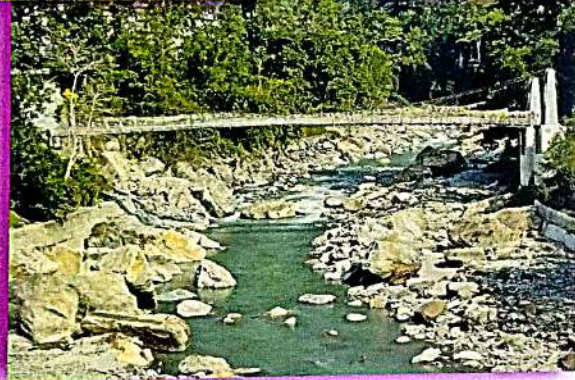
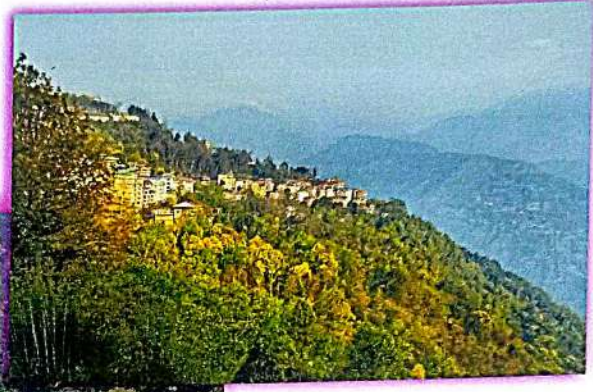


VIDYASAGAR UNIVERSITY

Report On

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



**B.SC HONOURS (GEOGRAPHY)
SEMESTER - VI**

REG. NO :- 1520143 OF 2020 - 2021

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Management: A Study in some parts of Sikkim
Himalayas

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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Sumon Dogra

signature

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1.1

1. Introduction

Introduction: → Disaster and natural hazards are common and occur not only in India but all over the world. India has been prone to natural disaster on account of geo-climatic conditions; disasters such as floods, earthquakes, droughts, cyclones and landslides have been major with in the country. (Kapur, R., 2018). A hazard may defined as the perilous conditions or events that are threatening or have the potential for causing injury to life, property or the environmental (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, landslide, floods, drought and volcanic eruptions. on the other hand, manmade hazard 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, pollutions, dam failure, wars or civil strife of occurrence of fires (Dey and Singh, 2006)

Landslide is also called as semi or quasi natural hazard as it originate due to natural phenomena and also by human activities. Landslide is the common disaster in different parts of sikim. The high steep slope, making of the houses or constructional work in the hilly slope etc. causes are responsible for landslide in sikim. In the present project paper it is discussed about the causes, effects and management of Landslide disaster in west and south sikim along with an overview of physical and socio-economic status of sikim as landslide is also triggered by human activities along with natural phenomena.

1.2: concept of Landslide :-> A landslide is the movement of a mass of rock, debris or earth down a slope. Landslide is a type of, mass wasting which denotes any down-slope movement of soil and rock under the direct influence of gravity (S. Singh 2018). The term "Landslide" encompasses five modes of slope movement, falls, topples, slides, spreads and flows. These are further subdivided by the type of geologic material (bedrock, debris of earth). A landslide is the movement down slope of a mass of rock debris, earth or soil. Landslide occurs when gravitational and other type of shear stresses within a slope exceed the shear strength of the materials that form the slope. Shear stresses can be built up within a slope by a number of processes.

India has been divided into a number of zones on the basis of vulnerability, very high and high vulnerability zones having highly unstable, relatively young mountainous areas in the Himalays, high rainfall, regions with steep slope, the north-eastern regions, along with areas that experience frequent ground-shaking due to earthquakes etc. and areas of intense human activities, particularly those related to constructions of road, dams, etc. are included in the zone. All the Himalayan states and the states from the north-eastern regions except the plains of Assam are included in the high vulnerability zones. Sikkim is one of the vulnerable state in India due to landslide.

1.3: Study area :→ Sikkim is a small, extremely mountainous state in the Himalayas with sharply defined and extremely deep water shed. The state is situated between $27^{\circ}04'N$ to $28^{\circ}07'N$ and $88^{\circ}01'E$ to $87^{\circ}06'E$. 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 East. Darjeeling district of West Bengal stretches along its southern boundary. The state has a total area 7096 sq. km. Sikkim is divided into four districts - East, West, North and South.

The state lies between very high and high landslide vulnerable zone on the basis of intensity of the controlling factors of landslide. Though North and East Sikkim are in the very 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 lies 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, intercepted by spring patches forests. Tourism development, road construction, increasing rate settlement triggering the rate of land slide 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.

