# LANDSLIDE SUSCEPTIBILTY ZONATION MAPPING USING GIS FOR IDUKKI REGION

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE

OF

**MASTER OF TECHNOLOGY**
**IN**
**GEOTECHNICAL ENGINEERING**

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## CERTIFICATE

I hereby certify that the Project Dissertation titled "**LANDSLIDE SUSCEPTIBILTY ZONATION MAPPING USING GIS FOR IDUKKI REGION**" is a bonafide work carried out in the fourth semester by "**Anmol Kumar (2k19/GTE/03)**" in partial fulfilment for the award of Master of Technology in Geotechnical Engineering from Delhi Technological University, Delhi during the academic year 2019-2021.

Place: Delhi DR. RAJU SARKAR

Date: 04 /09/2021 Supervisor

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I will be failing in duty if I do not acknowledge with grateful thanks to the authors of the references and other literatures referred to in this major project.

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## Abstract:

When weathering causes a rock to crumble and decay, the shabby material, wet with rain water, May float due to gravity.The phrase "land slippery" denotes to a rapid downhill slide movement of rock rubble. They may grow on any piece of ground if the soil, moisture, and slope conditions are rig ht. Landslides are an important part of the earth science activities on the surface of the planet and for happening of those when he condition of the soil is good and moisture contain is maintained and angle of slope must be maintained .Due to landslide failure of slopes, failure of earth surface and flow of mud, flow of boulders, can happened .the main factor of the movement is due to either earthquake which shakes the earth surface and movement of mass can happened and it could occur due to when deep excavation could have been made for the construction of various structures like buildings and it could happen because when the precipitation is heavy and its happening for long duration like what happened in Idukki in 2019. Water is not only the factor for landslide or movement of slope but weathering of rocks plays a predominant role in landslide .shear strength of the rocks is reduced due to weathering. Many researchers have found that the main reason is weight of building and their slope which act downwards due to gravity is one of the main reason for movement .to prevent the movement of mass some resisting force is applied which is in the opposite direction of friction angle and when the earthquake is for long duration the forces is automatically reduced for different kind of landslide the movement speed will be different its depend on the weight of the mass movement.

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# Introduction

## 1.1 Background.

When weathering causes a rock to crumble and decay, the shabby material, wet with rain water, May float due to gravity.The phrase "land slippery" denotes to a rapid downhill slide movement of rock rubble. They may grow on any piece of ground if the soil, moisture, and slope conditions are rig ht. Landslides are an important part of the earth science activities on the surface of the planet and for happening of those when he condition of the soil is good and moisture contain is maintained and angle of slope must be maintained .Due to landslide failure of slopes, failure of earth surface and flow of mud, flow of boulders, can happened .the main factor of the movement is due to either earthquake which shakes the earth surface and movement of mass can happened and it could occur due to when deep excavation could have been made for the construction of various structures like buildings and it could happen because when the precipitation is heavy and its happening for long duration like what happened in Idukki in 2019. Water is not only the factor for landslide or movement of slope but weathering of rocks plays a predominant role in landslide .shear strength of the rocks is reduced due to weathering. Many researchers have found that the main reason is weight of building and their slope which act downwards due to gravity is one of the main reason for movement .to prevent the movement of mass some resisting force is applied which is in the opposite direction of friction angle and when the earthquake is for long duration the forces is automatically reduced for different kind of landslide the movement speed will be different its depend on the weight of the mass movement.

### 1.1.1 Landslide Phenomenology.

In order to arrange the thesis consistently, it is very important to have the depth knowledge and required theoretical background of the landslide and mass movement and reason and forces acting behind it and the required technology and how its working everything must be known and the landslide susceptibility zonation mapping is prepared using the ArcGIS.

#### 1.1.1.1 Stability of slope

When the force which is resisting the soil mass yielded by the force which is behind the mass movement and which makes the changes in the slope and the resisting force is the internal cohesion between the soil mass and the shear strength between them and friction which is acting on the surface comes under driving force and each of the mentioned factors depends on the property of the soil and their environmental condition and the material which is used for the slope. The options that influence driving and resisting forces and their balance square measure usually known as learning factors and other than that as per bell the trigging factors are rainfall with heavy intensity ,change in the ground water table earthquake melting of snow and flood (jones, lee & bell 2007).

#### 1.1.1.2 Susceptibility, Hazard, Risk and Vulnerability.

The term "landslide susceptibility" refers to the geographical distribution and size assessment of landslides that exist or may occur in a given area. It might also be thought of as a pure geographical possibility of landslides. The total area, volume, or velocity (if relevant) of a landslide can be used to calculate its magnitude. Although it may seem logical that more sensitive slopes will be influenced more frequently than less susceptible slopes, susceptibility is expressed clearly in a spatial frame and has no time component. (Lee& Jones 2004, Chacón et al. 2006).

**Landslide Hazard** Landslide Hazard refers to the likelihood of a destructive landslide occurring in a particular area during a certain time frame. It's possible that it's a temporary extension of susceptibility. It's frequently mistaken with susceptibility, but distinguishing it is as simple as noting its temporal dimension. Susceptibility, rather than being a statistic, can be conceived of as a specific example of hazard that incorporates a single temporal perspective. In a broader sense, danger is based on assessments of the landslide's magnitude and likelihood of recurrence. (Einstein 1988, Lee & Jones 2004)

**Element** is basically defined as any entity (any component of the landscape) that is potentially affected by a harmful phenomena is referred to as an element in danger. It may includes people, private property (real estate and personal effects), engineering and infrastructure projects, economic activity, public services, and environmental assets. (Lee & Jones 2004, Fell et al. 2008).

**Risk** is articulated as a measure of landslide occurrence probability and severity of its possessions. Several risk categories will be separated, each with its own Element in danger, such as societal risk, individual risk, and group risk, as well as categories developed specifically for decision-making, such as acceptable and bearable risk. This thesis will mostly focus on susceptibility assessment due to the nature of the subsumed research effort (Fell 1994, Lee & Jones 2004).

## 1.2 GIS in Landslide Susceptibility Zonation.

The morphological properties of the terrain surface are used to establish a strong link between landslide vulnerability and the circumstances that host it. As a result, the advancement of Digital Elevation Model through GIS and Remote Sensing has nearly contributed to the morphometric revolution by bringing new, incomparable instruments for surface option extraction and construction of unique thematic spatial patterns.(Bonham-Carter 1994).

### 1.3 Objectives of Study.

The aim of the study is to demarcate the susceptible landslide areas within the spatial domain in Idukki India in various scales of susceptibility from very high to low using GIS. Landslide susceptibility zonation mapping has gained high importance amongst town planners. the end result of current study will act as a risk assessment tool and play major role in mitigating the danger to landslides during this area. It can even be a guide to carryout similar analysis in other areas.. The objectives of the study are as under;

- Exploiting To conduct the study, using minimal information resources such as accessible topographic, geologic, satellite images, and many other sources, as well as ArcGIS software.
- Simplifying data collection in terms of data type, size, and preparation processes, among Other things, in order to create completely equivalent landslide susceptibility model utilising GIS.
- Identification of the factors which contribute to landslide susceptibility. Prepare data as various thematic raster layers. Assign rank and weight to the factors supported their degree of influence in landslide susceptibility. Generate landslide susceptibility models using frequency ration and pair wise model.
- Visualizing and publishing the ends up in the shape of maps.

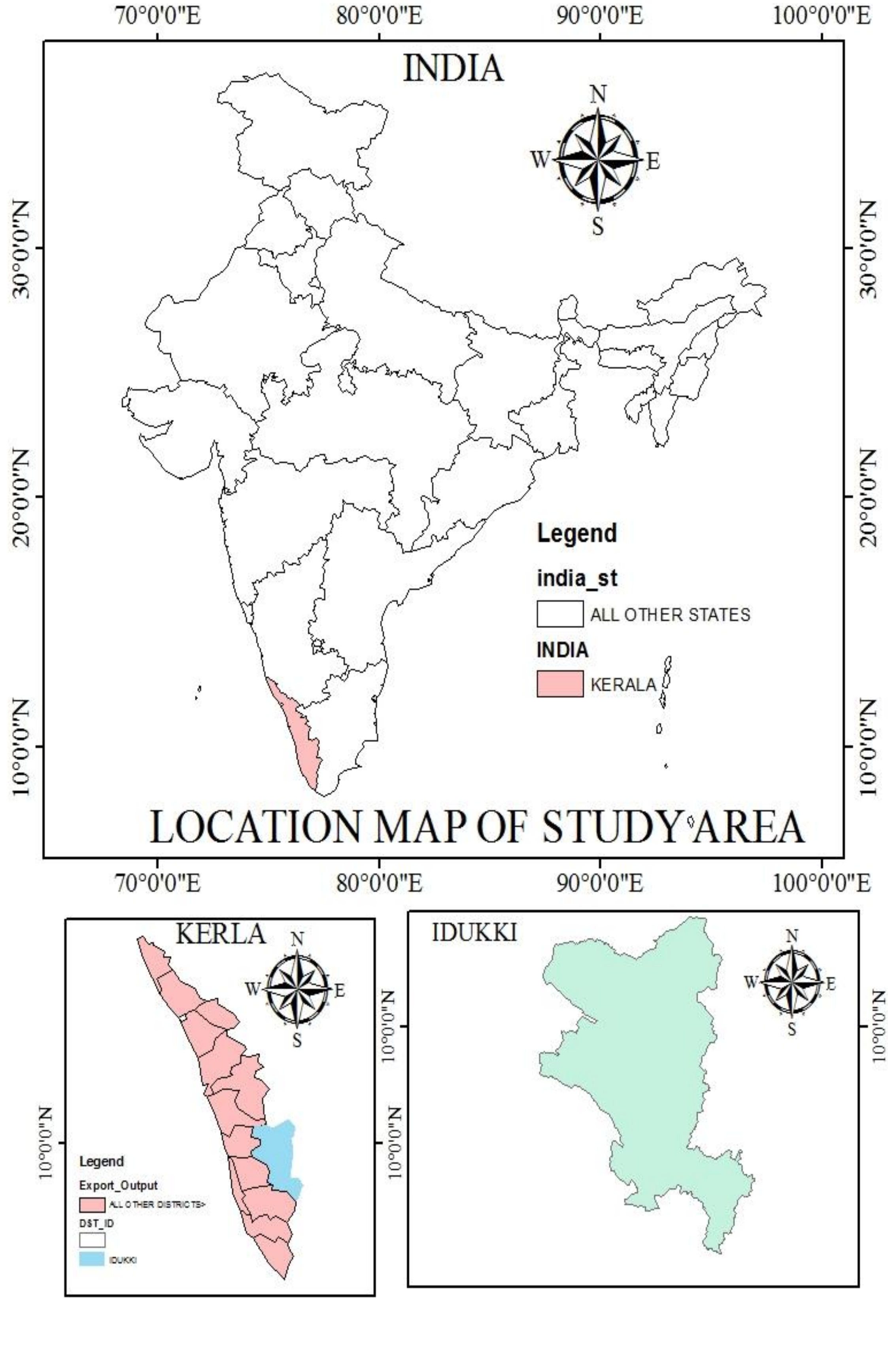
Based on the themes described above, this study was created to satisfy the standardised dem ands in terms of data collecting and manipulation methodology, modelling technique selecti on for landslide situation zonation, and modelling and analysis methodologies, all using GIS .

## 1.4 Location & General Description of Study Area.

Idukki is one in each of the fourteen districts of Kerala state, cover approx. 4358 sq. Kilometers, It lies between nine degree 15' and ten degree 21' of north latitude and seventy six degree 37' and seventy seven degree 25' of east longitudes. With a part of 4358 sq.km.Idukki ranks 1st among the districts inside the state in respect of space, (Refer Map one.1). Landslide composition of the study area unit the instabilities inside the slope faces, although the soil mantle is thick is at risk of shallow slides.

When the bodies of these shallow landslides experience sudden changes in thepore pressure Regime, which is usually produced by a large rainfall in addition to undercutting linear erosion, Dislocations occur. During high rainstorms, these and a few additional circumstances allow for Sluggish shallow motions with annual reactivation dynamics.In Kerala, the landslide season Begins once a year with the arrival of the southwest monsoon.Debris flows, rock falls, Rock slides, and soil slips all fall under the category of landslides.

They demolish hills and huge swaths of agricultural land, in addition to claiming human lives. Between 1961 and 2016, there were 295 people killed in 85 catastrophic landslides around the state. Thirty-eight people died in the Amboori landslide in Thiruvananthapuram district on November ten, 2001, according to the paper, which detailed the causes of landslides and the preventativeAccording to the paper, ten taluks or body divisions in Kerala are very sensitive to la ndslides, twentyfive taluks are moderately vulnerable, and fourteen taluks are the least vulnerable .




**MAP 1.1: LOCATION MAP OF STUDY AREA**

## 1.5 Literature Review.

A large number of articles (mentioned in the references) are examined, with landslide studies from all over the world. A wide range of methods are classified in the same way as projects with varying physical sizes and goals. It appears that methods wont to develop landslide susceptibility mapping are primarily smitten by four factors: the kind and availability of knowledge, derivation of knowledge, model generation and therefore the projectobjectivesMany studies are also projectdriven,in the sense that they concentrate on techniques that may be applied to roads, trains, pipelines, and other forms of physical infra structure.As one might assume, no single methodology is dominant, however GISbased so lutions have grown in popularity as computational power has increased. Some of the most important literatures are briefly mentioned

**Varnes 1984** has highlighted that The study of landslides has attracted international attention, owing to a growing awareness of the socioeconomic effect of landslides, as well as the rising pressures of urbanisation on the environment. These maps are referred to as landslide hazard zonation because they are split into nearly homogenous areas and graded according to degrees of potential hazard due to mass movements

**Guzzetti et al., 1999**, Landslide susceptibility mapping is that the identification of areas within the landscape that have characteristics that might make them vulnerable to land sliding. Susceptibility mapping makes no try and identify the hazard (the type and size of landslide) posed and therefore the risk (how much damage it'll cause, structurally, financially, emotionally) to humans from any landslides. Furthermore, it doesn't predict when a landslide will occur. Landslide susceptibility mapping may be a common practice in many locations and communities round the world, principally used for aiding and planning developments

**Guzzetti et al., 2005**, Landslide susceptibility mapping methods are diverse and diverse and sometimes vary passionate about the country, landscape, purpose and finances available for the project. Susceptibility is that the propensity of a vicinity to get landslides. Many methods are proposed to guage landslide susceptibility, and may be broadly classified into quantitative and qualitative. The boundaries between the methodologies don't seem to be rigid, especially the heuristic approach, which frequently features a degree of hybridization.

