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SLOPE STUDIES MAPPING OF LANDSLIDE HAZARD: A STUDY ON NAMCHI, SIKKIM USING GIS

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ABSTRACT

This paper presents a case study of slope studies in Namchi, Sikkim, India, using Geographic Information System (GIS) to map landslide hazards. The GIS analysis was used to identify areas of steep slopes that have high potential for slope instability and thus landslide hazard. The results of the study showed that the highest landslide hazard was located in the areas of steep slopes and along the river channels. The study also found that the areas of high landslide hazard were also areas of high land cover change. As per the Centre for Research at the Epidemiology of Disasters (CRED), landslide positioned fifth in expressions of number of passing is out of top ten biggest significant disasters. Inside Himalaya district, Sikkim Darjeeling Himalayas is one of the best landslide inclined regions. AHP is widely used in site selection and suitability, habitat suitability analysis, and LHZ and mapping. A formal land use land cover classification was prepared using Arc GIS. A soil map was available from DRDO database. Geology and lithology map were given by DRDO database and weightage was given according to the importance. A layer of relief including slope and degree of aspect were included in the study. This research at is an attempt on this way and attempts to investigate the components assuming principle role inside the occurrence of landslide in this area.

KEYWORDS: AHP, GIS, Indian Himalayan Region, WOA, Land Use & Land Cover Analysis

Slope studies are an important part of any development or hazard mapping project. They involve the mapping of existing and potential landslides in order to identify landslides which could potentially cause damage to buildings, infrastructure, and people. This paper will provide an introduction to slope studies, with a focus on mapping of landslide hazard in Namchi, Sikkim, using Geographic Information Systems (GIS). The region is located in the namchi south Sikkim Himalayas among 27.246157°" and 27.096570°" N latitudes and 88.465451°" and 88.449466°" E longitudes, overall area of observe 100sqkm (Sarkar, 2013). At an elevation of 1,675 m (5500 feet) directly above sea level. Landslide in Namchi Sikkim have constantly presented extreme dangers to settlements and structures that help transportation, natural resources, and the travel industry. In spite of the fact that limit of these landslide passed on cut slants or edges close by streets and interstates in hilly zones, landslide have occurred for in different zones also. A few of landslide have given near high rise settlement and in residential locations, perpetrating demise to individual (Pradhan, 2010). Namchi is located in southern part of Sikkim with rivers draining the area thoroughly. The total geographical area of Namchi is approx. 750 sq.km. and happens to be the one of the highest populated areas in Sikkim. The annual rainfall or snowfall is 1422.21mm. The AHP is a model of estimation for managing quantitative and indefinable devices has been useful to various areas, alongside choice standard and dispute resolution. Utilizing this strategy, each layer utilized in landslide susceptibility zoning is harmed into minor components. AHP used for giving weightage to the factors and sub factors based on their importance. An attempt was made to consider past incidents of earthquakes in the region. The layers included DEM, land use land cover, slope, distance to nearest stream, aspect, distance to road, data on earthquake. The current study also deals in AHP and found this source helpful in understanding AHP and factors. Some subjective procedures, be that as it may, incorporate the idea of positioning and weighting, and can develop to be semiquantitative in nature. In Cases of this are the utilization of the analytic hierarchy process (AHP) by (Saaty, 1980) and the weighted direct total (WLC) by means of AHP incorporates developing a hierarchy order of choice elements (components) and afterward making correlations among potential combines in a framework to offer a load for each component and also a consistency proportion. It depends on three concept: comparable judgment, disintegration and combination of needs. The AHP evolved by Saaty (1980) gives a bendy and easily comprehended way of analysis entangled issues. It is a few standards dynamic strategy that allows in abstract all the same objective components to be considered inside the dynamic framework. AHP grants the dynamic commitment of chiefs in arriving at agreement and gives

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administrators a rational premise on which to decide (Yalcin, 2008). Landslide is a final results of blended motion of several physical and anthropogenic factors which have an effect on the occasion directly or indirectly. Consequently all techniques of landslide susceptibility assessment related with more or less same conditions: (I) recognizable proof of causative components which may be responsible for incline variability, (II) computation of score or weight by choosing a appropriate strategy or method, (III) appraisal of capacity of frailty features for the occurrence of landslide on the reason of their essential rankings or weightage, (IV) identity of landslide weakness zones on the reason of the class of landslide susceptibility index (LSI).

CASE STUDY: NAMCHI, SIKKIM

Indian Himalayan Region (IHR) has one of the extraordinary mountainous geology in the Himalaya, which is topographically one of the most youthful mountain assortment inside the world geographically still dynamic, with enormous abundance of common assets. IHR involves 18% geologically place of the India with 6% occupant populace of the nation. It extends more than 2400 km from east to west and varies in width from 220 to 300 kms in north to south appearance. Present day geo-informatics instruments including Remote Sensing (RS) and Geographic Information System (GIS) are dynamically increasingly utilized for landslide trouble examinations. An total of facts derived from RS facts and ground bases discipline information arranged directly into a GIS centre licenses different types of investigation strategies. Landslide arise often inside the Himalayan State of Sikkim, India, because of the substantial precipitation. In this mountain terrain the different lithological systemic connection is actuality ache from glacial, periglacial and fluvial groups. The excessive tough inclines are as a rule unremittingly bared and washed by utilizing ice and water, and helped through the channel and stream arrange. In this technique, colossal debris and remains are being throw out on way. In the present year an immense number of landslide reason embraces harms to the agricultural fields, forest, settlement structures, and roads in lots of components of the landscape and additionally the proceeded with formative exercises increments towards unequal mountainous territory have genuine the slant stability. These risks can't be turned away in all cases taking amazing convenient measures to oversee up with them for catastrophe preparedness. Namchi is a municipality located in South Sikkim, India. It is an important tourist destination, as well as a major commercial hub. It is surrounded by steep mountains, making it vulnerable to landslides. In order to evaluate the risk from potential landslides, it is important to map the slope stability in Namchi. (Figure 1 & 2)