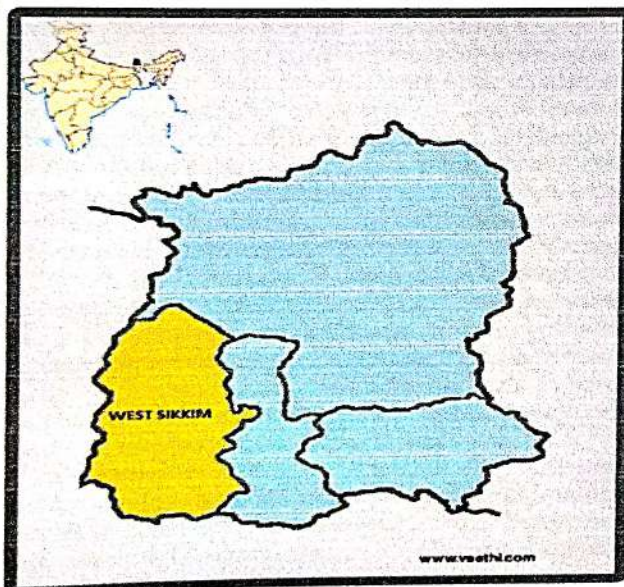
LOCATION MAP



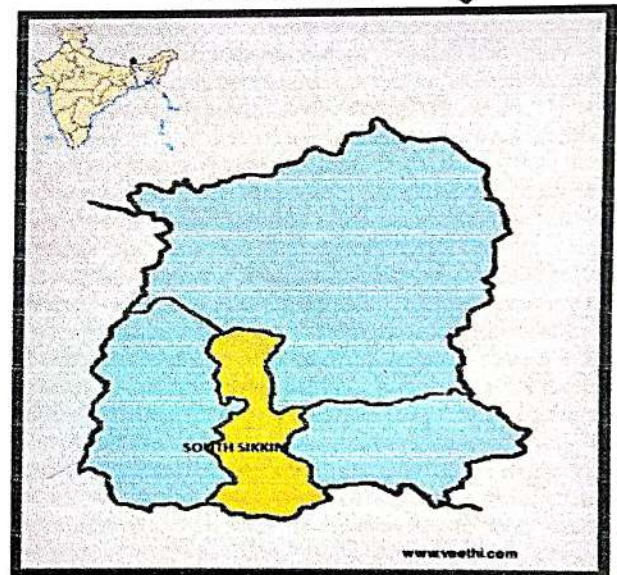
1. INDIA



2. SIKKIM



4. WEST SIKKIM



3. SOUTH SIKKIM

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

- To study the general overview physical and economic socio-cultural environmental of the study area as both are very much related to landslides.
- To identify the major causes of landslides 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 landslides in the study area.

1.5 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 effect of landslide on the lives of the local people?
- (iv) what measures have been taken to prevent landslide from government?

1.6 Data base and methodology :→

The data base has been collected from two sources - primary and secondary. The primary data has been collected from hotel manager, car driven, local people, and seller of souvenir shop. The secondary data were collected from various book, article, different link from website, journal etc.

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

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

1.7: Limitation of the study :->

Due to the limited time period surveyor were not able to collect data properly. Beside 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. General () overview on () Physical (incl socio-) economic environment of the study area

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, climate nature (specially rainfall), vegetation cover, etc. all are the controlling factor on landslide. Apart from these, human activities such as, economic activities, developmental works also effect on landslide. on the other hand, physical and socio-economic environmental 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

2.1.1 Physiography :→ situated in the Himalayan or mountains, the state of Sikkim is characterised by mountainous terrain. Almost the entire state is hilly, with an elevation ranging from 80 meters (260 ft) in the south at the border with West Bengal to 8,586 meters (28,169 ft) in 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 terraced farms.

2.1.2 Drainage :>

Sikkim is drained by large number of perennial rivers, which merge into two prominent rivers, the Teesta and Rangit; rest of other streams eventually joins one or the other. Rangit also joins Teesta just near the boundary between Sikkim and West Bengal.

The Rangit river and its tributaries originate in the Talung glacier in West Sikkim and after flowing for about 60 km, joins Teesta below Melli near the border of Sikkim with West Bengal. Rivers Rangit are Rimbi Khola, Rathangchu, Kaly Khola, Raman Khola and the Little Rangit.

2.1.3 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.