**Castellanos Abella and Van Westen (2008),** presents an illustration of a qualitative landslide susceptibility valuation by multi criteria analysis. The model associations all weights into one hazard value for every pixel of the landslide susceptibility map and based upon that result of analysis he game statement which is regarding how slope failure will occur.

# Chapter-2
# Methodology

## 2.1 Methodology

To accomplish the target of study, the primary and most vital criteria is selection and creation of attributes which shall hence be said as Conditional Factors which are deemed to be responsible to create the study area at risk of landslides. Subsequently these independent variables have to be evaluated and integrated as per their rank and weight into one index evaluation index to come up with susceptibility models of the study area. They also have to be categorized into various risk zones to map the susceptibility index of the study area. Finally analysis and outcomes must be drawn to test their accuracy. These shall be presented well within the study report.

### 2.1.1 Software

ArcGIS 10.8 a viable and most broadly accepted software as provided by UNIGIS has been used to carry out the GIS analysis of the thesis.

### 2.1.2 Data Used

The one amongst the stated objectives of the thesis is to use and exploit open source and freely available data to hold out the research. Keeping it because the backdrop the subsequent undermentioned data is used. Their sources have also been spoken. Raster DEM 30 M resolution downloaded for all the morphometric (landforms) analysis of the study area. The rainfall data of the Idukki was acquired from the IMD data supply portal, CHRS data portal and MOSDAC the identical was mapped and interpolated to derive the rainfall map. The land use land cover (LULC) details were acquired from USGS 24 M resolution satellite image acquired from resource sat. Quick bird pan sharpened image of 5 M resolution was downloaded from USGS earth explorer and AW3 S3 explorer and for

DEM data USGS earth explorer have been used and for analyzing the current situation of the study area various newspaper articles have been used.

## 2.2 Conditional Factors

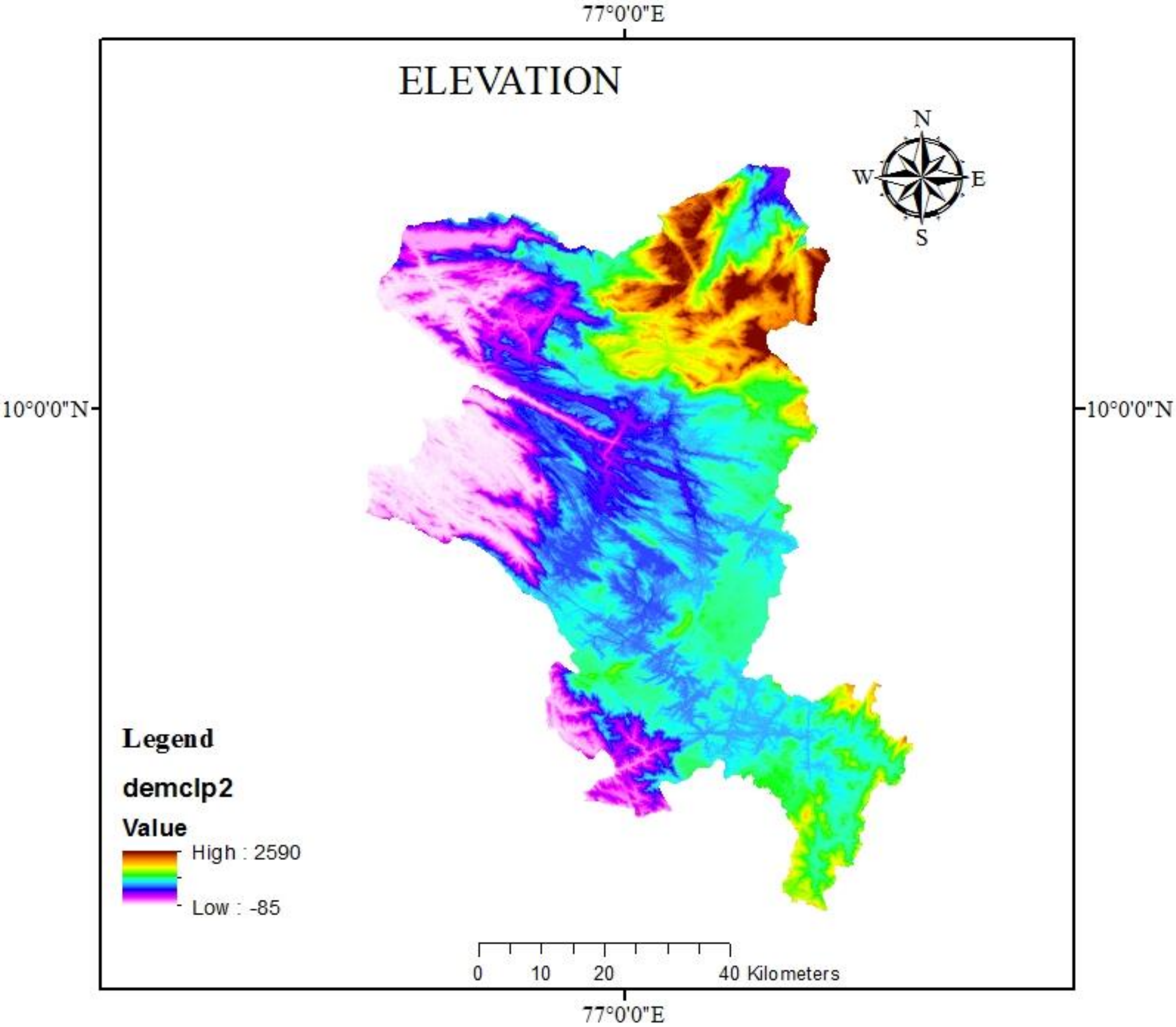
Landslides occur as a consequence of assorted factors termed as conditional factors. Conditional analysis method can be a multivariate statistical technique that's conceptually simple, highly compatible with GIS and produces results that will be easily assessed by non-specialists. Like all the statistical techniques, the strategy considers form of geo-environmental variables, Landslide occurrence could be linked and all the data which have been downloaded is layered and each layer data have been subdivided into various classes and for making or analyzing all the different layered data with different frequency is made. Therefore, the probability of landslide occurrence gives a singular combination of things is given by the landslide density during this specific UCU. (Malczewski 1999). Selection of conditioning factors could also be a pre-processing requirement in spatial modeling of the landslides also termed because the attribute selection.

Attribute Selection ends up in the formation of the number of input variables, i.e. the dimensionality of the input dataset, manifestation of landslide may not be controlled by only single variable it will be depending on the other factors too band it affords much improved ground for additional modeling. (Varmuza & Filzmoser 2009, Witten et al. 2011)

### 2.2.1 Morphometric Factors.

The morphometric parameters of the study area were derived from Aster DEM of 30M resolution (refer map 2.1). The elevation varied from 580 to 760 M. it had been further segregated to 6 unique values from 580 to 730 M. On analysis of the map it is safely assumed that the areas to the south have the max elevation and also the elevation gradually eases out as we move north- North West, the central and eastern areas are comparably lower in elevation. In other words Map 2.1 for making the more susceptible of the higher ground motorized energy has to be altered linearly

Topographic data is standard topographic maps from where contour lines is generated by first digitization, and then converted to DEM in GIS.A DEM resolution of 30 m was chosen for 2 reasons: firstly it meets the first objective of the research i.e. exploitation of low cost/ open source/ readily available data to hold out analysis and secondly because the adequate support grid size compatible with other data sources employed in this study. All DEM-related thematic maps kept the identical resolution because it involved derivation of diverse parameters. Direct geomorphological mapping will be combined with detailed field mapping. This is often a qualitative and subjective technique that may be achieved without the requirement for computer power or statistical modeling. These studies are assessments, where such investigations would be too costly and time consuming.




**MAP 2.1 : ELEVATION MAP OF IDUKKI**

### 2.2.1.1 Slope Angle

The one in every of the foremost important parameter within the landslide susceptibility slope angle is one of the most important parameter among the all because it is openly correlated with the landslide susceptibility analysis and it is very useful for making the landslide susceptibility zonation map, and it is linked with the landslide and it is prepared from the digital elevation model data which have been taken from the USGS earth explorer and it is mainly divided into six categories This brings out the spatial relationship between slope and landslide. It is the relative feature that is the increase in the steepness with respect to the horizontal plane and it could be denoted in terms of proportion. Slope Map for LSZ simply means the division of the study area into various classes in step with the angle. Slope instability is also a fancy phenomenon that features not only landslides but more subtle processes like soil creep.

The debris slope has associate angle of repose of 20° -30°, that is that the foremost angle at that loose material is stable (Hungr1997) refer figure 2.1 (surface analysis of slope)

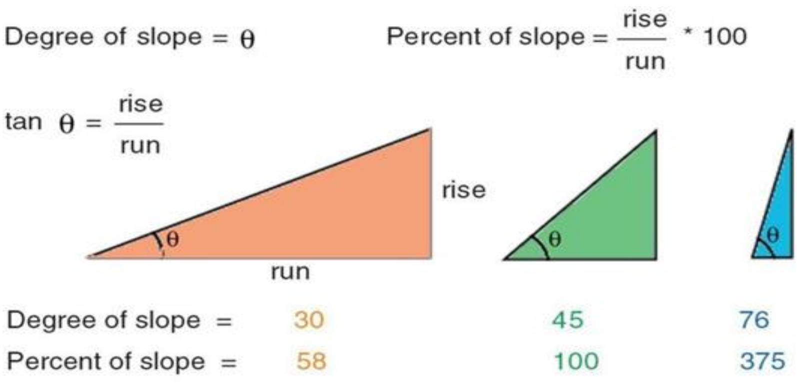
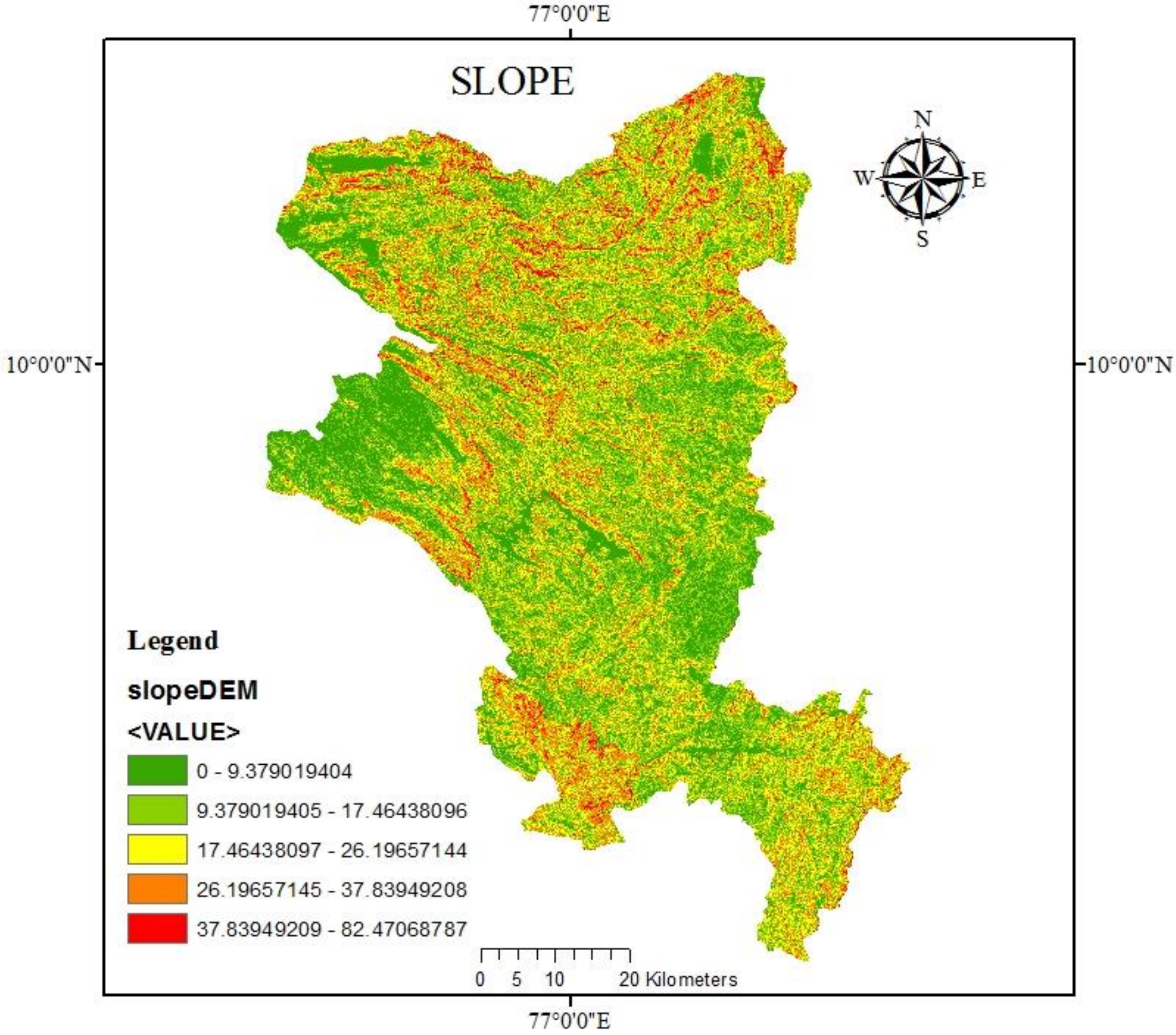



**Figure 2.1 Surface Analysis of Slope**
**Source :Hungr (1997)**

Map 2.2 Map 2.2 provides the slope angle of the study space derived from DEM in GIS. The realm was divided into 06 categories varied from 0° to 54°.The degree (The inclination of slope) is used instead of percent (percentage rise) to calculate slope angle of the study area. The deviation of slope values in degrees is zero to ninety. For p.c rise, the vary is zero for close to eternity.