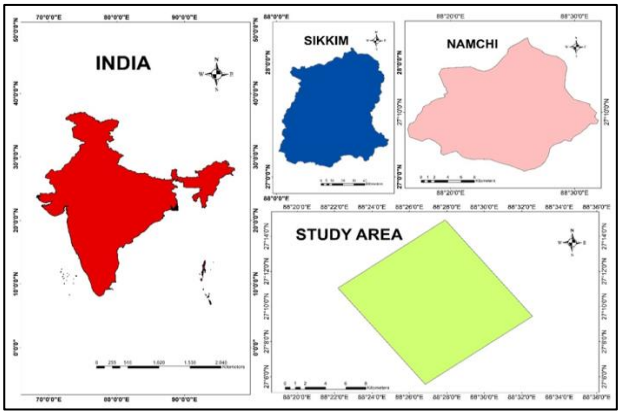


Figure 1: Study Area Namchi, Sikkim

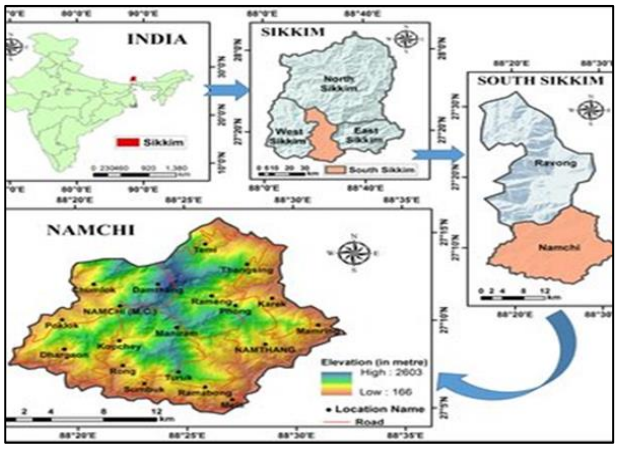


Figure 2: Municipality located in South Sikkim

METHODS AND METHODOLOGY

Methodological system of the investigation at is part into a few unique sections like, spatial database creation for landslide conditioning issue and avalanche areas, segments of the model, arrangement avalanche susceptibility maps and approval of the model. that structure was assumed the possibility of a premise familiar rule of "present and past are keys to the future". For the improvement of spatial database, all the avalanche causative components had been changed (Bai, 2010). Utilization of AHP technique is widely utilized in site choice, appropriateness investigation (Kumar, 2016). Analytic hierarchy order methodology and records value techniques are utilized to get ready landslide susceptibility maps for the considered zone. The statistical analysis is accomplished using an outer measurable parcel (MS Excel programming). At long last, approval of the two models transformed into executed to choose the most extreme superb landslide susceptibility map for the study area (Achour, 2017). AHP is a multi-basis result making strategy presented by Saaty (1980)

which permits subjective and target components to be taken into thought in the dynamic procedure (Kumar, 2016). It is create totally on three concepts: decomposition, synthesis of priorities, and comparative judgment. AHP breaks complex decision making into a progression of perspectives and options. (Figure 4 & 5)

M.1. AHP Method

The Analytical Hierarchy Process is a multi-rules end creation strategy that was firstly created by (Saaty, 1980), that idea of estimation for overseeing quantifiable and strife norms that has been executed to numerous locales, including choice hypothesis and compromise.

AHP is a multi-objective, multi-standards dynamic technique which permits the user to reach at a size of inclination drawn from a fixed of choices. AHP spend wide strategy in site determination, appropriateness analysis, regional development, and avalanche vulnerability assessment.

The fundamental steps of the AHP technique are:-

In the initial step, components and their spatial portrayal must be connected with a typical scale to make examinations weakness conceivable. The phase of was set to 0, if a class of a factor has no effect. On the other hand, a degree of powerlessness of 255 was given.

In the subsequent advance, an appraisal matrix is constructed, and every angle is as contrasted and the other factor, comparative with its significance (Yalcin, 2008) of deciding their loads as far as the two information layers and sub standards, in significance of the count done by the AHP.

M.2. Weightage Overlay Analysis

Landslide incidence is decided from landslide associated element and the destiny landslide can occur within the same condition with past landslide. Based on the belief using probability approach, the relationship among regions with landslide occurrences and landslide associated features can be illustrious from the association among place short of occurrences of landslide and landslide connected elements. To current the difference quantifiable, the weightage overlay technique turned into used for this study. The weighted layers might be significant to contain request of geo-processing tasks and to change over the records from one configuration to the next to make the assessment. In the raster overlay analysis, every cell of each layer should references the equivalent geographic area to makes it pleasantly immaculate to consolidating characteristics for various layers into a one layer. The weighted overlay examination put on a typical scale regards to the numerous topical layers to make a output layer (Kaliraj, 2015). (Figure 6 & 7)

Hence higher estimation of proportion of influencing weight is given to initially contributing layer between every single other layer. To meet the target, the numerous thematic layers have analysed utilizing a calculation of weighted overlay assessment in ArcGIS.

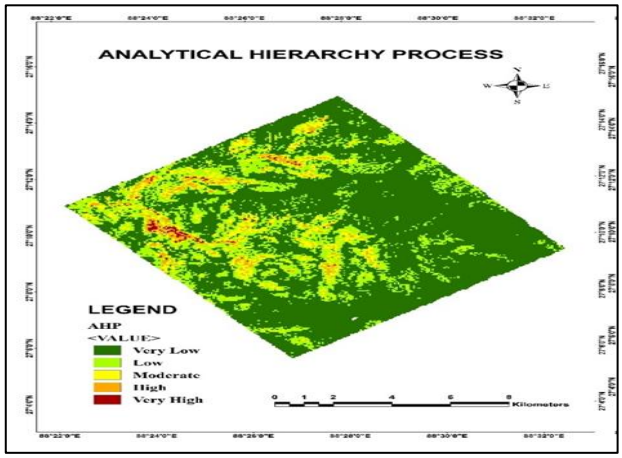


Figure 4: Landslide susceptibility zonation map

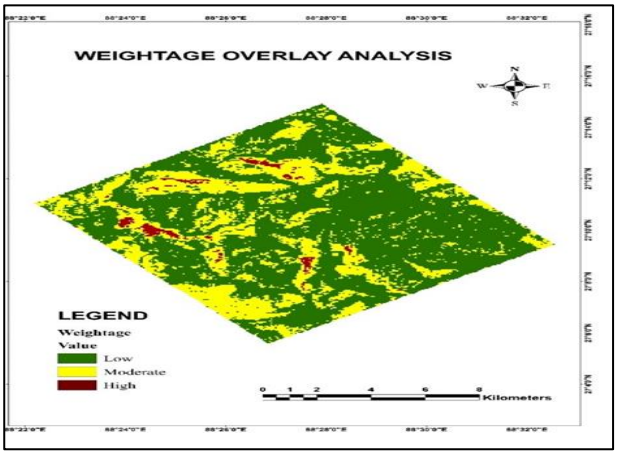


Figure 5: Landslide susceptibility zonation map

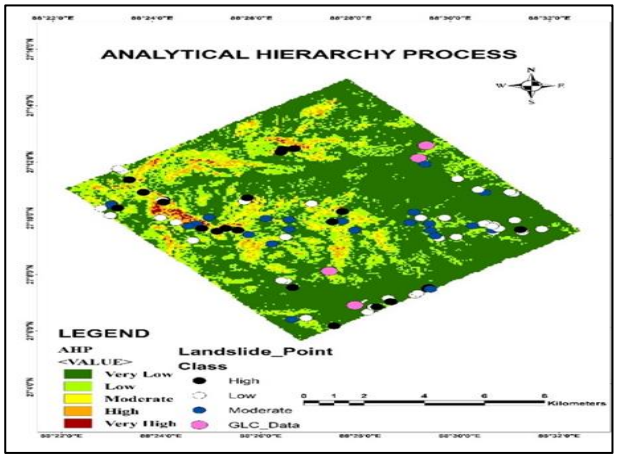


Figure 6: Landslide susceptibility zonation map with reference of Global Landslide Catalog Data (GLC)