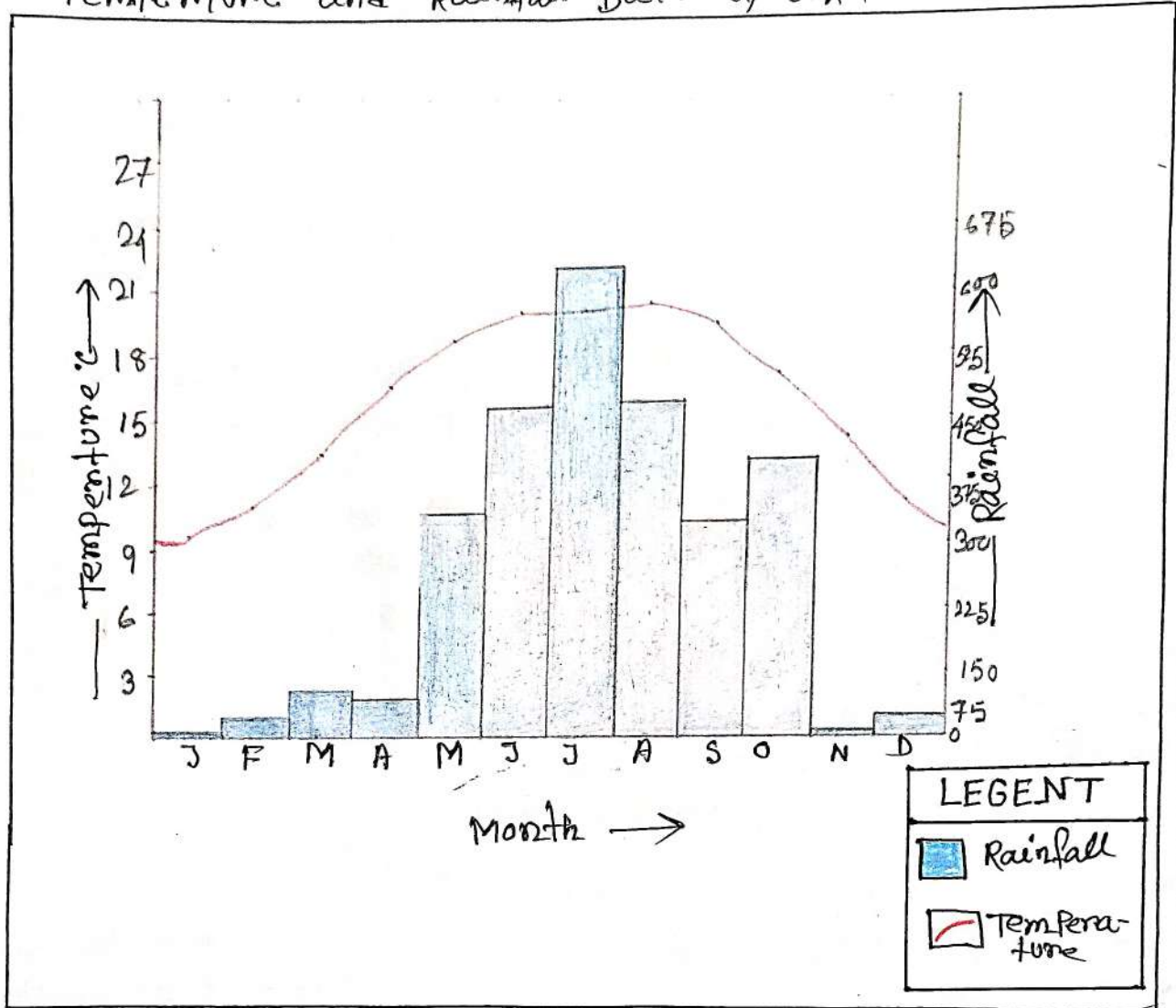
2.1.4 Climate :>

The state has five seasons; winter, summer, spring, autumn, and monsoon season. Most of the inhabited regions of Sikkim experience a temperate climate, with temperature set down exceeding 28°C in summer,

Temperature and Rainfall Data of Sikkim - 2021

Month	Temperature (°C)	Scale	Temperature (°C)	Rainfall (mm)	Scale	Rainfall (mm)
January	9.4	1 cm = 3°C	3.13	6.1	1 cm = 75 mm	0.8
February	10.9		3.63	21.9		0.29
March	13.7		4.56	57.0		0.76
April	16.6		5.53	45.5		0.60
May	18.7		6.23	266.4		3.55
June	20.3		6.76	394.0		5.25
July	20.3		6.76	554.1		7.38
August	20.4		6.8	401.3		5.35
September	19.6		6.53	255.8		3.41
October	17.3		5.76	334.9		4.46
November	13.9		4.63	3.9		0.052
December	11.1		3.7	22.7		0.30

Temperature and Rainfall data of Sikkim 2021.



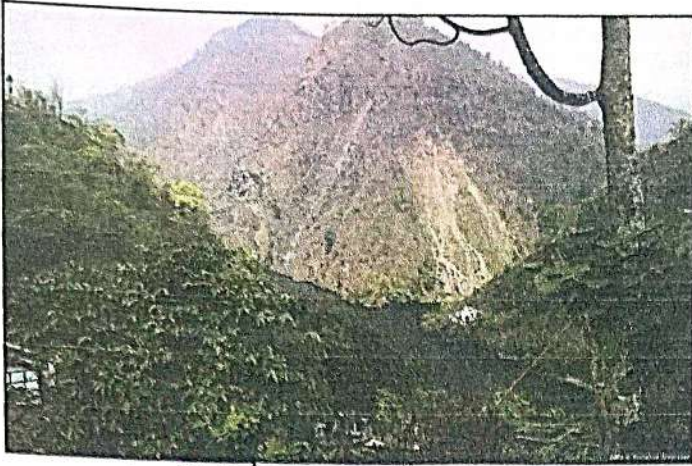
The average annual temperature for most of Sikkim is around 18°C. During the monsoon, heavy rains increase the risk of landslides. The record for the longest period of continuous rain in Sikkim is 11 days. Fog affects many parts of the state during winter and the monsoon, making transportation perilous. Temperatures in the mountains can drop to as low as -40°C in winter.