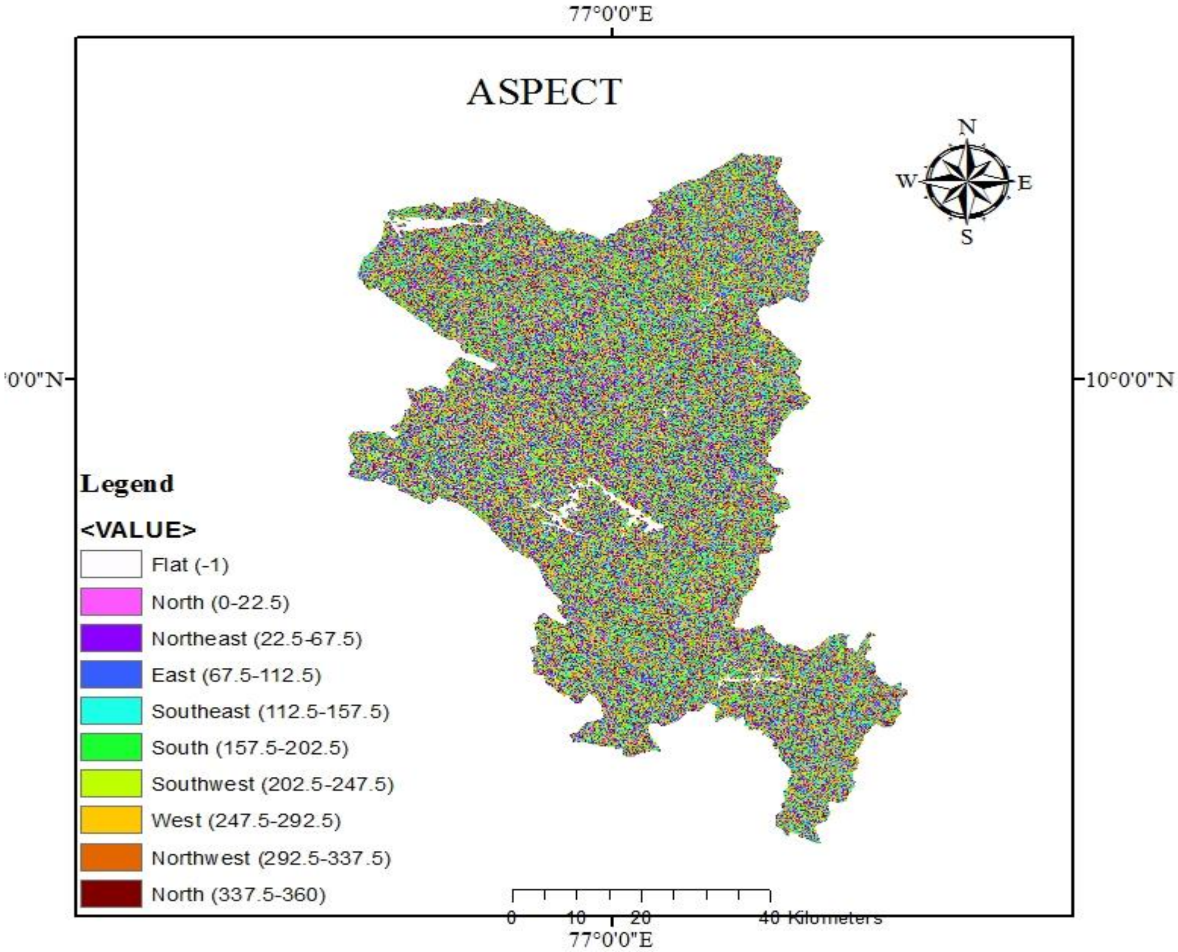
while in mountainous terrain the slopes are stable even with a steep slope angle, but in low hills/flattish terrain rather like the study area in question where slopes comprising of basalt rock and clay, don't need a steep angle and are at risk of landslides even at lower angles to congregation unpredictability. On analysis of the map a pair of.2 it's safely assumed that the areas to the south West to North West have AN angle on the far side angle of repose, at that loose material is unstable. It’s highlighting the particular indisputable fact that the areas in closer proximity to the Bangalore – kerla corridor of the study area are in danger of landslides. However it's to be further corroborated by aspect i.e. the direction to which these slopes face. Two factors have been discussed i.e. the elevation and slope and both point towards west of the study area because the areas which are at risk of landslides both variables Independent to 1 another but in agreement to each other. This could be dwelled upon thorough later.




**MAP 2.2 : SLOPE MAP OF IDUKKI**

### 2.2.1.2 Aspect

It shows that slope is facing north so in north direction it will dictate values as zero and calculation of slope is done by using GIS (map 2.3).

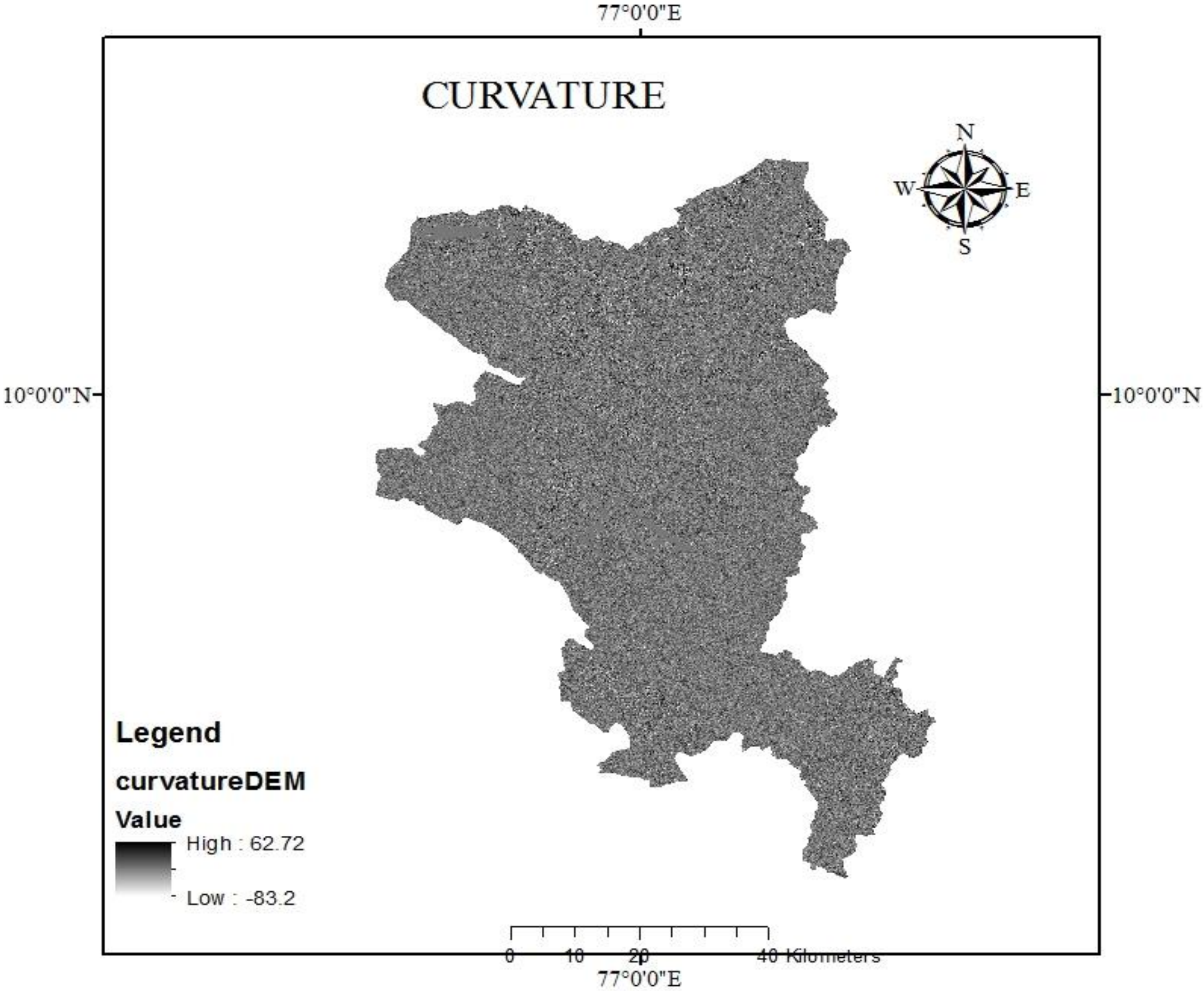



**MAP 2.3 : ASPECT MAP OF IDUKKI**

Aspect map 2.3 refers to the spatial exposure of the bottom element (its azimuth). It's been calculated from DEM and it is having very wide ranges of values lying from 0° to 360° (Anti clockwise). It suggests that the slopes moisture content will be affected by the solar path and the landslides susceptibility to is rising from South East to North West, Therefore North West slopes are having the more moisture content and it is not suitable for the further use while north to South East is that the least susceptible .Therefore at the same time as modelling the landslide susceptibility the North West slopes are going to be given a highest rank. the subsequent boundary values are given to the aspect map. -0.00001°(flat),67.5°(N-NE),157.5°(NE-E-SE),247.5°(SE-S-SW),337.5°(SW-N- NW),361°(NW-N)

#### 2.2.1.3 Plan Curvature

The calculation of plan curvature is done by using GIS .on the information taken from DEM data that is digital elevation model it suggests that concavity and convexity of the surface which is perpendicular to the elevation and negative values are showing it means it is convexity while positive values indicates that it is concavity and if the values what we are getting is 0 then it shoul be called as flat surface.Map 2.4 highlights the areas as indicated in yellow because the flat surfaces. Areas in inexperienced because the convexity (the orientation of the landslides) of the study spaces and therefore the areas in red because the concavity (accumulation of landslide mass) of the study area. this {can be} a vital geo morphological issue whereby the landslide condition can roughly express the areas wherever the scrap is probably going to be accumulated. Because the positive values would increase the degree of concavity would rise. The map 2.4 has been classified into flat, concavo-concave and convexo-concave zones. It will be assumed that the area unites in inexperienced within the map with negative values are additional susceptible to landslides than areas in red.




**MAP 2.4 : CURVATURE MAP OF IDUKKI**

### 2.2.2 Hydrographic Factors

There is very little discussion that rainfall has been the beginning (trigger) for the landslides in Idukki. Associate in nursing empirical information from the Idukki earth science society on the number of the downfall was collected. This information was as Associate in Nursing stand out sheet giving the placement and downfall. a similar has been premeditated on a graph (Refer Table 2.1).

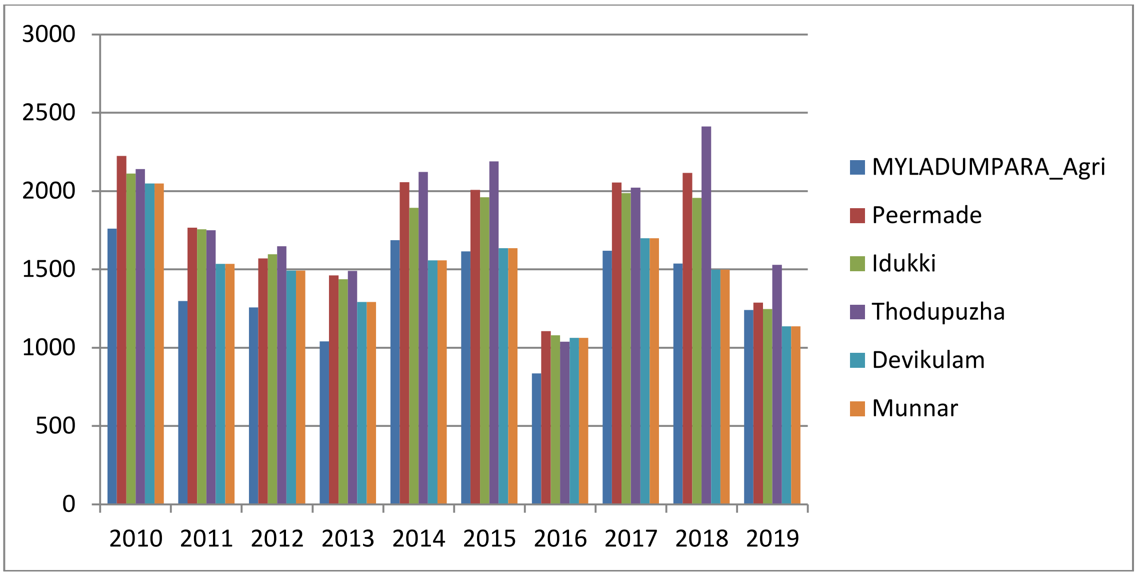
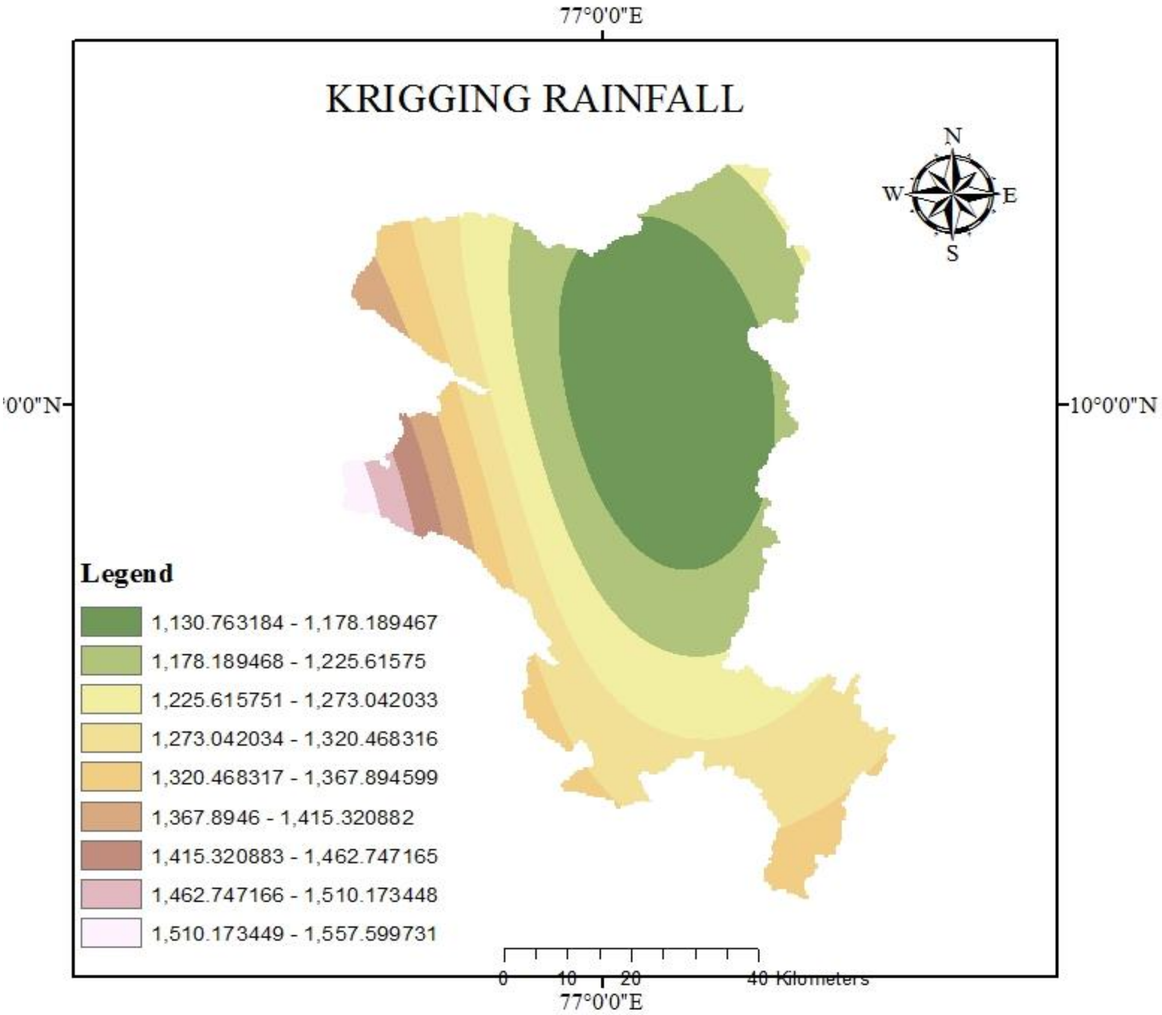