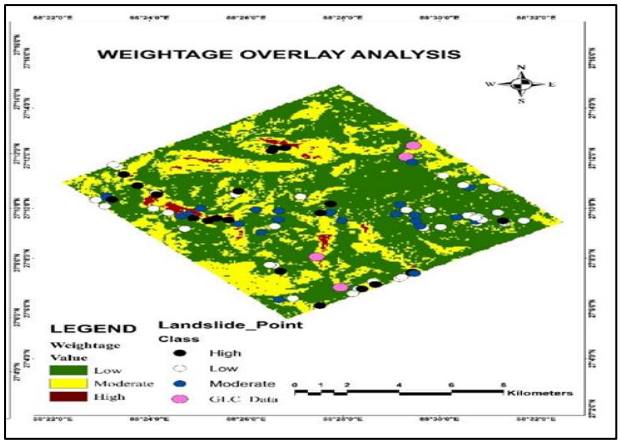


Figure 7: Geology Survey of India (GSI, Landslide Point)

Soil Map

The soil map diverted into arranged from spatial soil information with field analysis and furthermore alluded distributed writing. The influences of the fundamental soils at the avalanche shaking are extra significant. Seismologists have discovered that the solid seismic shaking is over and over situated in the coarse loamy powerless and liquefied soil (Sivakumar, 2017). The landslide incidence chance cost of rock sandy loam soil and also sandy loam are higher and lesser in exceptional sandy loam, silt loam, gravelly silt loam and loam.

Soils of the Namchi region are especially composed mainly Loamy soil group, that is classify Loamy Skeletal Weak Soil, Shallow Depth Soil, Loamy Skeletal Weathered Soil, Coarse Loamy Rock soil, Fine Loamy Mixed Soil, Coarse Loamy excessive drainage rock valley fill. In the study area, it is found that Loamy Skeletal Weak Soil and Loamy Skeletal Weathered Soil fall in south east part, Fine Loamy Mixed Soil and Coarse Loamy soil take a look at in north west part, in that area observe as a high landslide area (Sivakumar, 2017). (Figure 8)

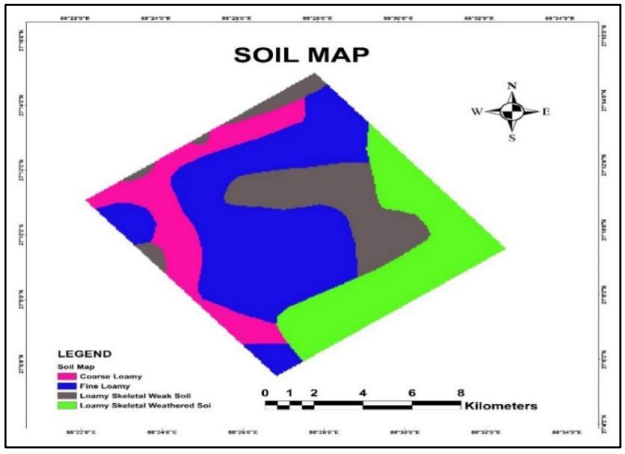


Figure 8: Soil Map

Slope Map

Landslides are more prominent generally inside the steep slope than in moderate and low slope areas. Slope is an essential variable for steadiness thought. It is the essential imitative of height with each pixel the point of slope at a particular spot. The western aspects of the central and the northern components of the study region are identified through very steep slope. Besides, steep hillside slopes are also observed in few places. The eastern parts of the observation location, by low and gentle slope. The slopes of the area are characterized in terms of degrees, and are divided into five slope type, viz., steep (> 60°), high (30°–40°), moderately high (20°–30°), gentle (10°–20°) and rolling slopes (0-10) (Lallianthanga, 2013). Movement of the fault because of tectonic action mains to alteration the slope representative excessive probability of landslide. In the northern a part of the have a observe area, much less frequency and significance of landslide became distributed within the moderate and very moderate slope location, signifying the location is seismically much a reduced amount of active (Sivakumar, 2017). (Figure 9)

Slope-Aspect Map

Aspect map for the most part signs to the course to which a height slope faces. The Aspect map is an exceptionally basic parameter to perceive impact of sun based on close by climate of the region. By and large west-bound slope recommends the most up to day time of the day toward the evening, and in greatest cases, a west-face incline might be more sultry than shielded east-face slope. The Aspect map of the Namchi region changed into got from ASTER DEM. The slant parts of complete bowl is isolated into ten classifications, those are flat—1, north 0–22.50, north-east 22.5–67.50, east 67.Five–112.50, south-east 112.Five–157.50, south 157.Five–202.50, south-west 202.5–247.50, west 247.Five–292.50, north-west 292.5–337.50 and north 337.Five–360 (Bera, 2019). (Figure 10)