2.1.5 Flora and fauna :->

Sikkim is situated in an ecological hotspot of the lower Himalayas, one of only three among the ecoregions of India, owing 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 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 5,000 species of flowering plants, 515 rare orchids, 60 poinsettia 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 a Christmas flower, can be found in abundance in the mountainous state.

The fauna of Sikkim include the snow leopard, musk deer, Himalayan lake red pandas, Himalayan marmot, Himalayan serow, Himalayan goral, mountain, common langur, Asian black bear, clouded leopard, marbled cat, leopard cat, 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



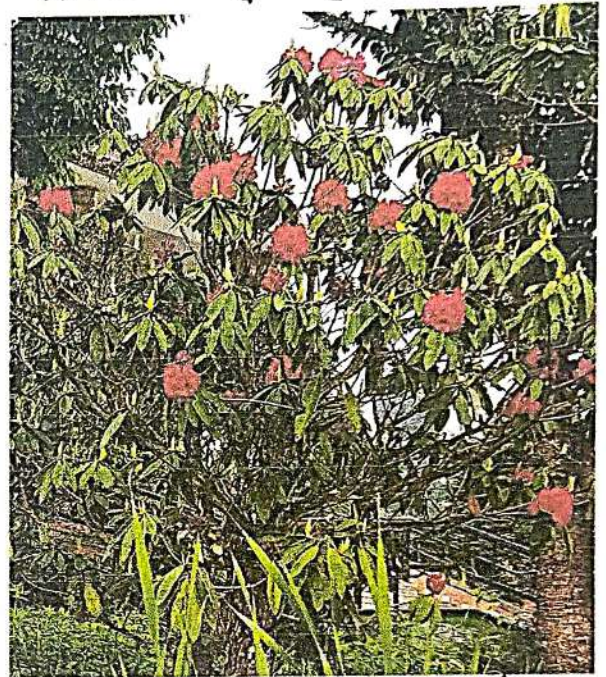
01. Physiography



02. Drainage system (Rangit)



03. Brown clay soil



04. Rhododendron (Flora)



06. National animal Red Panda

more than 550 species of birds, some of which have been declared endangered. The red panda is the 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 male 52.87% and Female 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 76.04%. 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. These are major two religions

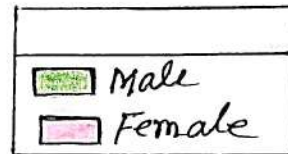
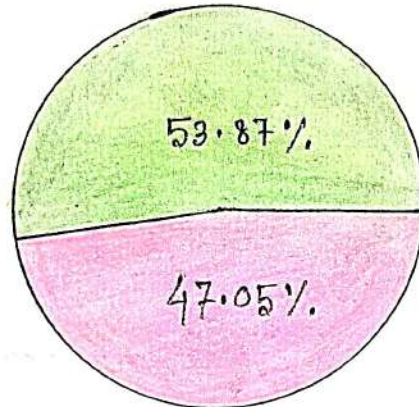
Population composition of Sikkim, 2011			
SEX	Percentage of Population	Total of Population	Population (C ^o)
Male	53.87	100	$\frac{53.87}{100} \times 360$ = 190
Female	47.05		$\frac{47.05}{100} \times 360$ = 169

Source : → Census of India, 2011

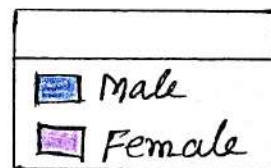
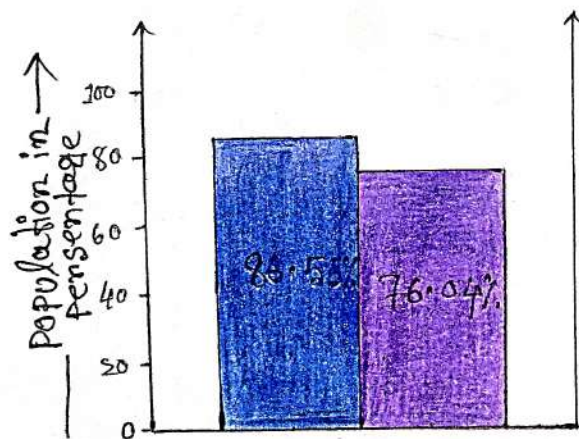
Literacy Rate of Sikkim, 2011			
SEX	Percentage of Population	Scale	Literacy Rate (cm)
Male	86.55	1cm = 20	4.32
Female	76.04		3.80

Source : → Census of India, 2011

Population Composition of Sikkim, 2011



Literacy Rate of Sikkim, 2011



Buddhism and Hinduism. And Sikkim is multi-lingual state where people of many communities reside harmoniously.

2.2.4 Health : →

These are few hospitals, health centers, 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 well.

