2.	District Hospital	1	1	1	1	4
3.	Community Health Centre	1	.	.	1	2
4.	Primary Health Centre	6	7	5	6	24
5.	Primary Health Sub-Centre	48	41	18	39	146
6.	District Tuberculosis Centre, Namchi	.	.	.	1	1
7.	Centre Referral Hospital Manipal Ta	1	.	.	.	1
TOTAL -		58	49	24	48	179



Culture of Sikkim



Culture of Sikkim



Primary Health Centre in Dantam



Cardamom cultivation



NH-10

[2.2.5] Economy:—

The economy of Sikkim is mainly based on agricultural and animal husbandry and tourism. Sikkim's nominal state Gross Domestic Product (GDP) was estimated at US \$ 4.6 billion in 2019, with GDP per capita being \$ 7,530 (₹ 5,50,000) thus constituting the third smallest GDP among India's 28 states.

[2.2.5.1] Agriculture: Economy of Sikkim is largely agrarian based on the terraced farming of rice and the cultivation of crops such as maize, millet, wheat, barley, orange, tea and Cardamom. Sikkim produces more Cardamom than any other Indian state and is home to the largest cultivated area of Cardamom (88%). It is estimated that over 80% of the rural population depend on agriculture and allied sectors for economic, food and national security.

[2.2.5.2] Industry: Sikkim has long been agro-based society. The Government has formulated certain policies such as Sikkim Industrial promotion and Incentive (SIPI) act 2000 and its subsequent amendments in 2003

The first part of the manuscript is a list of names of the persons who were present at the meeting. The names are written in a cursive hand and are somewhat difficult to read. The list includes the names of the following persons:

On 23rd July 1951, the Secretary of State for the Colonies, Mr. D. G. Hall, announced that the Government had decided to transfer the administration of the Colony of Sierra Leone to the Secretary of State for the Colonies. This decision was based on the recommendation of the Committee of Enquiry into the Administration of the Colony, which had been set up in 1948. The Committee had found that the existing system of administration was inefficient and costly, and that a more direct system of administration would be more effective. The Government had decided to implement the recommendations of the Committee, and to transfer the administration of the Colony to the Secretary of State for the Colonies. This decision was a significant step towards the development of Sierra Leone, and it was expected that it would lead to a more efficient and economical system of administration.

Protected areas are designated for conservation activities:- Kaziranga National Park, Singha Rhododendron Sanctuary, Fumad Wildlife Sanctuary, Kamakhya Hill Sanctuary, Nagorn Wildlife Sanctuary, Korcan Wildlife Sanctuary.

[2.2.6] Transport : —

■ Roadway : National Highway (NH 10; formerly NH 31A) links Siliguri to Gangtok. Sikkim nationalised transport runs bus and truck services. Privately run bus, tourist taxi and jeep services operate throughout Sikkim and also connect it to Siliguri. A branch of the highway from Melli connects Western Sikkim. Towns in eastern, southern and Western Sikkim are connected to the hill stations of Kalimpong and Darjeeling in northern West Bengal. The state is further more connected to Tibet by the mountain pass of Nathu La.

● List of National Highways of Sikkim

Number	Length (km.)	Length (mi.)	Southern or Western Terminus	Northern to Eastern Terminus
NH 10	52	32	Gangtok — Singtam — Ranapo — West Bengal Border	
NH 310	87	54	Ranipool (NH 31A) — Burtuk — Menla — Nathu La	
NH 310A	55	34	Tashi View Point — Phodong — Maragan	
NH 510	70	43	Singtam — Damthang — Leaship — Gyashing	

Number	Length (km)	Length (mi)	Southern to Western Terminus	Northern to Eastern Terminus
NH 710	45	28	Melli — Manpur — Namchi — Dumthang — Tarku	
NH 717 A	112	70	West Bengal border — Rhenock, Rorathang Pakyong a junction with new NH 10 at Ranipool near Gangtok	
NH 717 B	42	26	Junction with NH 717 A at Rhenock — Rongti, Rolep — Junction with NH 310 near Menda at Sherathang.	