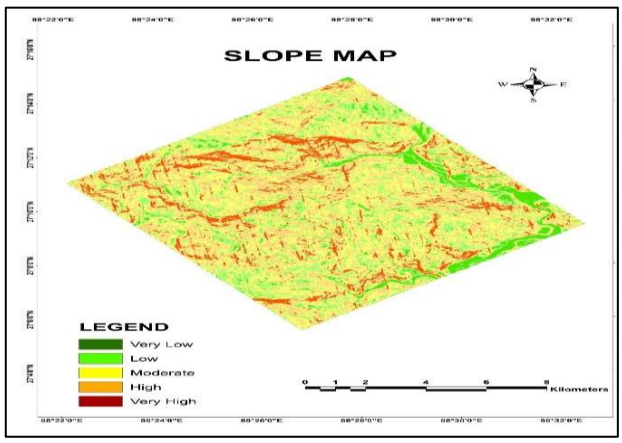


Figure 9: Slope Map

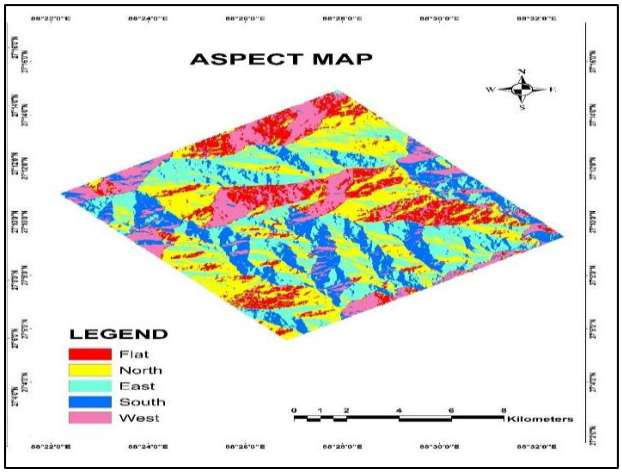


Figure 10: Aspect Map

Geology Map

The geology map prepared into organized using geological and mineral maps of Sikkim. The observation location is split into specific geological units with different lithological formations. In namchi Sikkim, these manifestations are found close by Phengtang, and Kibek cavern zone. Lithological part of this area recommends the making of different kind of rock molecule. Chlorite, schist, phyllite, quartzite, and mica schist are present here. The Reyang arrangement are propelled through components of Gorubathan and secured by method of Buxa Subgroups inside the Rangit Space Region close Namchi. The Buxa arrangement happens over the Reyang development and underneath the skyline of Rangit Pebble Slate arrangement. In the lower region belt, it's far decided as a spasmodic tight segment of variable width between the Gondwana residue on the most minimal and the Reyang Subgroup on the top. The exposures of the Buxa development in Sikkim are checked along the movement of the Rangit River near Namchi district wherein Dolomite rock outcrop is richly present. Lingtse gneiss development is found in the north piece of the zone. The rock records are pleasantly obvious near Naya bazaar, Namchi and neighboring zones of Rangit River. (Sivakumar, 2017). (Figure 11)

Lithology Map

Lithology performs an significant part in landslide susceptibility mapping. It is broadly perceived that lithology considerably impacts the commonness of avalanches. In the limit of most recent research, which include references and this restriction has been measured in light of the fact that the most significant issue in landslide vulnerability mapping. Other type of rock is present in study area, this is Greywacke rack, this rock is compose variation of sandstone that break from different to hardness, dark colour, and feldspar and poorly sorted angular grains of quartz. It is a appearance immature sedimentary rock discovered inside the Palaeozoic layers. Higher grains may be from sand to pebble duration, and matrix materials are in the order of 15% by means of quantity of rocks. A deep colour typical of deep seas in less oxygen environment. That rock are in particular found in center and western part of study area. Quartz arenite is a quartz sandstone (>95% quartz) held composed via cement induced into intergranular pore area. This rock has a great textural and mineralogical, with typically monocrystalline sand-sized quartz grains and lines of polycrystalline quartz and other large, rather-resistant substances like rutile, zircon and tourmaline. (Figure 12)

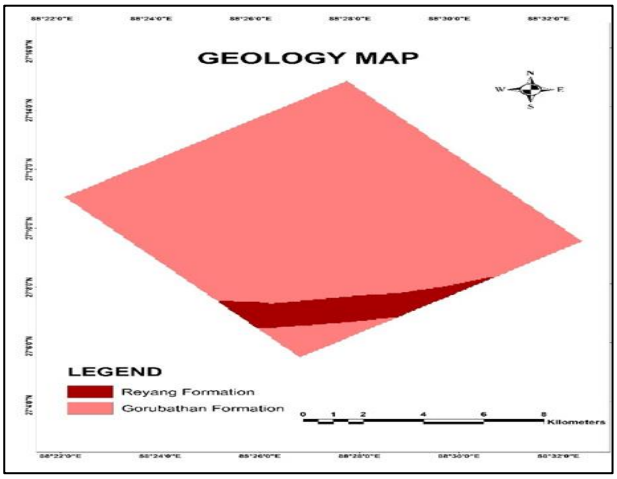


Figure 11: Geology Map

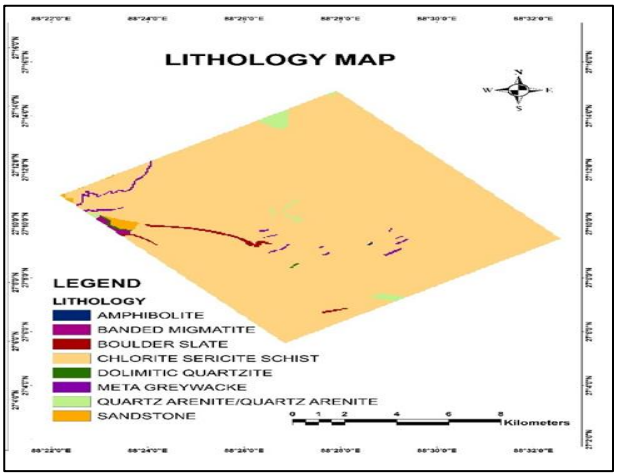


Figure 12: Lithology Map

Land Use and Land Cover Analysis

The land use and land cover map of the study region was produce from the remote sensing information. Landset 8 satellite images was deciphered for different land use as far as vegetation cover (Sarkar, 2008). The Land use and Land cover have to be acknowledged to decide which areas are more appropriate for a landslide. This is fundamental map of the observe or facilitates in producing several thematic maps compulsory for overlap

examination. It was created by image interpretation and classification. The study area is divided into 7 land use/land cover classes, (Lallianthanga, 2013). Build-up, Vegetation, Fallow Land, water body, Agriculture land, Forest, Barren land. Land use/land cover is an inclined indication of steadiness of mountain slope since it power the control of enduring and disintegration of the essential stone developments (Lallianthanga, 2013). In the land use/land cover mapping by utilizing full stereoscopic assessment, uncommon accentuation has been surrendered to the manufactured area which may be defence less against avalanches and they are mapped as high-chance, moderate-hazard and low- risk regions. Numerous investigations have discussed that the level of soil solidness provided by method of plants diminishes inside the accompanying request: hedges, bush, grass and bare soil. The region is usually protected by means of moderate and inadequate forest classes observed by utilizing agriculture land and Fallow land and built-up spread all over in the area. The barren land, which cover smallest area, is principal at higher rise in the south part. Water bodies are appearing in the south and south east part of the area. (Sarkar, 2008).

Distance from Road

The distance to road is one of the essential parameters in produce landslide susceptibility maps. Roads can be one of the reasons of happening landslides. Roads modified the nature of topography and reduce the shear energy of toe of slope and reason the tensile stress. Naturally, slope may be stable, but after road construction, road may have unwanted effect on slope. The road reasons sensitive of water in slopes and applies greater stresses because of traffic loads. The existing roads constructed on sloping lands reason of topographical adjustments under static load. These slope events may also happen as a effect of cracks that lead to excessive water absorption of the soil and these bad influences, inclusive of water capacity, can cause landslides.

Distance from Drainage Map

Drainage is one of the significant aspects that manipulate the landslide as its densities mean the nature of the soil and its geotechnical properties. Drainage pattern created by means of move erosion over time that reveals traits of the type of rocks and geologic structures in a landscape region tired by way of streams. Drainage pattern is the pattern shaped by using the streams, rivers, and lakes in a selected drainage basin. Governed through the topography of the land, whether a specific location is dominated with the aid of tough or tender rocks, and the gradient of the land.