**TABLE 2.1: RAINFALL GRAPH OF IDUKKI**

It is seen that the downfall old has been between 250 to four hundred millimeter. The most reason for landslide of the study space as per geologic specialists may be a natural structural weakness within the volcanic rock rocks here. Because of unplanned urbanization there has been an oversized quantity of levelling during this space not only for cultivation however conjointly by JCB machines to create roads. This has already triggered land-slides during this belt.

#### 2.2.2.1 Rainfall

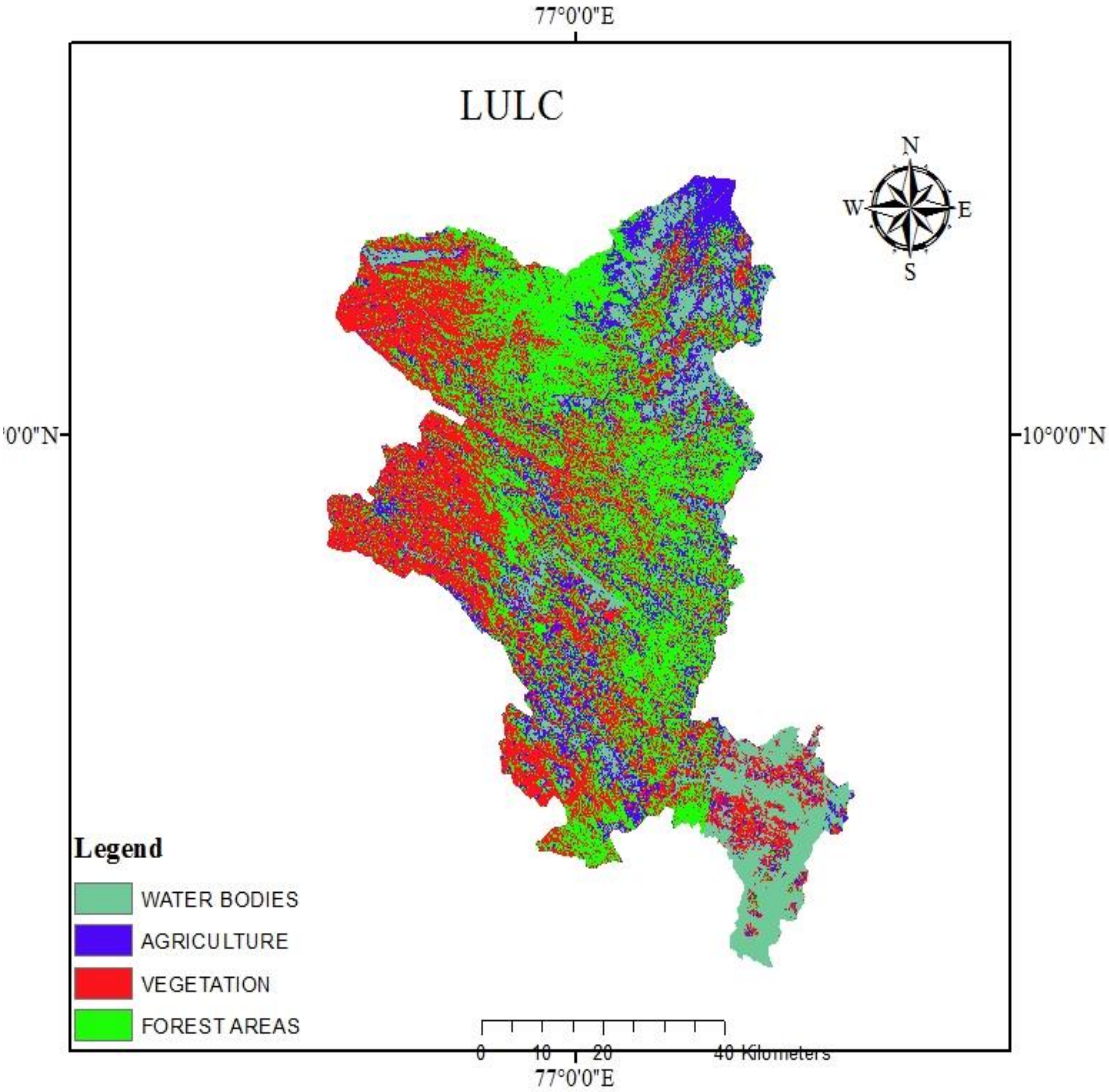
The average downfall within the study space ranges from 250 to three hundred millimeter. The latitudes and longitudes of every location sampled were manually digitized in GIS as a degree feature with the number of downfall in concert of its attribute field. so as to arrange a formation downfall map. The downfall information was additional spatially interpolated on GIS. (Refer Map2.5) With special interpolation, the goal is to make a surface that models the sampled development within the very best manner. (Longley 2001). For the aim of the thesis, actual interpolator i.e. Kriging interpolation is employed , whereby it incorporates the construct of randomness .It conjointly known as the spacial moving average (SMA) wherever within the SMA calculates new price of every location supported vary of values related to neighboring points. Neighborhood is decided by a filter size, form and character of filter. The Kriging estimation honors the really determined price. Until now we've seen the geophysical science factors, that acknowledge in linear erosion and downfall connects it with the groundwater variations. it's in all probability the mix of cycles throughout the realm through various shallow and comparatively little landslides. On analyzing Map two.5 it's clear that since the study space is comparatively little approx twenty sq. kilometers, most of the realm experiences downfall 350 to four hundred millimeter of downfall. If it's seen in context of slope the North western slopes that have higher angle of repose conjointly expertise terribly high downfall. selecting Associate in Nursing interpolation methodology is influenced by your data of the surface you're modeling. every methodology works otherwise, however most utilizes the construct of special autocorrelation; close to things area unit additional alike than things isolated. The downfall and landslides area unit intrinsic to at least one another within the study space as per the empirical data offered. Seismic reasons have not been a cause for triggering landslides within the space. Therefore it's not being thought of for the aim of this analysis.




**MAP 2.5 : RAINFALL MAP OF IDUKKI**

### 2.2.3 Environmental Factors

A supervised classified data for various land uses as best-known for the aim of the thesis was created from the USGS data. NDVI values vary from +1.0 to -1.0. Disseminated vegetation like shrubs and grasslands or senescing crops might cause moderate NDVI values (approximately zero.2 to 0.5). it is classified into of four types mainly ; water bodies, Agriculture, Forest Areas, and vegetation. The many classes were any refined through manual conversion (editing) overlaying on the lowest map (Quick bird data) of the realm. Ideally the data should be any supported with ground truth through field survey pattern DGPS for any accuracy. it's however a time overwhelming and a fashionable affair. For the aim of the thesis this step was obviated. the final word output is Associate in Nursing onscreen digitized LULC map, that's at first created through supervised classification creating five signature classes through visual interpretation of the satellite data and certification and rectification with baseline data. Finally we've a LULC map of the study area. Vegetation cowl may well be a separate formation that separates heavily and sparsely vegetated areas (barren).Information on LULC notably the extent and abstraction distribution aims to rise understands the link between landslide events and land use-land cowl. And it is one of the conditional factors we've got a bent to assume produce the study area at risk of landslides, ‘Weights of evidence’ may well be a amount statistical method that has been applied to landslide condition. It ranks the geo-environmental variables that cause landslides thus as of importance for promoting instability. For ‘weights of evidence’ to work, the geo- environmental variables ought to be conditionally freelance from each other with connectedness landslide incidence. Thus allowing the variables to be assessed on an individual basis of one another.




**MAP 2.6: LULC MAP OF IDUKKI**

# Chapter-3
# Modelling Landslide Susceptibility

## 3.1 Modelling Approach.

The selection of the conditional factors (i.e., the predictor variables) have highlighted that there are a unit variety of key parameters that area unit doubtless vital within the derivation of landslide status. Combining them to derive one representative worth for status analysis is very important; otherwise they're freelance variables giving indication singly.

Once the conditional factors area unit chosen and structured as was seen in chapter-2, they have to be fed to a correct modeling technique, wherever specific decisions powerfully influence the standard and sort of the outcomes of model's certainty. It merely suggests that the division and ideally subdivision of a land surface into varied zones consistent with the degrees of actual / potential status caused by landslides and connected phenomena. The Multi- Criteria Analysis (MCA) with the conception of rank and weight has been used for landslide status zonation in Idukki victimization GIS. MCA within the context of the thesis is additionally named as MADA (Multi Attribute call Analysis) whereby range to themes/ conditional factors area unit analyzed to achieve common objective i.e. landslide status analysis.

Rank decides the contribution of 1 unit over another inside a topic i.e. a conditional issue. for instance, it's understood that prime slope angle contributes a lot of towards landslide status than low angle slopes. A quality scale travel are often used (example a 5/10 purpose scale wherever every unit in an exceedingly theme is ranked/rated on a scale of 5/10), for the aim of the study rank values from one to five, was used. The worth of ‘2’ was appointed to very cheap tributary unit in an exceedingly specific theme and therefore the highest tributary unit was appointed a price of ‘5’

Weight decides the preference or priority of the one conditional issue over another in an exceedingly grid primarily based analysis. the load values and rank values facilitate bring out the variations in contributions between the themes and between units inside a topic throughout GIS analysis. The rank and weightage values got to be changed with ground truth to realize the simplest match between the rumored landslide status of the region and therefore the corresponding inferred LSZ map. The map might be as well as varied zones as per the danger issue similar to it;

**Very high**: the realm is at risk of Landslides and threat to life and property. Restrictions on urban development got to be inspired. Investments on landslide remedial measures on public education and on early warning systems area unit powerfully indicated.

**High:** the realm is at risk of Landslides and threat to life and property. Restrictions on urban development got to be enforced. Investments on landslide remedial measures on public education and on early warning systems area unit to be created obligatory

**Moderate to Low & Unlikely**: Zones wherever the possibilities of landslides area unit the smallest amount. Planned urban development activities will crop up during this space.

### 3.2 Multi-Criteria Analysis (MCA).

MCA analysis is primarily involved with a way to mix the knowledge from many criteria to create one index of analysis. This technique involves either qualitative or quantitative coefficient and grading or ranking of criteria in terms of their importance to realize one or a lot of objectives. Such coefficient and ranking technique is most typical modeling technique used wide. The foremost vital parameters needed to perform MCE to realize the explicit objectives of the study are:-

- Morphometric – Slope, Aspect, set up Curvature of the piece of land

- Hydrological – downfall, and interpolation victimization krigging
- Environmental- LULC

### 3.2.1 Assigning Rank.

The parameters area unit hierarchical on the idea of their importance in landslide status. A numeric estimation of the status on a 5 purpose scale i.e. the adopted values of every parameter is meted out victimization GIS of 1 unit over another inside a topic (conditional factor). The individual analysis while preparation of every conditional issue map as mentioned in chapter-2 was incorporated while assignment the ranks. This approach of assignment ranks to any or all the thematic input raster's ready is employed to rank attribute values by quality or risk so add them, to supply associate degree overall rank for every cell. Reclassification of a variable in our case thematic formation map of the conditional factors is needed to assign ranks in GIS. As solely distinct number raster's are often used. Reclassifying continuous raster's before adding them to weighted overlay analysis is vital.