■ Airway : There is just one Airport is Pakyong, which is around 111.9 km from Sikkim but Bagdogra is well connected to Sikkim (about 125 km. from Sikkim township).

Here, Helicopter service started mainly for tourism purpose.

■ Railway : The nearest railway station to Sikkim are New Jalpaiguri and Siliguri station located in West Bengal.

[3.0] Landslide in the Study Area :

The frequent occurrence of landslide is a very common phenomena in Sikkim Himalaya and one that causes the most damage to property and connectivity in the land locked state and also loss of the lives and property. Apart from this, recent unplanned development activities, particularly road construction and ill planned settlements, have further aggravated the incidence of the landslide and subsidence.

[3.1] Causes of landslide :

The frequent occurrence of landslides is a very common phenomena in Sikkim Himalaya. In the sikkim region can be caused by a variety of factors including geological, environmental and human-related. Here are some common causes that contribute to landslide —

i) Geological Causes:-

Sikkim is a state in north-eastern India, is located in a seismically active region and experiences various geological processes that can contribute to landslides.

④ Slope stability: Steep slopes and unstable geological formations can contribute to landslides. For example, the Sikkim region is characterized by rugged terrain with steep slopes, especially in the Himalayan mountain range. The presence of weak rock formations and loose soil can make these slopes prone to landslide.

⑤ Geological Formation: The geological formation of Sikkim consists of complex and varied rock types, including schists, gneisses, phyllites and quartzites. Some of these rocks have inherent weaknesses and discontinuities, such as bedding planes, joints and faults which can act as potential sliding surfaces.

ii) Environmental causes:-

Sikkim state is prone to landslide due to its rugged terrain and high rainfall. Several environmental causes contribute to landslide.

⑥ Heavy Rainfall: Intense or prolonged rainfall can saturate the soil, increasing its weight and reducing its stability. Sikkim experiences heavy monsoon rains, particularly during the months of June to September. The excess water can infiltrate the ground,

leading to landslides.

① Earthquakes: Sikkim falls in a seismically active region due to its proximity to the Himalayan tectonic plate boundary. Earthquakes can generate ground shaking, which can disturb the balance of slopes and trigger landslides.

② Erosion: Natural erosion processes such as river can undercut slopes and weaken their stability. Continuous erosion removes support from the base of slopes making them prone to landslides.

iii) Human-Related causes:-

Human activities can also contribute to the occurrence or exacerbation of landslides. Here are some man-made causes of landslides —

③ Deforestation: Clearing large areas of forests for agriculture, logging or urbanization reduces the stability of slopes. Tree roots help bind soil and prevent erosion, so their removal can make slopes more prone to landslides.

⑥ Construction and Excavation: Poor construction practices, improper grading of slopes and excessive excavation can alter the natural stability of the land. Building roads, highways or structures on steep slopes without appropriate engineering measures can increase the risk of landslide.

⑦ Defective drainage systems: Inadequate or poorly designed drainage systems can lead to the accumulation of water in the soil, increasing pore pressure and reducing the shear strength of slopes. This can result in slope failures and landslides.

⑧ Surface Modification: Altering the natural drainage patterns by modifying rivers, streams or water channels can cause increased water flow and erosion, which can weaken slopes and trigger landslide.

⑨ Irrigation and water leakage: Improper irrigation practices, such as excessive water application or inadequate drainage systems can saturate slopes and increase their susceptibility to landslide. Water leakage from pipes or sewers can infiltrate the soil, leading to instability.

[3.2] Consequences of Landslide: The effects of landslides in Sikkim can be significant and have various consequences on the region, the environment, and the local communities. Here are some of the effects:-
potential

A. Physical Effects:-

■ Damage to Infrastructure:

The infrastructure facilities such as telephone and communication system, electricity supplies, water and oil pipelines, offices, furniture, commodities, transport system etc. are severely damaged and put out of gear by massive landslide.

B. Social Effect:-

(I) Human casualties: If landslides occur in the inhabited areas, the first and foremost adverse impacts are on human population. If there is no timely forewarning of probable occurrence of landslides and if there is no proper timely evacuation, a large number of people are buried under enormous mass of debris of varying sizes and there is heavy toll of human lives.