The vicinity to the Streams arrange is a basic thing in expressions of equalization. A basic parameter that controls the stableness of an incline is the limit level of the material on the slope. The closeness of the incline to drainage system is some other significant angle as far as security. Streams can also gravely influence solidness through disintegrating the inclines or by means of soaking the minor a piece of material until resulting in water level will increment. Majority of landslides are observed closer to the drainage location. To create the correct valuation of landslides drainage buffer map with buffer distance. 5 exclusive buffer regions had been created within the observe area to regulate the grade to which the streams precious the slopes. That is 50m, 100m, 150m, 200m and more than 200 are organized.

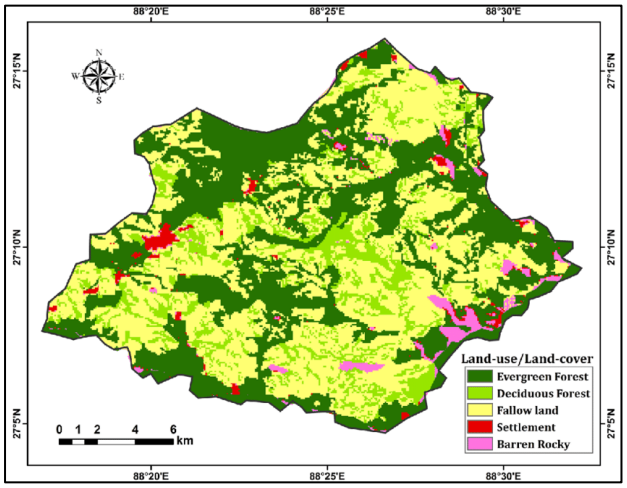
Relative Relief Map

Relative relief shows the capability strength for mass wasting and soil erosion (Kayastha, 2013). Relative relief is determine because the change among the maximum and minimum altitudes within a certain cell. In this study, relative alleviation is derived from the digital elevation data, It is determined that the raise differs from 300 min south component to 7000 min the north portion of the study area. The observation location which is actually a portion of inside elevation ranges of Himalaya is completely hilly, have less plan area with rugged topographic functions (Sivakumar, 2017). The maximum top elevation is found within the north western part of the study area (Kumar, 2016).

Curvature Map

The term curvature and flow is normally defined on the grounds that the curvature and flow of a line shaped by means of the association of an arbitrary airplane with the territory surface. The curvature of the slope and aspects are also related to the flow of water. The flow of water in stream do lead to landslides in neighbouring areas of the slope. Also, after rainfall the water loosen the soil and lead to mud flows, on a bigger scale it leads to landslides. The curvature of slope and aspect can hence be an important factor in causing landslide. The importance of the factor can be given weightage in AHP model. The influence of flat shape on the land corruption approaches is the combination or uniqueness of water during downhill flow. On account of the curvature, terrible curvature comprise a sunken surface, zero curvature and flow mean a flat surface, and fine ebbs and flows describe a raised surface. The curvature became organized out the utilization of the roads routine in ArcView (Pradhan, Landslide susceptibility mapping by neuro-fuzzy approach in a

landslide-prone area (Cameron Highlands, Malaysia), 2010).



Distance from Lineament Map

Lineaments as map capable, unassuming or composite straight structures of a surface, whose parts are go in a rectilinear or scarcely curvilinear association and which vary extraordinarily from the examples of together abilities and perhaps mirrors a subsurface wonder. In various expressions, they are significant lines of scene that uncover the concealed structure of the stone storm cellar. Lineaments were normally utilized in topographical applications. Faults and joints in rocks for the most part give signs to the predominance of ground water, oil, and minerals. Research have demonstrated that the possibility of avalanche prevalence is significantly extended at those locales towards lineaments. Lineaments not handiest affect surface material frameworks however can likewise make a huge commitment to landscape penetrability, preferring incline insecurity. Lineaments are generally mapped because of a visual translation method.. The understanding transformed into done utilizing the spatial modeler in Arc GIS programming. Lineament is a maps capable simple or composite straight element of the surface whose components are adjusted in a promptly or scarcely bended and which shift rather from the example of the contiguous capacities and reflects a subsurface phenomenon. As the distance from the lineament rises the landslide interest decreases (Pandey, Landslide hazard zonation using remote sensing and GIS: A case study of Dikrong river basin, Arunachal Pradesh, India, 2008). (Figure 13)

RESULTS

The slope stability model identified several potential landslide sites in Namchi. The most severe sites were identified as having a high risk of landslides, while less severe sites were identified as having a moderate risk. The locations of the potential landslide sites were then mapped, allowing for further analysis and monitoring of the region. Suggest that area occupied through agricultural, typically falls below moderate zone, anywhere steep slope are comes under high zone, that zone is also show nearby ridges and drainages areas, lineament and road buffer zone.

Typically very high zone are discover around the steep slope, roads, agricultural and cliffs. Settlement regions are normally located at the flat terraces and are observed in mild to Low susceptibility zone Low susceptibility classes are located in areas having flatter terrain, forest cover (Anbalagan, 2015). The weighted overlay analysis has been completed on the basis of overlaying the different thematic raster maps defined above and multiplying each by their given weight and marge them together. The weight of each criterion was finalized on the base of the ranges of the maximum and minimum values of each theme. The weight calculated for every class of every parameter is assigned to each basic grid cell. Settlement areas were determined in slight to low susceptibility classes. Combining all the supervisory parameter, and by way of giving different weightage value for all of the themes. Weighted overlay analysis map is categorize into 3 categories: (Figure 14 to 22)

1. Low susceptibility zones,
2. Moderate susceptibility zones, and
3. High susceptibility zones.

Table 1: Scale represents preference of judgement (Saaty T. L., 1977)

Preference / ordinal scale	Degree of preference	Remarks
1	Equally	Factors inherit equal contribution
3	Moderately	One factor moderately favoured over other
5	Strongly	Judgement strongly favour one over other
7	Very strongly	One factor very strongly favoured over other
9	Extremely	One factor favoured over other in highest degree
2,4,6,8	Intermediate	Compensation between weights 1,3,5,7 and 9
Reciprocals	Opposite	Refers inverse comparison

Table 2: Random Consistency index (Saaty T. L., 1980)

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53	1.56	1.57	1.59

Table 3: Pairwise comparison matrix, Weightage and consistency ratio of the data layer