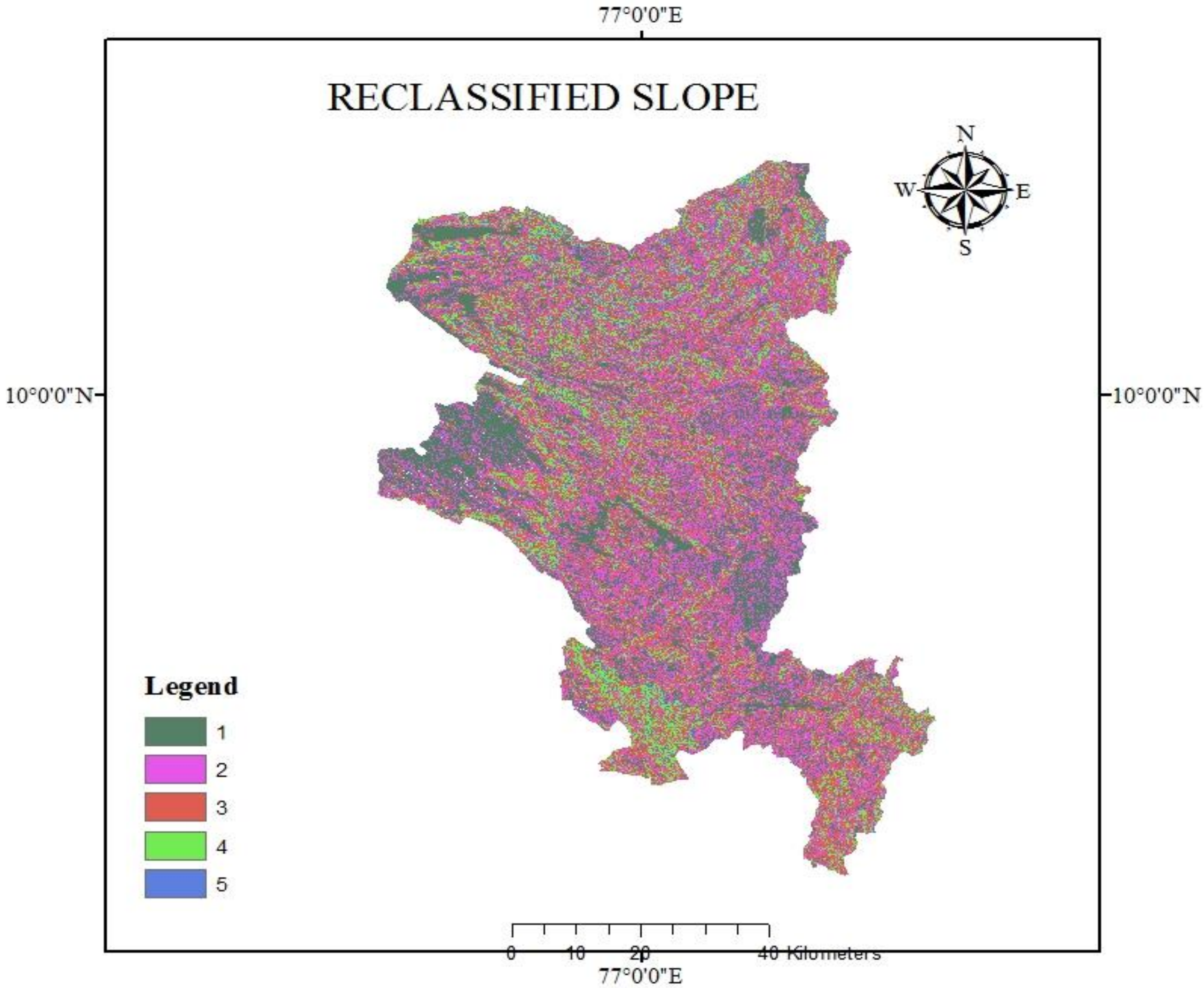
#### 3.2.1.1 Assigning Rank for Slope

Among the piece of land variables slope issue has high influence of landslide initiation as a result of a landslide could be a mass of soil, rocks, debris etc. moving downhill with gravity and friction deciding whether or not landslide can occur or not. Previous researches have well-tried that the angle of repose is between 20° to thirty ° wherever the landslide is stable ,thus all element values up to 30° are appointed rank a pair of Slope angles on the far side it i.e. 30° to forty ° and on the far side are hierarchical four and 5respectively. Lower slopes below contribute the required stability to cancel the possibility of a landslide event whereas higher slopes enable continuous purges. Little slides stop the formation of larger slides necessary to trigger a substantial landslide. The danger issue for the slope is given in table 3.2.

| Slope Angle in Degrees | Rank in 5 Point |
|---|---|
| 0-10 | 1 |
| 10-20 | 2 |
| 20-30 | 3 |
| 30-40 | 4 |
| 40-50 | 5 |

**TABLE 3.1: SLOPE RANK SCHEME**

The new values got to be appointed to the slope formation i.e. it must be reclassified in GIS for abstraction analysis i.e. the method of taking input cell values and substitution them with new output cell values. classification is usually accustomed change or modification the interpretation of formation information by ever-changing one worth to a brand new worth, two to cells that vary from fifty one to one hundred, and so on. The study space is low hills with elevation starting from 580 to 760M. The bulk of the realm is flat parcel of land with only a few undulations. The rampant urbanization and construction has created the mineral binding the volcanic rock rocks porous and unstable that is more aggravated once rain is high. For maintaining the lowest error among the stable populations and unstable slopes we have to maximize the linear combination of environmental variables having unique values. They represent the chance of a mapping unit bearing on one among the teams established a priori. The map isn't being ready on a regional scale thus we'd like to be terribly precise on the abstraction location and extent of high risk landslides i.e. why up to 30° the slopes are reclassified along as two.




**MAP 3.1: RECLASSIFIED SLOPE MAP OF IDUKKI**

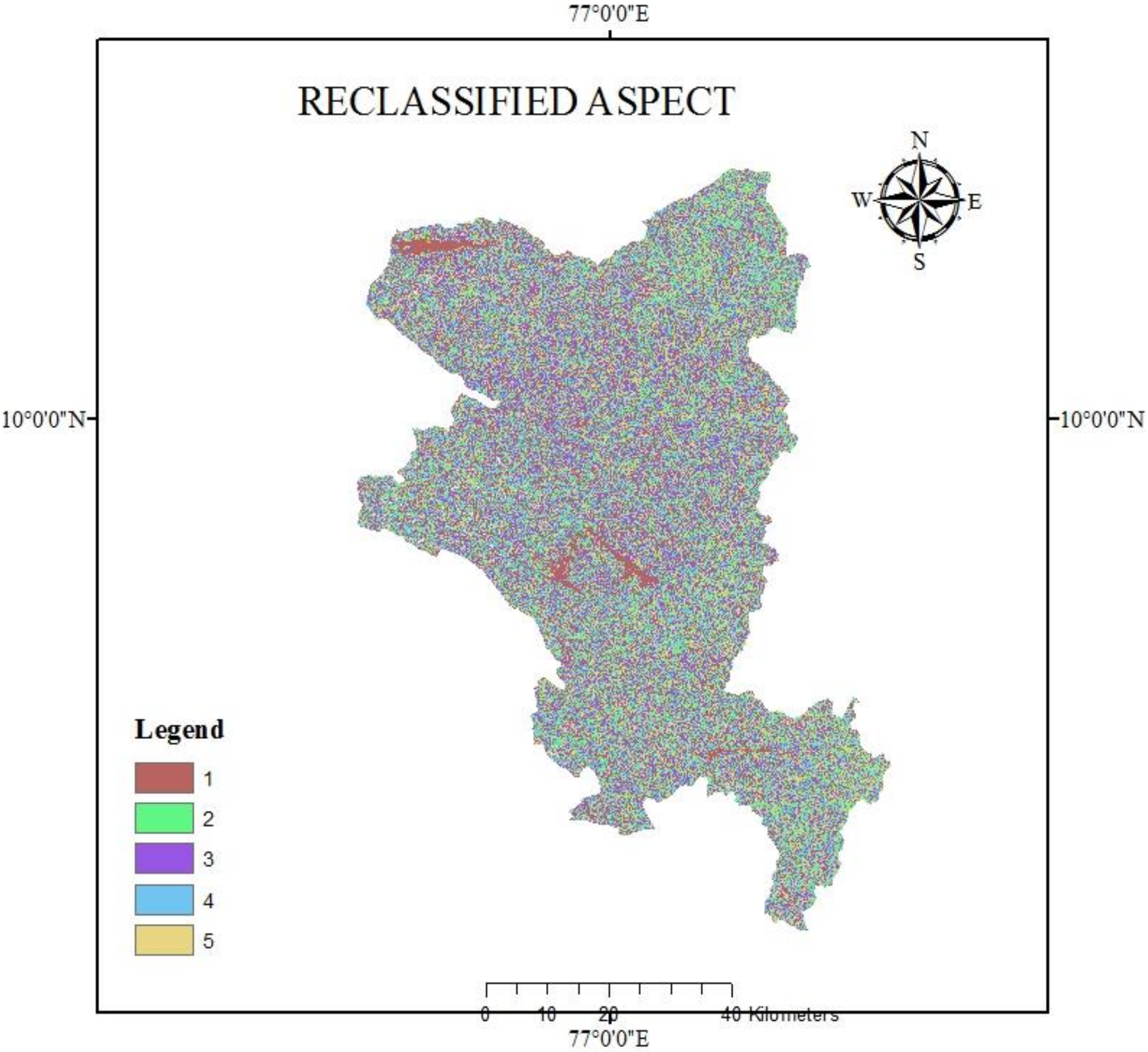
#### 3.2.1.2 Assigning Rank for Aspect

Aspect is that the direction that a surface faces. The derived facet from DEM displays six directions. It's been discovered within the study space that the area units from SE to compass point are additional at risk of landslides. The table three.3 shows the distribution of rank to direction angles with relevance sun's path on the day.

| Slope Aspect in cardinal Directions | Rank in 5 Point |
|---|---|
| North-North West | 5 |
| South west- North -Northwest | 4 |
| South east –South –Southwest | 3 |
| North east-east- Southeast | 2 |
| North- Northeast | 2 |
| Flat | 1 |

**TABLE 3.2: ASPECT RANK SCHEME**

The ranks from North to SE are unbroken an equivalent as their condition issue is from moderate to low. And one amongst the objectives of the study is to hold out the condition analysis in classes from terribly high, high and moderate to low being a little space covering twenty sq. kilometers. Additionally sure ground truth connected info recommend that the most condition is seen on the Bangalore- Kerla passageway that is familiarized from SW –NW- North to the west of the study space. Only some of those directions play an important role and is effective. Therefore a vital issue within the study of this development includes a basic role, within the diagnosing of alternative effective factors on prevalence of this development importance. for sure field studies and specialists opinion may be a nice assistance on identification of the effective factors.




**MAP 3.2: RECLASSIFIED ASPECT MAP OF IDUKKI**

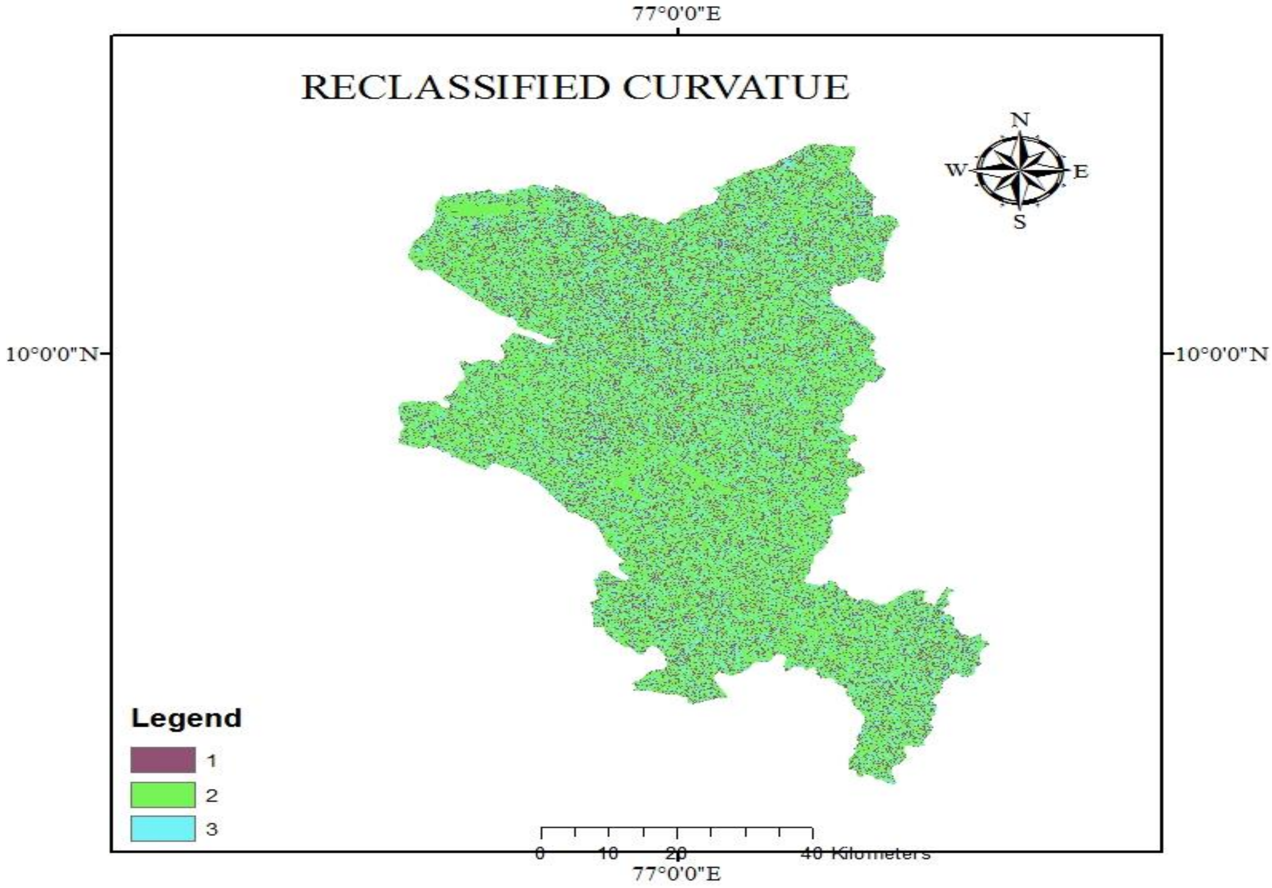
#### 3.2.1.3 Assigning Rank for Plan Curvature

In the study, arrange curvature has been chosen because it defines the existence of tensile stress influenced by gravity and is outlined because the distinction of slope angle. The positive values are outlined as recessed surfaces as a result of the slope angle decreases, on the opposite aspect biconvex surfaces area unit surfaces with negative values creating it unstable and at risk of landslides. Values up to zero show the plane/flat surface. Recessed surface favor landslide stabilization because of compression/ accumulation.

| Curvature | Rank in 5 Point |
|---|---|
| -9 to -0.01(Convex) | 2 |
| -0.01-0(Flat) | 1 |
| 0- 9.2(Concave) | 3 |

**TABLE 3.3: CURVATURE RANK SCHEME**

It’s reclassified as per the new ranks assigned thereto. The areas in red depict the convexity of the stable showing instability and condition to landslides. The areas in inexperienced is that the flat surface and also the areas in blue show concavity of the piece of land i.e. accumulation/ compression wherever the condition issue is a smaller amount.