(II) Damage to settlements, roads and railroads:

Settlements comprising both rural and urban located at vulnerable sites such as on hill slopes, at the foothills, alluvial fans and cones, in the valleys facing steep hill slopes etc. are damaged and sometimes villages are completely destroyed by the thick debris of rocks,

muds and other materials dislodged from the hills caused by landslides of various sorts triggered by earthquakes, or heavy rainfall or human activities.

C. Economical Effect:—

■ Loss of agricultural farms and crops: At the very outset it may be pointed out that majority of settlements are built on the hill slopes and foothills in mountainous areas, and thus agriculture is also practiced on hill slopes and in the valleys. Generally, terraced cultivation is in practice. In the event of massive landslides the terrace farms are completely destroyed by falling debris of rocks, boulders, mud, fine loose materials etc. the debris is dumped in the valleys and hence farms and crops on the valley floors are also buried under thick debris cover.

D. Environmental Effect:—

■ Damming of rivers and flash floods: Huge volume of debris produced by landslides of various sorts coming into the rivers forms temporary dams across the rivers and thus blocks the river flow. In such situation substantial volume of water is impounded behind the temporary dams and some lakes are also formed. When the impounded water overtops the debris dams, they are suddenly breached and impounded water rushes downstream with high velocity result-

ting into flash floods. Such landslide-dam generated flash floods wash out everything coming in their way including human settlements, domestic animals, inhabitants and their belongings resulting in heavy loss of human lives and their properties in the downstream section of the rivers.

E. Effect on Ecosystem:—

(I) Impact on water quality: When landslide occur, they can seriously damage or destroy ecosystem. Sometimes the effects can last for thousands of years. They can pollute streams and water bodies with sediment and debris. This invariably has severe repercussions on water quality and marine life.

(II) Wipe out forest land: What's more, these hazards can wipe out large tracts of forests, wildlife habitats and remove productive soils from slopes.

(III) Dam up or flood streams: Also, they can dam up rivers and streams. In so doing, water flow is restricted. Marine and terrestrial organisms that depend on the water flow may eventually die. Conversely, dams may flood the opposite side too. Outburst floods can introduce a tremendous amount of new sediment into streams. Or they can submerge and kill vegetation in the flooded region. In Sikkim Flash flood killed 22 people,

triggered a series of landslides and washed away nearly 30 km of highway in north Sikkim amid torrential rain.

(IV) Loss of lives and social disruption: Landslides are responsible for a number of deaths, injury to people, damage to housing, infrastructure and agricultural lands. In Sikkim on Sunday, 18 September 2011 at 6:11 PM (local time), a Mw 6.9 earthquake with an epicenter located near the Sikkim region (27.723°N , 88.064°E), killed 77 people, including 16 at the Teesta Stage III Hydroelectric power project site, injured 719, left thousands homeless, and temporarily displaced many and also caused substantial loss to livestock.

(V) Socio - Economic effects of landslide: socio economic effects include adverse impacts, as enumerated above, on people, their homes and properties, industries and factories, agricultural lands and crops, timber, life lines such as roads and highways, railroads, and communication systems, educational institutions etc. It is significant to note that socio-economic problems caused by mass movement of rock waste and landslides due to slope failures are many fold and are assuming larger proportion due to expansion of built environment in environment fragile and vulnerable mountainous areas.

2003) Some instances of landslides in the early 1990s

• 2003 198. 1991:-

Heavy rain triggered a landslide in Pelling, Sikkim. The Sikkim National Highway had been closed for as many as 11 days after the North-Sikkim road via Darjeeling had been closed because of an uprooted tree.



North-Sikkim road was closed due to landslide

• 23rd June, 2011:-

A torrential spell of rain from 7:30 am to a little past midnight on the 23 June 2011 triggered numerous small landslides in Pelling, where 14 people perished on the Pelling-Dentong road in West Sikkim.