Sl. No	HEALTH INSTITUTION	EAST	WEST	NORTH	SOUTH	STATE
1.	State Referral Hospital, Gangtok	1	.	.	.	1
2.	District Hospital	1	1	1	1	4
3.	Community Health center	1	.	.	1	2
4.	Primary Health centers	6	7	5	6	24
5.	Primary health sub-center	48	41	18	39	146
6.	District Tuberculosis center Namchi	.	.	.	1	1
7.	Central Referral Hospital, Gangtok	1	.	.	.	1
8.	Total	58	49	24	48	179

2.2.5 Economy : → The Economy of Sikkim is mainly based on agricultural and animal husbandary and tourism. Sikkim's nominal state Gross Domestic Product 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 terraced farming of rice and the cultivation of crops such as maize, millet, wheat, barley, oranges, 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 percent 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 an agrobased society. The Govt. has formulated certain policies such as Sikkim Industrial Promotion and Incentive (SIPDI) Act 2000 and its subsequent amendment in 2003 and 2007. Some of the industries of Sikkim that deserve special mention in this context are: Pharmaceuticals, cosmetics, Food, Processing, Breweries, Metallurgy, Corrugated Boxes, Tea Processing etc.

2.2.5.3 Eco-tourism :>

In January 2016, Sikkim became India's first "100 Percent organic" state. The Directorate of Eco-tourism under the Forest, Environment and Wildlife Management Department has identified and

delineated 11 areas in sikkim as ecotourism, Eco-tourism in sikkim started in the year 1995-96 with training, awareness, changes in regulations to adapt to the mountainous terrain and entry of foreign tourists in many of restricted and protected areas,

Protected parks and sanctuaries for eco-tourism activities :- Kanchenjunga national park, Singha Rhododendron sanctuary, Fambong Lho wildlife sanctuary, Kyongnosla alpine sanctuary, macnam wildlife sanctuary, varsey 'Rhododendron' sanctuary.

2.2.6 Transport :->

① Road ways :-> national Highway 10 (NH 10; formerly NH 31A) links siliguni to bangkok. sikkim nationalised transport runs bus and truck services. privately run bus, tourist taxi and Jeep services operate through sikkim and also connect it to siliguni. A branch of the highway from millie connects western sikkim towns in eastern, southern and western sikkim are connected to the hill stations of, kalipong and dandajoling in northern west bengal. The state is further more connected to Tibet by the mountain pass of north La.

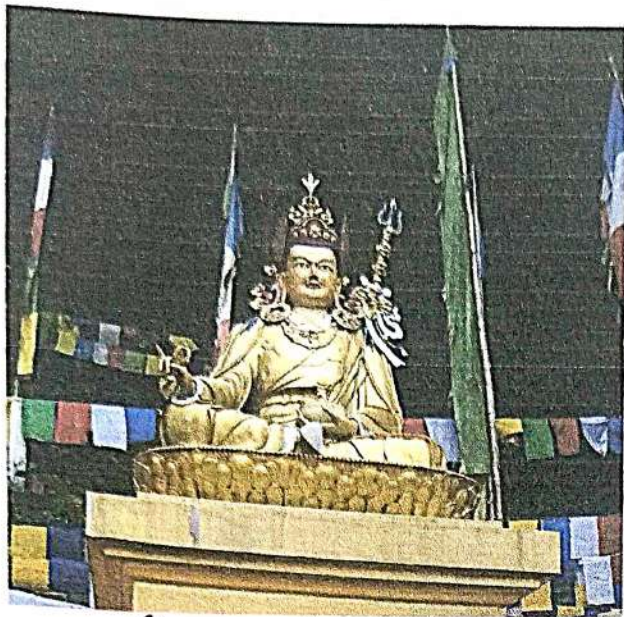
List of National Highway of Sikkim

Number	Length (km)	Length (mi)	Southern or west-tern Terminus / Northern or Eastern Terminus
NH 10	52	32	Gangtok - Singtam - Rangpo - West Bengal border
NH 310	87	54	Ranipool (NH 31A) - Bunk - Mena - Nathula
NH 310A	55	34	Tashi view point - Phodong - Mongan
NH 510	70	43	Singtam - Damthang - Legshep - Gyalshing
NH 710	45	28	Melli - Manpur - Namchi - Damthang - Tanke
NH 717A	115	70	West Bengal border - Rhenock, Rongthang Pakyong a junction with new NH 10 at Ranipool near Gangtok.
NH 717 B	42	26	Junction with NH 717A at Rhenock Rongthang, Rolip - junction with NH NO 310 near Mena at Sherathong

(i) Airways :-> 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.

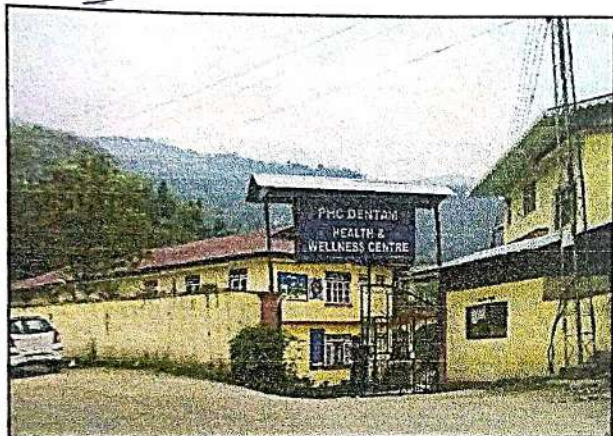
(ii) Railways :-> The nearby railway station to Sikkim are New Jalpaiguri and Siliguri station located in West Bengal