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**Weightages**
Geology	1														0.037
soil	3	1													0.07
Rainfall	1	2	1												0.125
LULC	3	4	1/4	1											0.109
Lineament	3	3	1/2	1/4	1										0.103
Drainage	3	4	4	1/3	4	1									0.157
Slope	4	1/4	1/3	1	1/2	1/3	1								0.052
Aspect	4	4	1/3	1/2	1/5	1/3	1	1							0.066
Relative Relief	4	1/3	1/5	1/3	1/3	1/3	4	1	1						0.051
TWI	1/3	1/2	1/4	1/4	1/4	1/2	1/3	1/3	1/3	1					0.028
SPI	2	1	1	3	2	1/3	4	4	2	3	1				0.107
Lithology	1/3	1/2	1/5	1/4	1/2	1/4	1/5	1/5	1/2	1/4	1/3	1			0.18
Curvature	1/4	1/3	1/5	1/5	1/4	1/5	1/5	1/6	1	1/3	1/4	3	1		0.02
Roads	4	1/4	1/3	2	1/6	1/3	1	1	1	3	1/2	5	2	1	0.057

Principal Eigenvalues: 17.4, Consistency Ratio (CR): 0.095

Table Summery of assigned weight and rating

Table 4 Weight and Rating

Thematic Raster Layer	**Field**	**Rates**	**Influence**
Geology	Reyang Formation	1	7
	Gorubathan Formation	1	
Soil	Loamy, Shallow Depth Soil	1	9
	Loamy, Coarse Loamy Rock Soil	2	
	Fine Loamy Mixed Soil	3	
	Coarse Loamy	4	
Lithology	Dolimitic, Quartzite	1	11
	Sandstone	2	
	Quartz Arenite, Black Slate	3	
	CHLORITE SERICITE SCHIST	4	
	BOULDER SLATE	5	
	BANDED MIGMATITE, MICA SCHIST	6	
	AMPHIBOLITE	7	
	META GREYWACKE	8	
Land Use and Land Cover	River	1	14
	Forest	2	
	Barren Land	2	
	Agricultural Land	3	
	Fallow land	6	
	Built-Up	7	
Distance From Lineament	0 - 50	1	13
	50 - 100	2	
	100 - 150	3	
	150 - 200	4	
	> 200	5	
Distance From Drainage	0 - 50	1	
	50 - 100	2	
	100 - 150	3	
	150 - 200	4	
	> 200	5	

Slope	0 - 10	1	10
	10 - 20	2	
	20 - 30	3	
	30 - 40	4	
	> 60	5	
Aspect	Flat	1	5
	North	2	
	West	3	
	South	4	
	East	5	
Relative Relief	Very Low	1	4
	Low	2	
	Moderate	3	
	High	4	
	Very High	5	
TWI	-4 - 0	1	7
	0 - 2	2	
	2 - 4	3	
	4 - 8	4	
	8 - 12	5	
SPI	-4 - 0	1	2
	0 - 1	2	
	1 - 3	3	
	3 - 6	4	
	6 - 9	5	
Curvature	-21 - 2	1	5
	2 - 6	2	
	6 - 8	3	
	8 - 12	4	
	12 - 16	5	
Distance From Road	0 - 50	1	6
	50 - 100	2	
	100 - 150	3	
	150 - 200	4	
	> 200	5	