**MAP 3.3: RECLASSIFIED CURVATURE MAP OF IDUKKI**

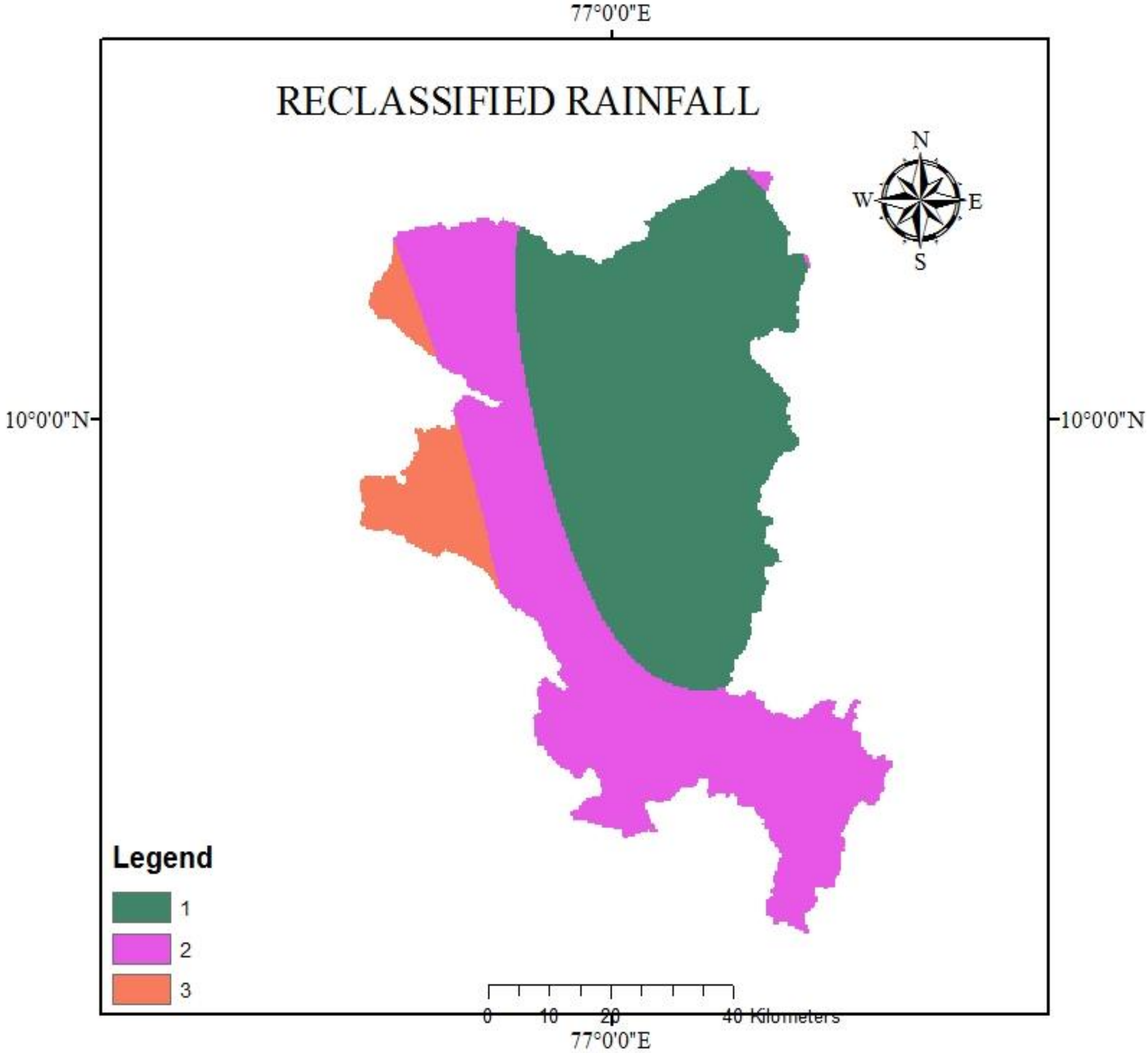
### 3.2.1.4 Assigning Rank for Rainfall

The rainfall is that the triggering issue for the landslides within the study space as has been seen from ground truth. The areas receiving the very best downfall are hierarchical the very best within the down order.

| Rainfall(MM) | Rank in 5 Point |
|---|---|
| 247-300 | 1 |
| 300-350 | 2 |
| 350-400 | 3 |

**TABLE 3.4: RAINFALL RANK SCHEME**

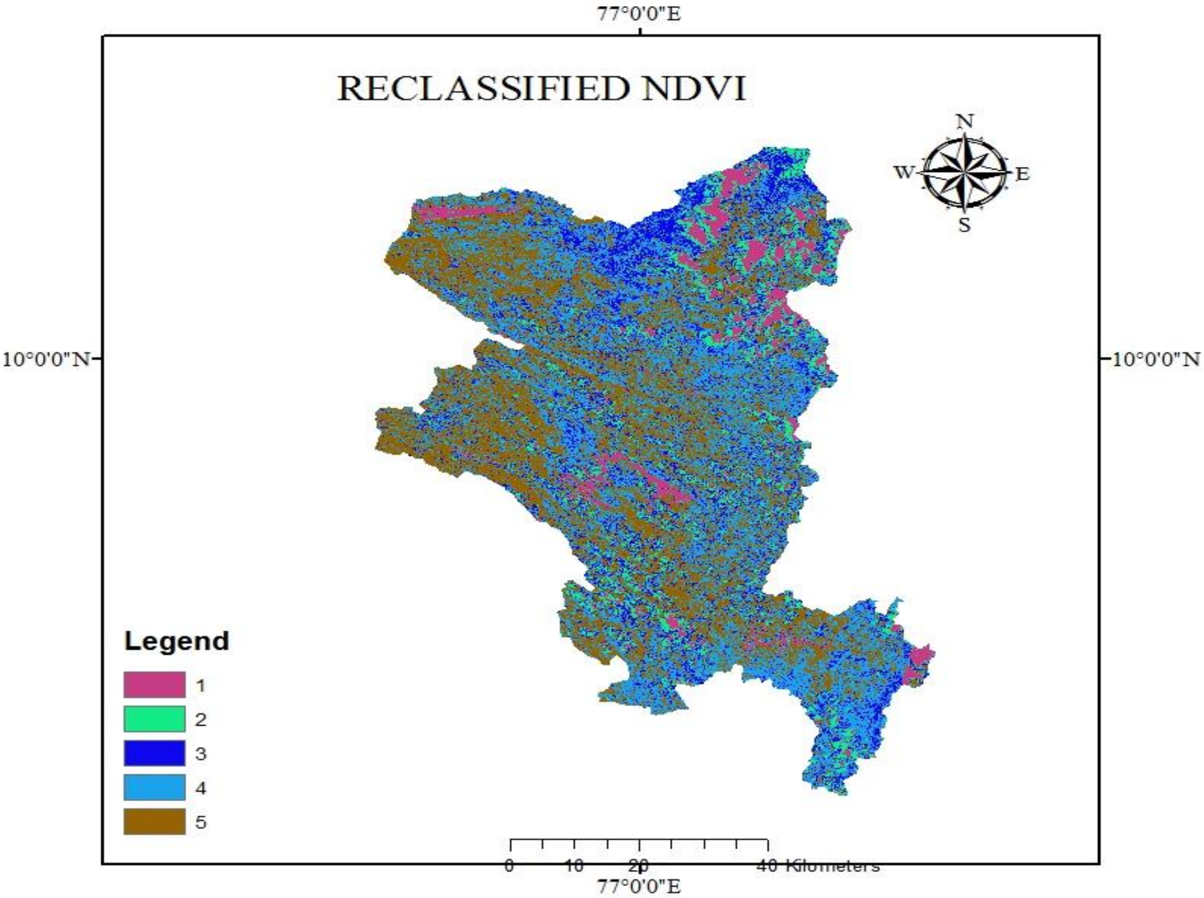
Rainfall is that the most significant acquisition think about triggering the landslide in Idukki as has been seen over the previous few years. Landslides being initiated is substitutable with intense and high density rain prolonged over seventy two hours and on the far side creating the clay binding the volcanic rock ground configuration to slip in conjunction with the scrap because of significant construction activities via construction and blasting on the Bangalore- kerla passageway creating the water flow therefore creating the social class of earth surface very volatile. Many tries were created to get a possible relation between the several parameters. The downfall information wont to get the vital thresholds should be thought-about with caution. However, necessary results emerged from the period characteristic curves that might separate fields with totally different degrees of stability: stability, unsure stability and instability. The high price is perhaps connected to the high mean precipitation and to the high frequency of rainstorms within the study space. Refer reclassified Map three.4, the area unit as in red are those receiving the most quantity of downfall, the areas in inexperienced the second highest and also the areas in blue the smallest amount as per the ranks assigned to them.




**MAP 3.4: RECLASSIFIED RAINFALL MAP OF IDUKKI**

### 3.2.1.5 Assigning Rank for NDVI

NDVI is used to identify where the vegetation is growing and where it is less growing or it is used to identify the change in the vegetation due to various factors either it can be natural or it could be manmade like desolate fervors or removal of forest or due to any human changes and either it could be changing of stages of plants and it is having the range between +1.0 to -1.0.




**MAP 3.5: RECLASSIFIED NDVI MAP OF IDUKKI**

### 3.2.1.6 Assigning Rank for LULC (land Use Land Cover)

Within the context of the study the designed up areas to incorporate roads have most condition to landslides vis a vis unrewarding land, The tree cover/ farmstead have a binding issue with the soil and have lower condition to landslides. Waterbodies area unit least inclined. This investigation aims to raised perceive the connection between landslide events and land use-land cowl (LULC) changes. The main focus of the study is predicated on the construct that in significant monsoons the Idukki and also the near regions area unit suffering from landslides. The identification of spacing between the various landslides and to recognize the area which is prone to landslide will be acknowledged by this LULC classification. The ranks assigned to the varied land categories are given in table three.7. The highest rank is assigned to the designed up areas owing to the part of risk and vulnerability associated thereto. The barren area unit as are next as they're potential areas for development and urbanization. The instabilities in these areas got to be known for city planners. Vegetation includes a binding issue and thus reduces the eroding condition. Finally waterbodies and agriculture have the smallest amount risk issue associated to them and thus area unit given the bottom rank. Map 3.6 is reclassified LULC map. The areas in red have the very best condition followed by the areas in blue.

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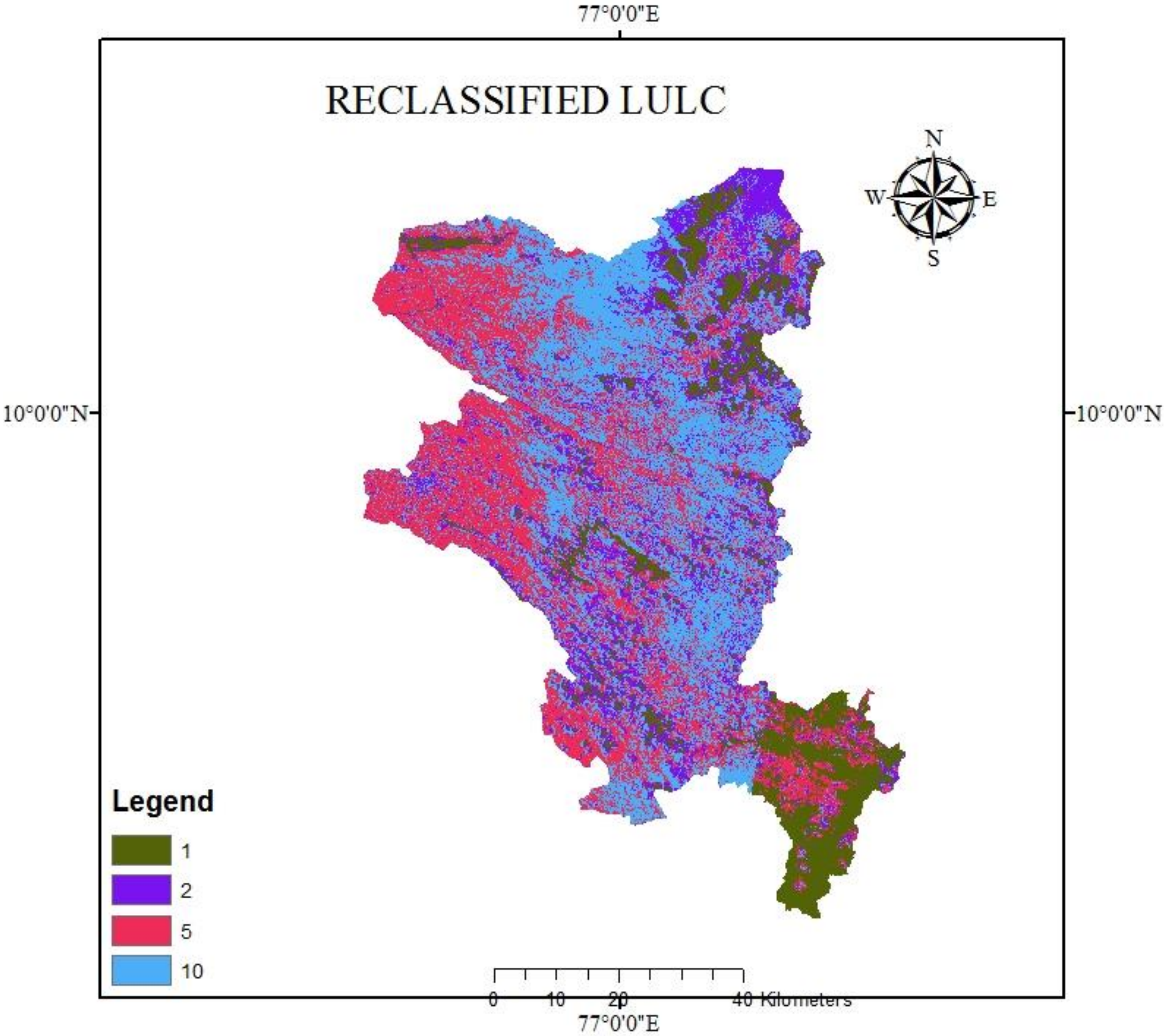



**MAP 3.6: RECLASSIFIED NDVI MAP OF IDUKKI**

### 3.3 Landslide Susceptibility Model Generation Using frequency ratio (FR) model and pairwise comparison model

Frequency ratio model is a statistical approach and it is one of the most popular bivariate method of analyzing landslide susceptibility It is very popular because very simple to use and give more accurate result.

$$FR= \frac{\%\ target\ occurance\ in\ ach\ subcategory}{\%\ category\ of\ an\ independent\ factor} = \frac{(points\ in\ factor\ class/total\ points)}{(factor\ class\ area\ /total\ area)}$$

$$RF = \frac{Factor\ class\ FR}{\sum factor\ class\ FR}$$

To consider the mutual interrelationship among the independents.