culture of sikkim



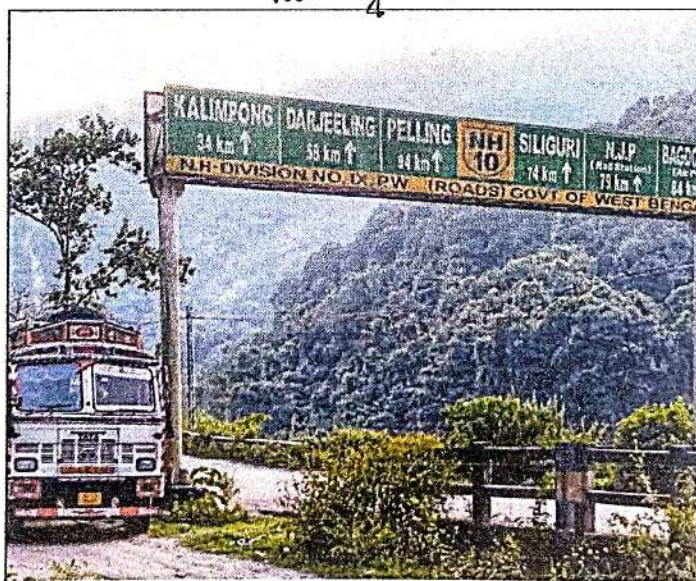
culture of sikkim



primary health center in dentam valley



cardamom cultivation



NH 10

3. Landslide in 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. A part from the recent unplanned development activities, particularly road construction and ill planned settlements, have further aggravated the incidence of the landslide and subsidence.

3.1. Causes

The frequent occurrence of landslide is 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-

(A) Geological causes: → Sikkim a state in northeastern India is located in a seismically active region and experience various geological process that can contribute to landslide

(i) Slope stability: → steep slope and unstable geological formations can contribute to landslide. The Sikkim region is characterized by rugged terrain with steep slope, especially in the Himalayan mountain range. The presence of weak rock formations and loose soil can make these slope prone to landslide.

(ii) Geological Formation
The geological formation of Sikkim consists of complex and varied rock types

including schists, gneiss, phyllites and quartzites, some of these rocks have inherent weaknesses and discontinuities, such as bedding planes, joints and faults which can be act as potential sliding surfaces.

(B) Environmental causes :-

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

(i) Heavy Rainfall :- Intense or prolonged rain fall can saturate the soil, increasing its weights and reducing its, particularly during the months of June to September. The excess water can infiltrate the ground, leading to landslide. 6th August, 2020 Jomethang Landslide in Sikkim.

(ii) 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 slope and trigger landslide. 2011 Sikkim earthquake, with a magnitude of 6.9 caused significant landslide in the region resulting in loss of life and infrastructure damage.

(iii) Erosion :- Natural erosion processes such as river erosion can undercut slope and weaken their stability. Continuous erosion removed support from the base of slope making them prone to landslide.

(C) Human-Related causes :-

Human activities can also contribute to the occurrence or exacerbation of landslide. Here some man-made causes of Landslide -

(i) Deforestation: \rightarrow clearing large areas of forests for agriculture, logging or urbanization reduces the stability of slope. Tree roots help bind soil and prevent erosion, so their removal can make slope more prone to landslides.

(ii) Construction and Excavation: \rightarrow poor construction practices, improper grading of slopes and excessive excavation can alter the natural stability of the land. Building roads, highways or structure on steep slopes without appropriate engineering measures can be increase the risk of landslide.

(iii) Defective Drainage system: \rightarrow Inadequate or poorly designed drained system 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.

(iv) Surface modification: \rightarrow Altering the natural drainage patterns by modification rivier, streams or water channels can causes increased water flow and erosion, which can weakes slope and trigger landslides.

(v) Irrigation and water leaks: \rightarrow Improper irrigation practices, such as excessive water application or inadequate drainage system can saturate slopes and increase their susceptibility to landslide. water leakage from pipes or sewers can infiltrate the soil, leading to instability.

3.2. Consequence

The effects of landslide in Sikkim can be significant and have various consequences on the region, the environment, and the local communities. Here are some of the potential effects -

(A) Physical Effects : → Damage to Infrastructure The Infrastructure facilities such as telephone and communication system, election supplies, water and oil pipelines, offices furniture, commodities, transport system etc. are severely damaged and put out of gear by massive landslide.

(B) Social Effects : →

(i) Human casualties :- If landslide occur in the inhabited areas, the first and foremost adverse impact are on human population. If there is not timely forewarning of probable occurrence of landslide and if there is no proper timely evacuation, 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, road and railway :- Settlements comprising both rural and urban located at vulnerable sides such as on hill slopes, at the foot of hills, alluvial fans and cones, in the valleys facing steep hill slopes etc. are damaged and sometimes villages are completely destroyed by the chief debris of rocks, muds and other materials dislodged from the hill causes by landslide of various sorts triggered by earthquakes on heavy rainfall or human activities.