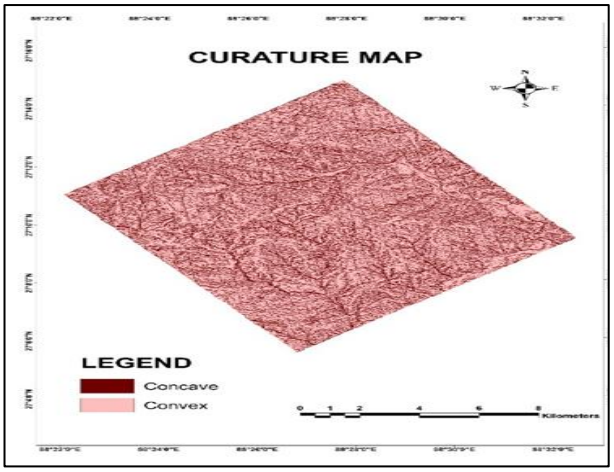


Figure 14: Curvature Map

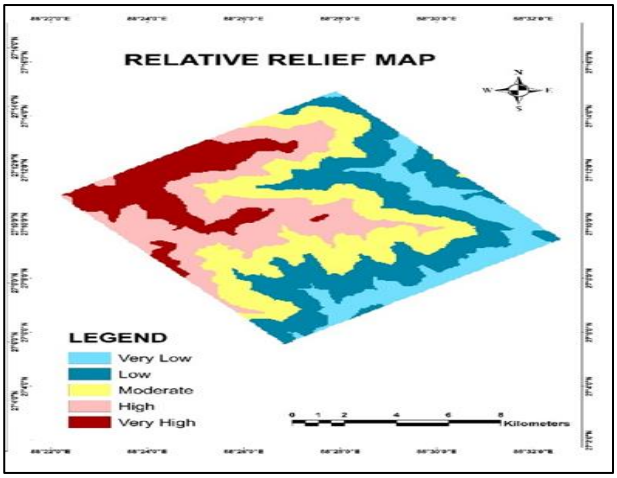


Figure 15: Relative Relief Map

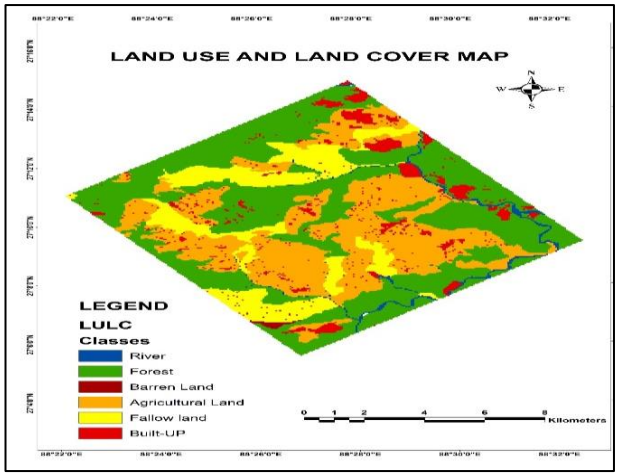


Figure 16: Land use and land cover

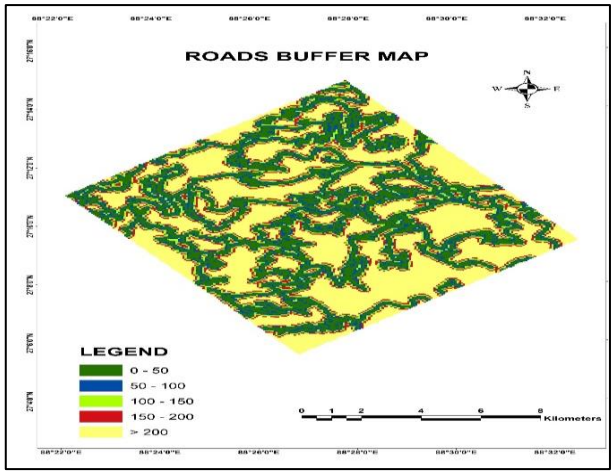


Figure 18: Distance from road

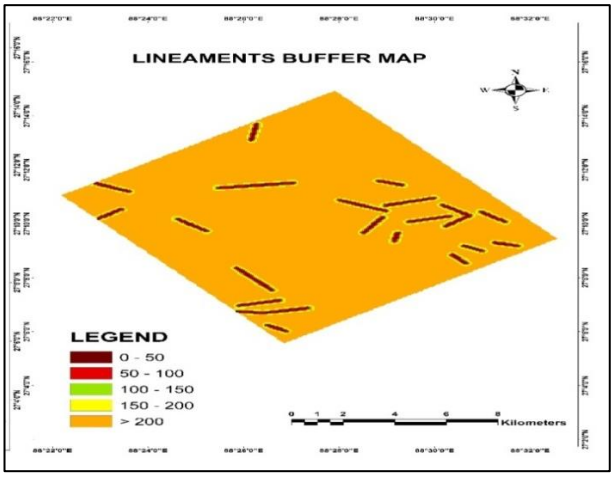


Figure 17: Distance from Lineament

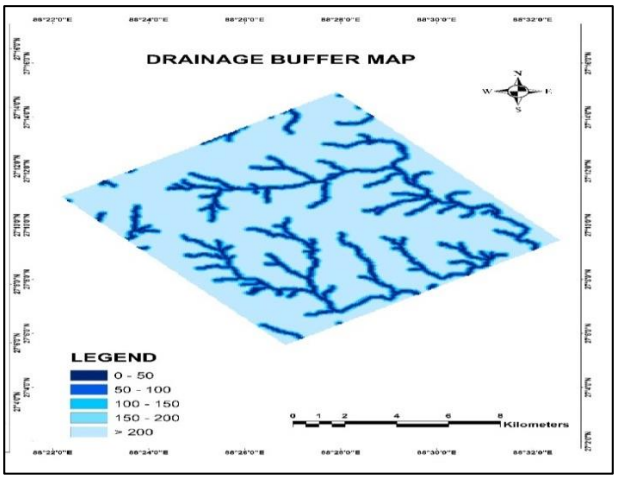
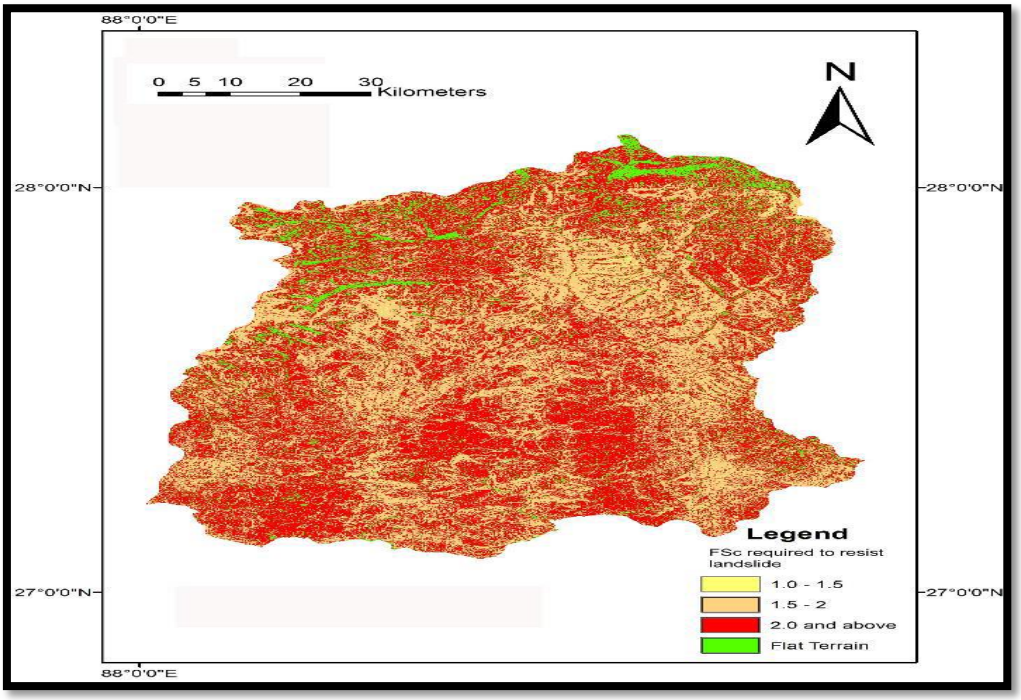
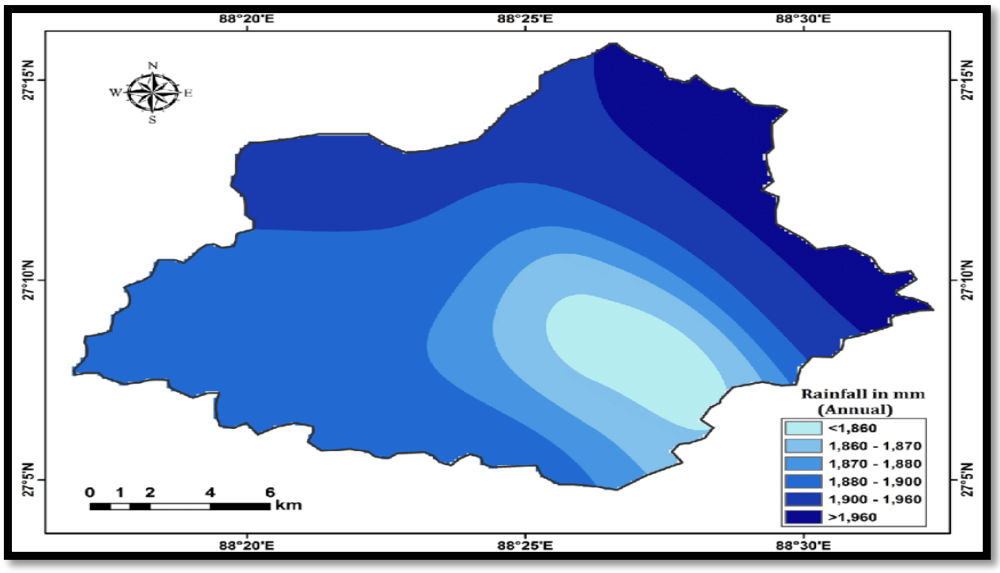