PR = $(RF_{max} - RF_{\min})/(RF_{max} - RF_{\min})_{min}$

SI = $\frac{\sum(RF \times PR)}{Max\ (RF \times PR)} \times 100$

Where,

FR – frequency ratio

RF – index of spatial association (relative frequency ) of spatial factors and targets.

| Factor | Factor classes | No. of points | % of points | Class area | % of class area | Ratio(+) | RF |
|---|---|---|---|---|---|---|---|
| SlopeAngle | 1 | 6400 | 25 | 8111321 | 25.35541344 | 0.9859827 | 0.233607 |
| | 2 | 8000 | 31.25 | 9743173 | 30.45646691 | 1.0260547 | 0.243101 |
| | 3 | 6400 | 25 | 8113358 | 25.36178095 | 0.9857352 | 0.233549 |
| | 4 | 4800 | 18.75 | 4904863 | 15.33225343 | 1.2229122 | 0.289743 |
| | 5 | 25600 | 100 | 1117775 | 3.494085273 | 4.2206848 | 1 |
| | | | | 31990490 | 100 | 0 | 1 |
| | | | | | | | |
| Dem elevation | 1 | 8000 | 31.25 | 6605830 | 20.61489324 | 1.5158943 | 0.358864 |
| | 2 | 9600 | 37.5 | 8297597 | 25.8944109 | 1.448189 | 0.342835 |
| | 3 | 6400 | 25 | 11058686 | 34.51097459 | 0.7244072 | 0.171492 |
| | 4 | 1600 | 6.25 | 3738831 | 11.66781493 | 0.5356616 | 0.126809 |
| | 5 | 25600 | 100 | 2343025 | 7.311906337 | 4.2241521 | 1 |
| | | | | 32043969 | 100 | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Curvature | 1 | 4800 | 18.75 | 6593382 | 20.57604662 | 0.9112538 | 0.315495 |
| | 2 | 16000 | 62.5 | 18902551 | 58.98941857 | 1.0595121 | 0.366825 |
| | 3 | 4800 | 18.75 | 6548036 | 20.43453481 | 0.9175643 | 0.31768 |
| | | 25600 | 100 | 32043969 | 100 | 2.8883301 | 1 |
| | | | | | | | |
| NDVI | 1 | 1600 | 6.25 | 2058248 | 6.422692026 | 0.9731122 | 0.175588 |
| | 2 | 3200 | 12.5 | 3055300 | 9.533958467 | 1.3111028 | 0.236575 |
| | 3 | 6400 | 25 | 4887726 | 15.25198072 | 1.6391314 | 0.295764 |
| | 4 | 4800 | 18.75 | 10646696 | 33.22264834 | 0.564374 | 0.101835 |
| | 5 | 9600 | 37.5 | 11398530 | 35.56872045 | 1.0542971 | 0.190237 |
| | | 25600 | 100 | 32046500 | 100 | 5.5420176 | 1 |
| | | | | | | | |
| LAND COVER | 1 | 1600 | 6.25 | 4120786 | 12.85383171 | 0.4862363 | 0.123289 |
| | 2 | 6400 | 25 | 5290085 | 16.50118747 | 1.5150425 | 0.384151 |
| | 5 | 8000 | 31.25 | 10942864 | 34.13371437 | 0.9155171 | 0.232136 |
| | 10 | 9600 | 37.5 | 11705079 | 36.51126645 | 1.0270802 | 0.260424 |
| | | 25600 | 100 | 32058814 | 100 | 3.9438762 | 1 |
| | | | | | | | |

Relative frequency has been calculated for all the factors by dividing the each factor class relative frequency by the total relative frequency and the sum of all must be one then then calculation is right .The frequency ratio model parameters results into different relative frequency which will be further useful for finding the prediction rates of all the factors .

All six factors i.e. slope, aspect, plan curvature, rainfall, NDVI and LULC were generated based on that all the minimum and maximum relative frequency have been identified and the difference of maximum and minimum for each and every class is taken into account and my dividing it by the minimum of all will give the prediction rate of the factors and it is observed that land cover is the most dominant factor in all whereas curvature having the lowest value which implies it will not affect much in the model analysis

### 3.3.1 Calulcation of PR for different factors

| | Min RF | Max RF | [Max]- [Min] | Min tot | PR |
|---|---|---|---|---|---|
| SlopeAngle | 0.233549 | 0.289743 | 0.056193967 | 0.051330104 | 1.094756548 |
| | | | | | |
| Dem elevation | 0.126809 | 0.358864 | 0.232054328 | 0.051330104 | 4.520823267 |
| | | | | | |
| Curvature | 0.315495 | 0.366825 | 0.051330104 | 0.051330104 | 1 |
| | | | | | |
| NDVI | 0.101835 | 0.295764 | 0.193928893 | 0.051330104 | 3.778073269 |
| | | | | | |
| LAND COVER | 0.123289 | 0.384151 | 0.260861676 | 0.051330104 | 5.08204068 |
| | | | | | |

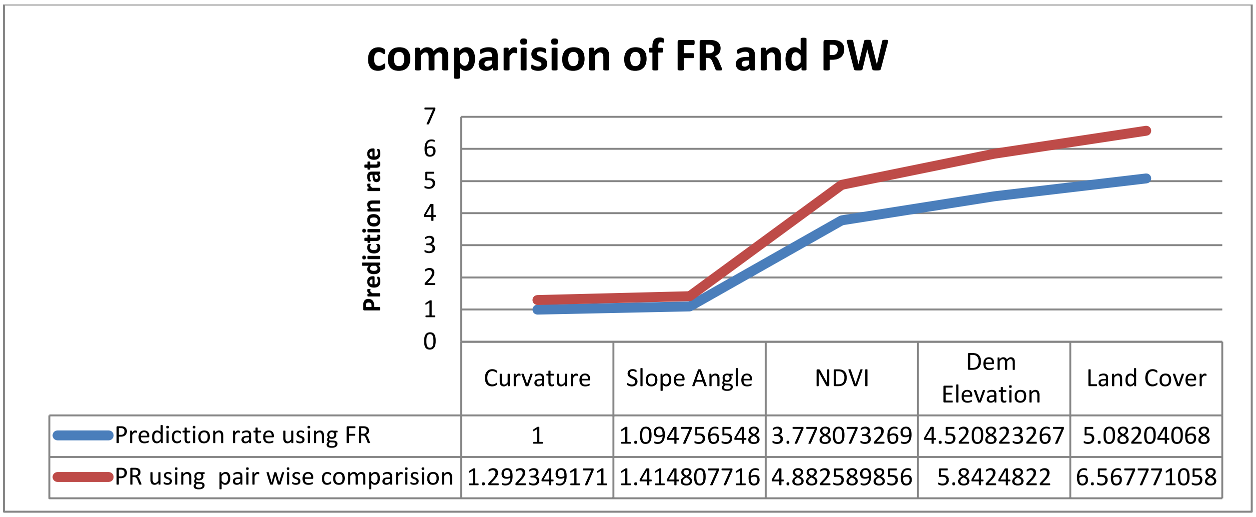
| FACTOR | PR |
|---|---|
| Slope Angle | 1.094756548 |
| Dem Elevation | 4.520823267 |
| Curvature | 1 |
| NDVI | 3.778073269 |
| Land Cover | 5.08204068 |

The prediction rate of each factor are calculated and all told that factors land cover having the utmost value i.e. 5.0820 which suggests it'll be the dominant factor of this model and curvature with the smallest amount are less dominant factor. To analyze the pair wise comparison model it is basically depends on the how many factors we have accordingly we have to make square matrix of same number of variable where the diagonal matrix element will be always one and if the value is left side we need to take reciprocal. As to develop a landslide susceptibility model and to produce a way to define the factor weights within the linear based of Saati's guidelines mentioned .By varying the importance for a set of two factors at a time importance matrix table has been generated in table 3.6.

| | | | | | | |
|---|---|---|---|---|---|---|
| PR | | 1.094756548 | 4.520823267 | 1 | 3.778073269 | 5.08204068 |
| | **Predictors** | **Slope Angle** | **Dem Elevation** | **Curvature** | **NDVI** | **Land Cover** |
| 1.094756548 | **Slope Angle** | 1 | 0.24215867 | 1.094756548 | 0.289765833 | 0.215416723 |
| 4.520823267 | **Dem Elevation** | 4.129523844 | 1 | 4.520823267 | 1.196594916 | 0.889568493 |
| 1 | **Curvature** | 0.913445096 | 0.221198649 | 1 | 0.264685179 | 0.196771349 |
| 3.778073269 | **NDVI** | 3.451062501 | 0.835704704 | 3.778073269 | 1 | 0.743416574 |
| 5.08204068 | **Land Cover** | 4.642165138 | 1.124140534 | 5.08204068 | 1.345140848 | 1 |
| | | | | | | |
| | **Sum** | 14.13619658 | 3.423202556 | 15.47569376 | 4.096186776 | 3.045173138 |
| | | | | | | |
| PR | | 1.094756548 | 4.520823267 | 1 | 3.778073269 | 5.08204068 |
| | **Predictors** | Slope Angle | Dem Elevation | Curvature | NDVI | Land Cover |
| 1.094756548 | **Slope Angle** | 0.070740386 | 0.070740386 | 0.070740386 | 0.070740386 | 0.070740386 |
| 4.520823267 | **Dem Elevation** | 0.29212411 | 0.29212411 | 0.29212411 | 0.29212411 | 0.29212411 |
| 1 | **Curvature** | 0.064617459 | 0.064617459 | 0.064617459 | 0.064617459 | 0.064617459 |
| 3.778073269 | **NDVI** | 0.244129493 | 0.244129493 | 0.244129493 | 0.244129493 | 0.244129493 |
| 5.08204068 | **Land Cover** | 0.328388553 | 0.328388553 | 0.328388553 | 0.328388553 | 0.328388553 |
| | **Sum** | 1 | 1 | 1 | 1 | 1 |

| Sum | Integer weights |
|---|---|
| 0.3537019 | 1.414807716 |
| 1.4606205 | 5.8424822 |
| 0.3230873 | 1.292349171 |
| 1.2206475 | 4.882589856 |
| 1.6419428 | 6.567771058 |

| Factor | Prediction rate using FR | integer | PR using pair wise comparison | integer |
|---|---|---|---|---|
| Curvature | 1 | 100 | 1.292349171 | 129.2349 |
| Slope Angle | 1.094756548 | 109.4756548 | 1.414807716 | 141.4808 |
| NDVI | 3.778073269 | 377.8073269 | 4.882589856 | 488.259 |
| Dem Elevation | 4.520823267 | 452.0823267 | 5.8424822 | 584.2482 |
| Land Cover | 5.08204068 | 508.204068 | 6.567771058 | 656.7771 |



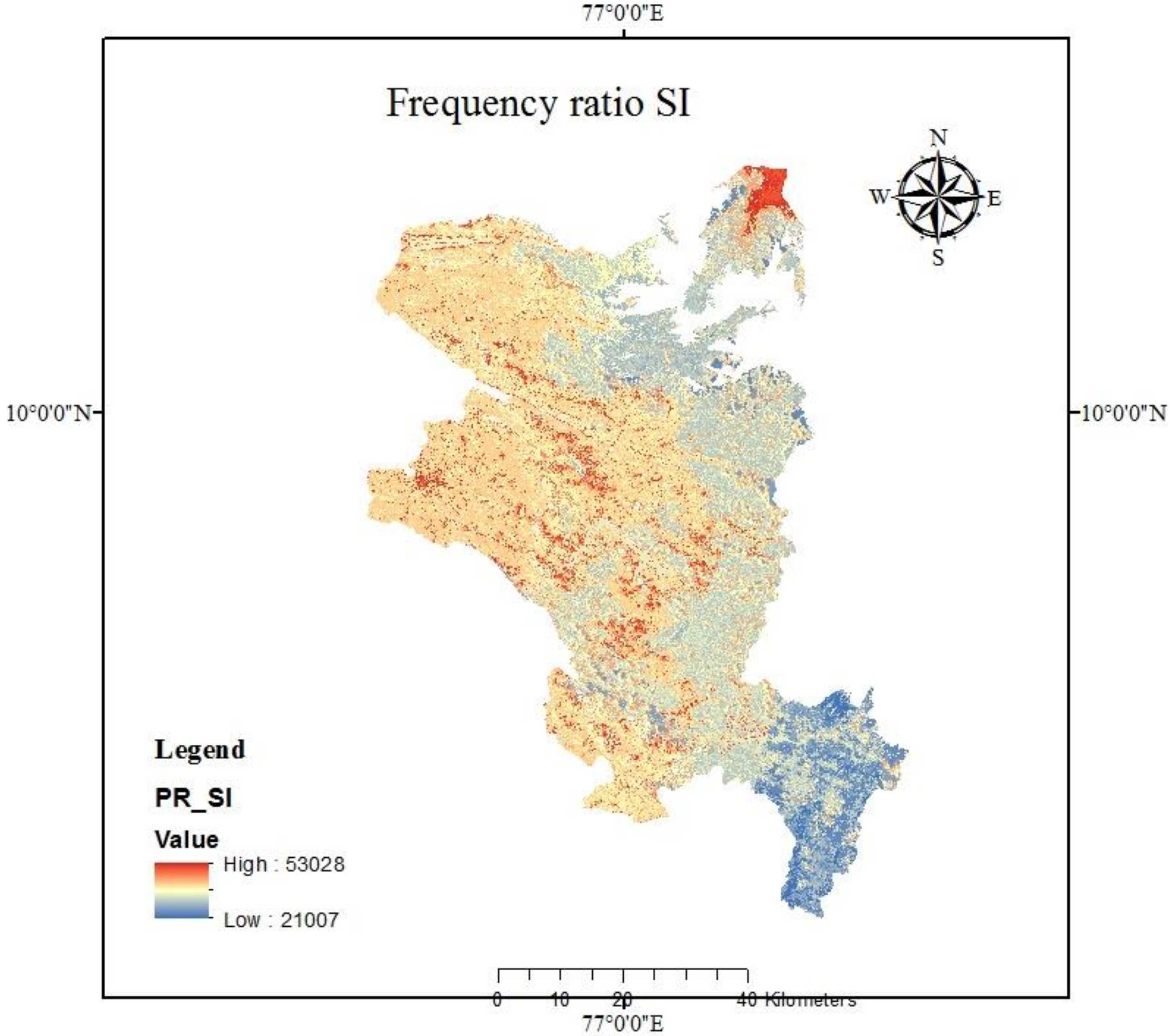

| | Curvature | Slope Angle | NDVI | Dem Elevation | Land Cover |
|---|---|---|---|---|---|
| Prediction rate using FR | 1 | 1.094756548 | 3.778073269 | 4.520823267 | 5.08204068 |
| PR using pair wise comparision | 1.292349171 | 1.414807716 | 4.882589856 | 5.8424822 | 6.567771058 |

Values of equal importance 1 are highlighted in yellow and are the diagonal elements of the matrix.These relational scores have been obtained through ground survey and interactions. Let us understand how have the pairwise judgement values been computed with an explanation of one factor i.e. Elevation.