14 people died in Pelling due to landslide

● 18th September, 2011 :—

On September 18, 2011, a 6.9 magnitude earthquake struck the India-Nepal border region. According to news reports, impacts of the earthquake included landslides in the northern Indian state of Sikkim, between Nepal and Bhutan.

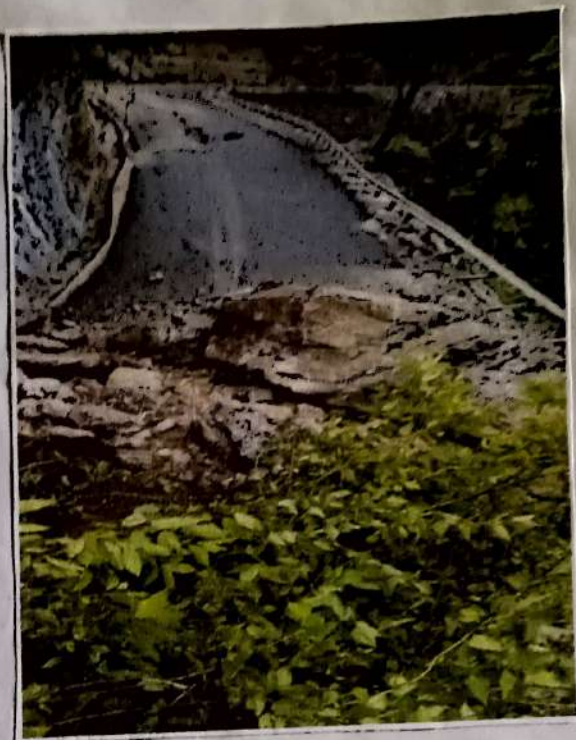


Landslides all over Sikkim due to earthquake

● 21st June, 2020 :—

A landslide occurred in Totapani at 6 PM on Friday. The road constructed across a steep terrain near Totapani remains vulnerable to landslide especially during rainy season and recent back cutting initiated for the road extension has added to risk of landslips during on going monsoon season. Leaship-Naya-bazar road was blocked near Totapani due to the landslide. The commuters travelling

from Jorethang to Geyzing, Yulsam and Tashiding were compelled to take Reshi-Rinehenpong route via Leaship to reach their destination.



Leaship-Nayabazar road was damaged due to landslides

● 27th June, 2020:—

A landslide occurred at National Hydropower project of corporation (NHPC) Teesta stage-V dam on the left bank of the river in Dikheh. According to the local people of Jang and Aapara, the landslide was occurred due to the negligence of NHPC, and it could have been avoided with proper preventive work on time. The landslide has severely damaged the 55 metre high dam of the

510 MW Teesta Hydropower project of NHPC.



Teesta Stage-V dam was broken due to landslide

● 6th August, 2020 :-

A massive landslide occurred in Jorethang in South Sikkim. A road in Jorethang was also washed off due to heavy rainfall in the region. The IPCA laboratory in Mazhitap, Jorethang was badly damaged in the landslide. The house was also completely washed away due to the landslide triggered by heavy rainfall in the area.



The IPCA laboratory was badly effected due to landslide

● 5th February, 2022 :—

A landslide occurred at Pathing village in Namchi district due to heavy rainfall. 60 houses were damaged in this village landslide.



A landslide occurred at Pathing village in Namchi district due to heavy rainfall

● 18th June, 2023 :—

Multiple landslides induced by heavy rainfall have damaged over a hundred houses in West Sikkim district. The incessant rain has caused extensive damage to infrastructure and property in the state.



Landslide occurred by heavy rainfall had devastated over a hundred houses in West Sikkim

[3.4] Management of landslide:

These guidelines by the National Disaster Management Authority (NDMA) on management of landslides reduce the enormous destructive potential of landslides and minimize the consequential losses by institutionalizing the landslide hazard mitigation efforts.