Figure 19: Distance from Drainage



Earthquake Map



Rainfall Map

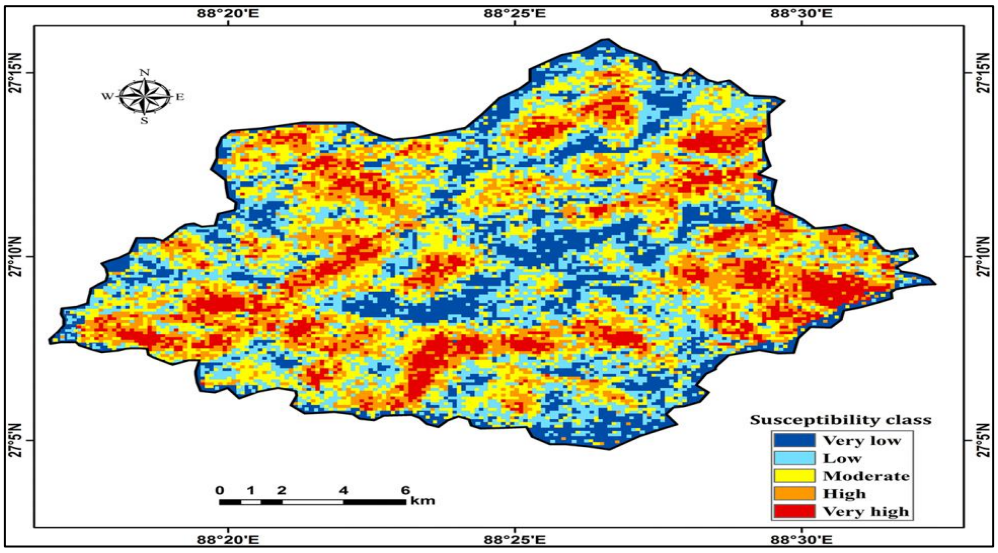


Figure 20: Susceptibility Zones

Figure 21: Different places in Sikkim where landslide occurred at different height with different intensity of disaster

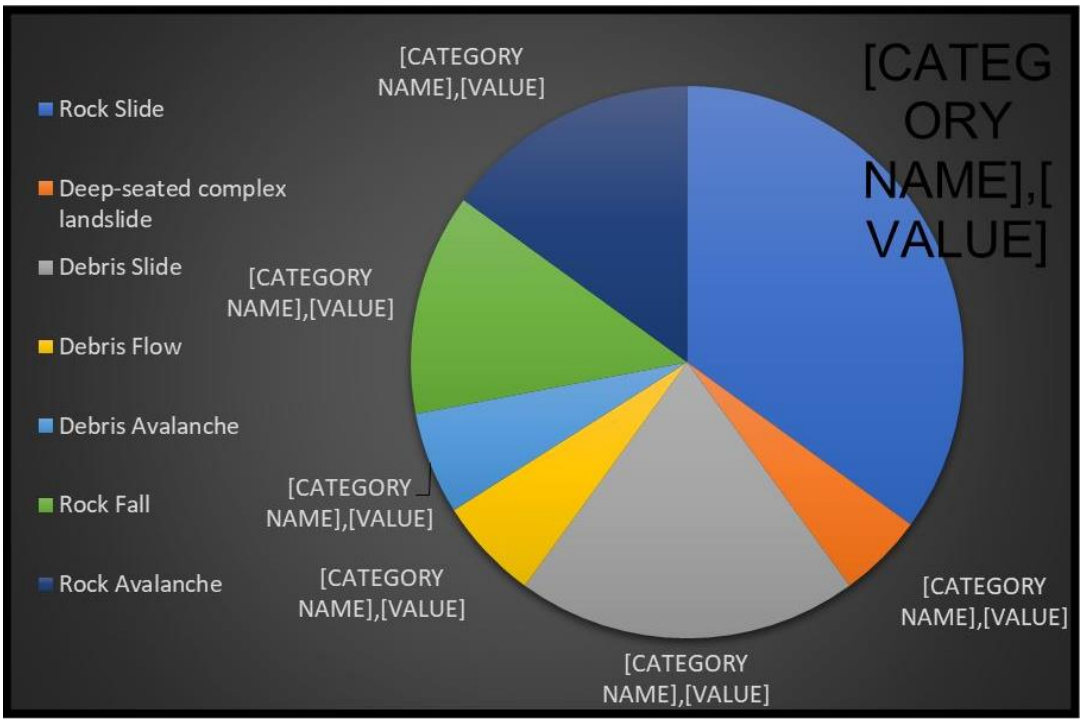


Figure 22: Factors Responsible for landslide

DISCUSSION

LHZ (Landslide Hazard Zonation) turned into executed by analytical hierarchy processes technique. This technique will be applied to weight factor too individual class. In this technique Raster maps are create for every component and provide values of every cell on the basis of weight parameter. Combination of all weighted layers will be used for the result of landslide susceptibility zone map. Whatever weight value proved result are show according to that parameter which greater LSZ value specify to hold high susceptibility fact that show as a high susceptibility zone. Less weight value specify for low susceptibility zone (Kumar, 2016). Every group of LSZ Zone maps comprises danger facts over incessant in a range that is (0, 1). A geometric kind based on natural breaks technique turned into apply for the zonation maps. Classes of nature breaks are totally based of natural clustering essential on facts. Natural breaks classes area recognized these satisfactory group of same value and maximum value are show in different classes. LSZ maps were produce through use of five different values operator characteristic. The classification of the LSZ maps are divided into 5 different classes:

- Very Low Susceptibility,
- Low Susceptibility,
- Moderate Susceptibility,
- High Susceptibility,

Very high Susceptibility (Anbalagan, 2015).

CONCLUSION

Slope studies are an important tool for identifying potential landslide sites. In this paper, GIS was used to map the slope stability of Namchi, Sikkim. The data was used to identify potential landslide sites, which were then mapped. This information can be used to monitor the region for potential hazards, and to develop strategies for mitigating the risk from landslides.

In the research has been revealed that the landslide activity of Namchi Sikkim area. There have many research on landslide based on Remote sensing and GIS technique. According to literature study, AHP and weight methods are more essay to use methods for find out landslide susceptibility zone. In this research are also use AHP and weight methods and compare for landslide assessment. For the AHP methods and weightage methods usually want survey for the comparative weight values (Park, 2013). Result are classified into Five Category of landslide susceptibility zones that is Very low class, Low class, Moderate Class, High class, and Very high class. Weightage overlay analysis are classified into landslide susceptibility zones that is three classes Low class, Moderate Class, and high class. Both of the result are show high in western part and low in southern pert in the study. Also compare from landslide susceptibility Zone with use of point data, that data we take from Geology survey of India (GSI), there is total 60 point showing in landslide zone. These point data is classified all 60 point into three classes; Low Volume, Moderate Volume and high Volume, that classification

based on volume of landslide. According to this, high landslide incidence in western and northern part and low are showing in south part of the area. High class are show around the steep slope, cut slopes adjacent the roads, and fallow land. Low class are discovered in regions have flat area, forest, river and built-up area (Kumar, 2016). Settlement area and developed area are normally located at the flat terraces and are observed in mild to Low susceptibility zone. According to the both reference data, over result are showing with 85% accuracy.

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