© Economic Effect

Loss of agricultural forms and crops

At the very outset it may be pointed out that majority of settlements are built on the hill slope 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 landslide the terrace forms are completely destroyed by rainfall debris of rocks, boulders, mud, fine, loose materials etc. the debris is dumped in the valleys and hence forms and crops on the valley floors are

© Environmental Effect :->

Damming of rivers and flash floods

Huge volume of debris produced by landslide of various sorts coming into the rivers forms temporary dams across the river and thus blocks the river flow. In such situation substantial volumes 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 breach and impounded water rushes downstream with high velocity resulting 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.

Effect of Ecosystem :->

① Impact on water :-> when landslide occur they can seriously damage or destroy ecosystem some

times the effects can last for thousand of years. They can pollute streams and water bodies with sediment and debris. This invariably has severe repercussions on water quality and marine life.

⑥ Wipe out forest land : → What's more, these hazards can wipe out large tracts of forests, wildlife habitats and remove productive soils from slope.

⑦ Dam up on flood streams : → Also, they can dam up rivers and streams. In also 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 to. outbursts floods can introduce a tremendous amount of new sediments into streams. on they can submerge and kill vegetation in the flood region. In sikkim flash flood killed 22 people triggered a series of landslide and washed away nearly 30 km of highway in north sikkim amid torrential rain

Loss of lives and social disruption

Landslides are responsible for a number of deaths, injury to people, damage to housing, infrastructure and agriculture 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.

Socio - Economic effects of landslide

Socio-economic effects include adverse impacts, as enumerated above, on people, their homes and properties

Industries and factories, agricultural land and crops, timber, life lines such as roads and highway, railroads, and communication systems, educational institutes etc. It is significant to note that socio-economic problems caused by mass movement of rock, water and landslide due to slope failures are many fold and are assuming larger proportions due to expansion of built environment in environmentally fragile and vulnerable mountainous areas.

Some instances of landslide
in the study area: →

2007, 19th July: → Heavy rain triggered a landslide in Rabangla, south Sikkim. The Singtam, Rabangla road has been as many as 11 landslides while the Namchi Rabangla route via Darithang has been closed because of an uprooted tree.

2011, 23rd June: → A torrential spell of rain from 7.30 PM to little past midnight on the 23rd June 2011 triggered numerous small landslides in Pelling, where 4 people perished on the Pelling - Dentam road in west Sikkim.

2011, 18th September: → 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 India state of Sikkim, between Nepal and Bhutan.

2020, 21st June: → A landslide occurred in Tatapani at 6 PM on Friday. The road constructed across a steep terrain near Tatapani remains vulnerable to landslides especially during rainy season and recent back cutting initiated for the road expansion has added to risk of landslide during on going monsoon season. Legship Nayabazar road was blocked near Tatapani due to landslide. The commuters travelling from Jomethang to Beyzing, Yuksam and Tashiding were compelled to take Reshi - Rinchenpong route via Legship to reach their destination.

2020, 27th June : → A landslide occurred at national Hydropower project of Corporation (NHPC) Teesta stage 1 dam on the left bank of the river in Dikchu. According to the local people of Jang and Nopara, 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.

2020, 6th August : → 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 IPA Laboratory in Mazhaton, 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.

2022, 5th February : → A landslide occurred at Petling village in Namchi district due to heavy rainfall. 60 houses were damaged in this landslide.

2023, 18th June : → Multiple landslide 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.

Management : →

Guidelines by the national disaster management Authority (NDMA) on management of landslides reduce the enormous destructive potential of landslide and minimize the consequential losses by institutionalizing the landslide hazard mitigation efforts. Preventive and corrective measures to lessen the impacts of

Some Instances of Landslide in the study area



Pathing village in namchi district due to heavy rainfall



The IPCC laboratory was badly effected due to landslide



Teesta stages - V dam was broken due to landslide



Landslide all over sikkim due to earthquake



14 people died in pelling due to landslide



Legship - nayabazar road was damaged due to landslide



namchi - Parbongla road was closed due to rainfall

landslide its may be mentioned that landslide cannot be stopped. But number, frequency, recurrence and severity can be minimized. Some preventive measure have been taken to manage landslide in the study area-

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.

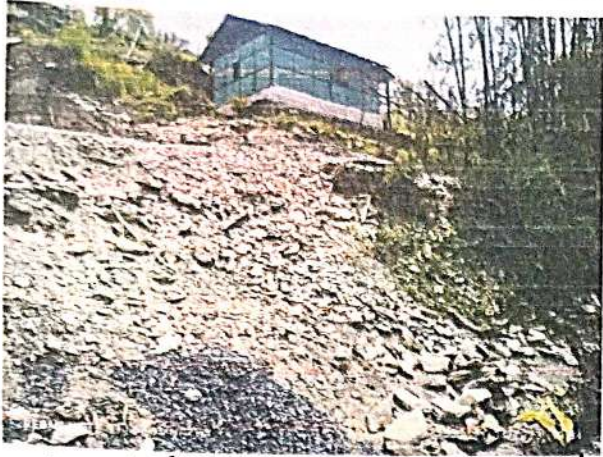
Bench terracing :> Relatively steep land was transformed into a series of level or nearly level strips or steps running across the slope of many landslide in south Sikkim.