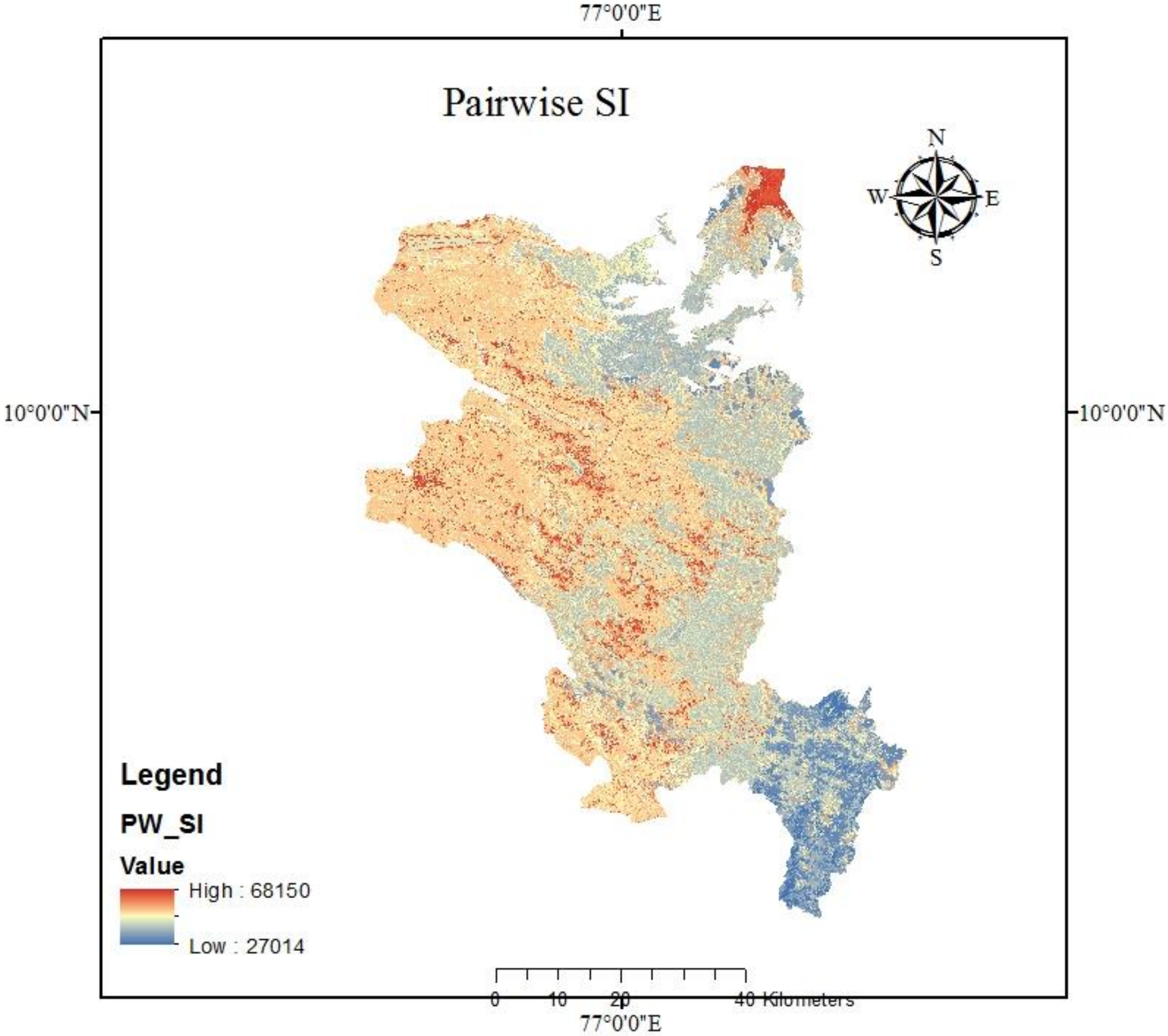
Elevation is the actually a triggering factor, Slope beings factors of importance have been given value 1 . Between elevation and slope pair wise comparison the judgement value is nearly 5 times higher value. It implies that slope has moderate importance over elevation. Between elevation and curvature the pair wise comparison the judgement value is 4 times higher. However the judgement of elevation is higher than curvature .The overall sum (Σ =) pair wise comparison of elevation with other factors totals to 3.42.

For analyzing or calculating the significance vector we have to take average of all the rows and to normalize the cell value we divide the cell values by its total column

The pairwise comparison matrices show how other factors respectively satisfy the conditions. For required answer what we need it is significant to do the very standard calculation of matrix mainly for Percentage weightage of each factor contributing towards landslide susceptibility zonation in Idukki, kerla.




**MAP 3.7: FR SUSCEPTIBILTY INDEX MAP OF IDUKKI**




**MAP 3.8: PAIRWISE SUSCEPTIBILTY INDEX MAP OF IDUKKI**

## 3.4 Model evaluation using area under curve (AUC)

The influence of landslide susceptibility zoning produced from the two models was investigated using the area under the curve (AUC). The evaluation accuracy of the models is validated using the success rate curve and the prediction curve. Both numbers are in the 0.5–1 range and the higher the AUC, the better.

| Training Bel | | | | | |
|---|---|---|---|---|---|
| ROWID | VALUE | OBJEC_1 | percentage | cumulative area | Auc |
| 0 | 0 | 0 | | | |
| | 1 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 0 | 0 | 83.75 |
| 1 | 3 | 1600 | 6.25 | 6.25 | 251.25 |
| 2 | 4 | 1600 | 6.25 | 12.5 | 335 |
| | 5 | 0 | 0 | 12.5 | 335 |
| | 6 | 0 | 0 | 12.5 | 335 |
| | 7 | 0 | 0 | 12.5 | 418.75 |
| 3 | 8 | 1600 | 6.25 | 18.75 | 502.5 |
| | 9 | 0 | 0 | 18.75 | 502.5 |
| | 10 | 0 | 0 | 18.75 | 502.5 |
| | 11 | 0 | 0 | 18.75 | 502.5 |
| | 12 | 0 | 0 | 18.75 | 502.5 |
| | 13 | 0 | 0 | 18.75 | 502.5 |
| | 14 | 0 | 0 | 18.75 | 502.5 |
| | 15 | 0 | 0 | 18.75 | 502.5 |
| | 16 | 0 | 0 | 18.75 | 502.5 |
| | 17 | 0 | 0 | 18.75 | 502.5 |
| | 18 | 0 | 0 | 18.75 | 502.5 |
| | 19 | 0 | 0 | 18.75 | 502.5 |
| | 20 | 0 | 0 | 18.75 | 502.5 |
| | 21 | 0 | 0 | 18.75 | 586.25 |
| 4 | 22 | 1600 | 6.25 | 25 | 670 |
| | 23 | 0 | 0 | 25 | 670 |
| | 24 | 0 | 0 | 25 | 670 |
| | 25 | 0 | 0 | 25 | 670 |
| | 26 | 0 | 0 | 25 | 670 |
| | 27 | 0 | 0 | 25 | 753.75 |
| 5 | 28 | 1600 | 6.25 | 31.25 | 837.5 |
| | 29 | 0 | 0 | 31.25 | 837.5 |
| | 30 | 0 | 0 | 31.25 | 837.5 |
| | 31 | 0 | 0 | 31.25 | 837.5 |
| | 32 | 0 | 0 | 31.25 | 837.5 |
| | 33 | 0 | 0 | 31.25 | 837.5 |

| | | | | | |
|---|---|---|---|---|---|
| | 34 | 0 | 0 | 31.25 | 837.5 |
| | 35 | 0 | 0 | 31.25 | 837.5 |
| | 36 | 0 | 0 | 31.25 | 837.5 |
| | 37 | 0 | 0 | 31.25 | 1005 |
| 6 | 38 | 3200 | 12.5 | 43.75 | 1172.5 |
| | 39 | 0 | 0 | 43.75 | 1340 |
| 7 | 40 | 3200 | 12.5 | 56.25 | 1507.5 |
| | 41 | 0 | 0 | 56.25 | 1507.5 |
| | 42 | 0 | 0 | 56.25 | 1507.5 |
| | 43 | 0 | 0 | 56.25 | 1591.25 |
| 8 | 44 | 1600 | 6.25 | 62.5 | 1758.75 |
| 9 | 45 | 1600 | 6.25 | 68.75 | 1842.5 |
| | 46 | 0 | 0 | 68.75 | 1842.5 |
| | 47 | 0 | 0 | 68.75 | 1842.5 |
| | 48 | 0 | 0 | 68.75 | 1842.5 |
| | 49 | 0 | 0 | 68.75 | 1842.5 |
| | 50 | 0 | 0 | 68.75 | 1842.5 |
| | 51 | 0 | 0 | 68.75 | 1842.5 |
| | 52 | 0 | 0 | 68.75 | 1842.5 |
| | 53 | 0 | 0 | 68.75 | 1842.5 |
| | 54 | 0 | 0 | 68.75 | 1926.25 |
| 10 | 55 | 1600 | 6.25 | 75 | 2010 |
| | 56 | 0 | 0 | 75 | 2010 |
| | 57 | 0 | 0 | 75 | 2010 |
| | 58 | 0 | 0 | 75 | 2010 |
| | 59 | 0 | 0 | 75 | 2010 |
| | 60 | 0 | 0 | 75 | 2093.75 |
| 11 | 61 | 1600 | 6.25 | 81.25 | 2177.5 |
| | 62 | 0 | 0 | 81.25 | 2177.5 |
| | 63 | 0 | 0 | 81.25 | 2261.25 |
| 12 | 64 | 1600 | 6.25 | 87.5 | 2345 |
| | 65 | 0 | 0 | 87.5 | 2345 |
| | 66 | 0 | 0 | 87.5 | 2428.75 |
| 13 | 67 | 1600 | 6.25 | 93.75 | 2596.25 |
| 14 | 68 | 1600 | 6.25 | 100 | 1340 |
| | | 25600 | | | 78875 |
| | | | | Area under curve = 78.875 | |

Increased analysis exactness the landslide susceptibleness curve is employed to make the success rate curve. Within the analysis work, we tend to stack every issue over one another for landslide susceptibleness web site choice model through analysis of the many various factors. By analyzing and calculating the accuracy of the model it is found that it is 79%

# Chapter-4
# Conclusion

It is very hectic for the GIS analysts to collect information from various sources having different degree of reliability. Since not all information is of equal value, the main problem is to find information having a very good quality having very less error the quality should be like we can present in meeting or and workshops ,for disaster alert/impact systems and satellite based maps. The rapid mapping activities as seen within the research work are geared toward supporting the primary stage of disaster management. Different Data sources kinds of USGS raster file data of band 8 has to be downloaded and further used for all the map and calculation purposes.

Data access must run to student community like UNIGIS for educational and research work.

A rapid estimate of this information may be obtained by overlaying potential computer file.Stastistics of raster will be computed using statistics zonal functions within each theme as defined in another dataset, which during this case are the conditional factors.

Mapping standards, for instance, a map representing outputs derived from the analysis of images should be supported medium to large scale maps. As per Slum Atlas of Idukki (2009), over 40% of Idukki's population lives in slums. However, it's feared that if slums still grow at this pace, almost 50% of the city's population will soon be residing in Idukki city. So on tackle this issue, boundaries outlined by Capitol Hill and Hill Slopes department should be followed stiffly. This, as well as encroachment of footpaths built for pedestrian use, may be a grave issue which needs immediate attention. The increasing population has resulted in utilization of slopes for construction purpose. Also, many unauthorized stone quarrying activities are going unchecked. this could result into overloading of the slopes, run-off mud leading to exposure of rocks and eventually leading to landslides. The research work can aid as a call making tool in identification of slope instabilities for planning by the regime agencies.

Main achievements of this project is it has completed using the data available on various data portal sources like USGS data portal (for band 8 images) , CHRS data portal ( for rainfall ) ,IMD (Indian metrological department ) ,MOSDAC , USGS earth explorer and AWS S3 earth explorer in all the listed above most of them are available for free. The selected region is some more similar but different properties like slope, curvature, rainfall, aspect and other conditional factors. Furthermore, every input underwent the identical processing procedure, implementing a range of well-known modeling approaches using GIS Subsequent models area unit to gift transient relative values over the globe, pinpointing landslide-endangered zones and safe zones.

On calculating and analyzing all the two models it is found that it is 78% accurate and on single model analysis performance it seems like frequency ration model is more promising and more accurate but both frequency ration model and pairwise model are widely accepted.

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