Preventive and corrective measures to lessen the impacts of landslides. It may be mentioned that landslides cannot be stopped but their number, frequency, recurrence and severity can be minimized. Some preventive measures have been taken to manage landslide in the study area.—

i) Contour Bunding:-

Earthen embankment was constructed at intervals across the slope and along the contour line of the many landslides in Sikkim. A series of such bund is very useful in dividing the area into strips and act as barrier to the flow of water.

ii) Benah Terracing:-

Relatively steep land was transformed into a series of level or nearly level strips or steps running across the slope of many landslides in South Sikkim.

iii) Rock Slope Netting:-

Rock Netting is used to cover an entire area of unstable rock. The slope netting can be either draped or bolted in each corner of each panel. Rock netting is used where the unstable rock is big and blocky. It is a new technique of landslide control which is used for landslide control in Sikkim.

iv) Contour Trenching:-

Series of deep pit or trenches across the slope at convenient distance was built within the landslide of south Sikkim. The soil excavated from the trenches was deposited on the lower edge of trenches where forest trees were planted.

v) Sausage wall:-

Preference was given to sausage wall among the mechanical method in every landslide of Sikkim and every landslide was nearly checked by applying sausage wall.

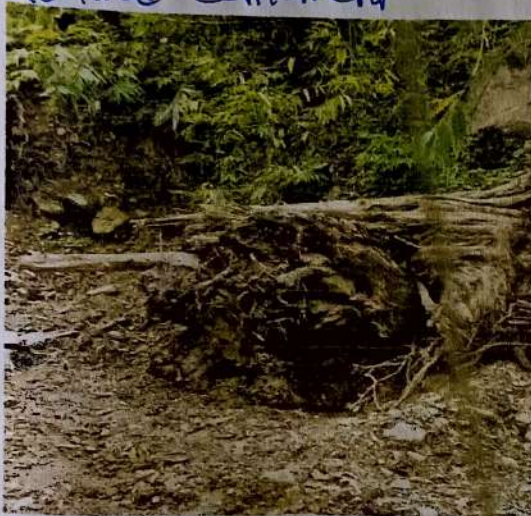
SOME OTHERS PHOTOGRAPHS RELATED TO LANDSLIDE



Landslide prone area, un-planned settlement



Landslide occurred by heavy rainfall had devastated over 100 houses in Sikkim



Uprooted tree due to landslide



Subsidence of slope



Rock slope netting



Bench Terracing

[3.5] Suggestive Measures:

Along with the management system of landslide in Sikkim Himalaya some other measures should be taken.

- a) During persuing of any disruptive projects in the high risk zone like Sikkim, should be proceed, with prudence.
- b) Environmental Impact Assessment standards should be followed before mining or dam building.
- c) Landslide micro-zoning method should be implemented in the extremely vulnerable areas.
- d) To strengthen disaster management potential more funding should be given to landslide planning and mitigation agencies.
- e) To strengthen hazard reduction and public awareness efforts, locally available trained people should be enlisted.
- f) Mitigation techniques such as confining agriculture to valleys and places with moderate slopes, fostering large-scale afforestation initiatives and building water bunds should be encouraged.
- g) Encourage the use of effective landslide rehabilitation and mitigation techniques.

4.1] CONCLUSION:—

Physiography, climate and other natural phenomena of Sikkim Himalayas make it hazardous with frequent landslide. Human activities play the role as positive catalyst for this calamity. There are spatio-temporal variation in frequency of landslide throughout the districts of Sikkim. In the study area landslides occur basically due to heavy rainfall along with some associated factors. Many times it creates massive and unwarranted loss of life and property. Therefore, there ~~shall~~ should be efficient management of the landslide hazard. There are necessities of the development of institutional capacity and training for geo-scientist, engineers and planners. It may be mentioned that landslide can not be stopped but their number, frequency, recurrence and severity can be minimized with some preventive and corrective measures to lesser the impacts of landslides which will help to prevent water ~~enter~~ entering the hill slopes through joints and cracks, decrease water pressure water pressure in the rocks through shallow and sub-shallow drainage, place drainage trenches

In order to reduce water pressure in the vicinity of hill slopes, The inhabitants of this area should be sensitized through awareness programs, mock drills, posters, and so on and the landslide prone areas of Sikkim require special attention and vigilance to cope up with this calamity.

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