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.

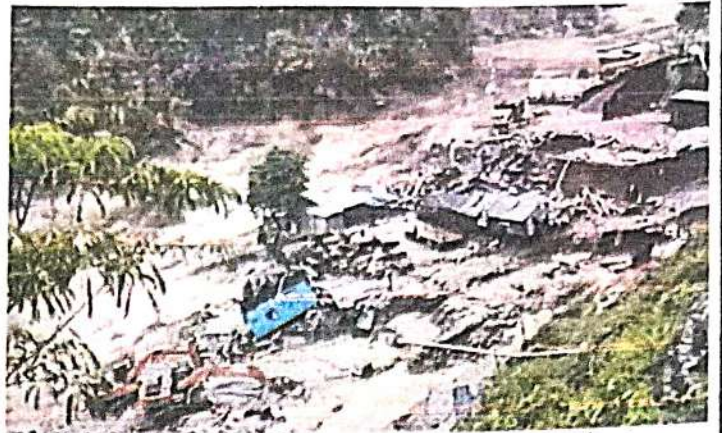
Contour trenching :> series of deep pit or trenches across the slope at convenient distance was built with in the landslide of south Sikkim. The soil excavated from the trenches was deposited on the lower edge of trenches where forest trees were planted

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



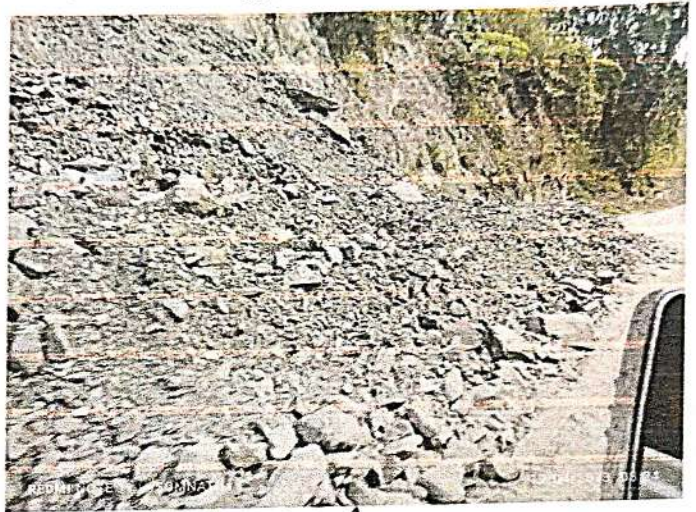
Landslide prone area unplant settlement



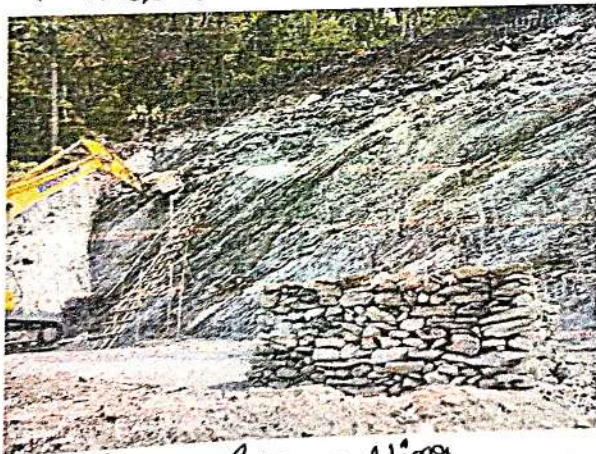
Heavy Rainfall had devastated hundreds houses in west sikkim



Uprooted plants due to landslide



Land Subsidence



Rock slope netting



Bench terracing

Suggestive Measure :->

Along with the management system of landslide in Sikkim Himalaya, some other measure should be taken

- (i) During pursuing of any assumptive project in the high risk zone, like Sikkim, should be proceed with prudence
- (ii) Environmental Impact Assessment standards should be followed before mining or dam building.
- (iii) Landslide micro zoning method should be implemented in the extremely vulnerable areas.
- (iv) To strengthen hazard reduction and public awareness effort, locality available trained people should be considered
- (v) To strengthen disaster management potential more funding should be given to landslide planning and mitigation agencies.
- (vi) Mitigation techniques such as confining agriculture to valleys and place with moderate slopes, fortifying large-scale afforestation initiative and building water bunds should be encouraged
- (vii) Encouraged the use of effective landslide rehabilitation and mitigation techniques.

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 district of Sikkim. In the study area landslide occur basically due to heavy rainfall along with some associated factor. many times it creates massive and unwarranted loss of life and property. Therefore, there 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 measure to lessen the impacts of landslides which will help to prevent water entering the well slopes through joints and cracks, decrease water pressure in the rocks through shallow and sub-shallow drainage, place drainage trenches in order to reduce water pressure in the vicinity of well 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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