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Landslide Spatial Data Analysis Using Decision Tree Classification Approach

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Abstract

Spatial data analysis has been an active area of research in spatial domain for several decades. Huge amounts of spatial data have been collected in various applications, ranging from remote sensing to geographical information system, urban planning and disaster management. In today environment disaster causes huge damage to human life and infrastructure of the society. Natural disasters are categories into landslide, earthquake, tsunami, cyclone and floods. Landslide disaster is major threat to the people who lives in hilly region. The aim of this paper is to analyze landslide risk using GIS and data mining classification approach. Remote sensing images and field data are used to prepare various thematic maps. In this paper six factors such as rainfall, slope, geology, Geomorphology, soil and land use/ land cover are considered for landslide risk analysis. Ooty, Nilgiri district of Tamilnadu is considered as study area. The Decision Tree data mining classification approach is applied to analyze the landslide risk and the results are validated with real time data.

Keywords: Landslide, GIS, Classifier, Risk, Decision Tree

Introduction

In natural systems, landslides are recognized as one of the most significant "natural hazards" in many areas throughout the world (Crozier, 1986) [6]. Globally, landslides cause billions of dollars in damage and thousands of deaths and injuries each year. Landslides have always posed serious threats to settlements and structures that support transportation, natural resources and tourism. Nilgiri District of Tamilnadu is

considered as study area. It's situated in Western Ghats and the total area of the district is 2452.50 sq km. In Nilgiri district, landslide occurred because of the heavy rainfall and modification of landuse features. The major rain induced landslide occurred in the year of 1978 and 2009 in which 543 landslips were occurred and many people's were killed and lost their properties. Huge landslide happened recently at Nilgiri hills in Tamilnadu enforce us to propose this problem.

Landslide occurrences are attributable to the resisting strength of the soil or rock forming the slope against gravity and a landslide results when the balance is tipped in favor of gravity. This balance can be changed by both natural and man-made circumstances. In the previous studies, various approaches were applied to such problems which show that it is difficult to understand and tricky to predict accurately. In order to analyze these landslides, various factors such as Rainfall, Geology, Slope, land-use/land cover, soil and Geomorphology are considered and the relevant thematic layers are prepared in GIS for landslide susceptibility mapping. The data collected from various research institutes related to landslide helped to predict and analyze the landslide susceptibility.

In this study, the GIS and Data mining concept are integrated to predict the possibilities of landslides. Design and development of a Landslide Susceptibility Model (LSM) is the primary objective of this work and it is developed using Decision Tree classification approach for ooty, Nilgiri district, Tamilnadu.

Related Work

An integration of remote sensing, GIS and Data mining techniques has been used to predicting the landslide risk. Discrete Rough Set method (Wan et al, 2009) [27] for evaluating landslide occurrence performs an improved classifier in landslide problem. To identifying the landslide susceptibility, GIS used for the input data from both the satellite and field data (Biswajeet, (2011). The Indian Remote Satellite (IRS), Multi Spectral Sensor (MSS) and Panchromatic (PAN) image are merged for improving the quality of image features. A landslide hazard zonation map has also been proposed based on the historical landslide data (Chau et al ,2004; Wang and Peng,2009) [5] [27], like geological, geomorphology, population, climatic and rainfall data. The fuzzy k-means (Gorsevski et al, 2003) [7] classification endow with an important quantity of information about a landslide factors and changeability of data. It is useful for the landslide prediction.

The landslide susceptibility model performances are compared and evaluated with various methodologies such as bivariate statistical and expert based method (Venkatesan et al,2012;Sarkar et al,2006;Paolo et al,2009;Vaani and Sekar,2012) [16][21][26]. The importance of the landslide factors was determent using the analytical hierarchy process (Marko Komac,2006) [13] method ,where the error rate of the prediction is 4.3% to 73%. Various geosystem parameters (Ramasamy and Muthukumar,2008)[19] were identified and the reflectance of the factors occurred in landslides. The landslide chosen factors were identified and landslide hazard map was prepared using the Thematic Mapper (TM) and then Vegetation index map derived from SPOT satellite images(Lee and Jasmi,2005) [10]. The difference of the neural

network analysis (Biswajeet,2011) [3] susceptibility map was validated using ROC method(Akgun et al,2012;Hyun and Biswajeet,2011) [1]. In the thematic layer, each of the categories has been determines the membership values and implemented using fuzzy set (Rajesh and Evany,2011;Hyun and Biswajeet,2011; Gemitzi et al ,2011) [8][9][22]. The landslide hazard map were prepared and classified based on equal interval method (Ram Mohan et al,2011) [23]. The Analytical Hieratical Process (AHP) Vaani and Sekar (2012) [24] method provides a systematic approach to integrate the factors and it will be used for preparing Landslide Hazard Zone map.

The probabilistic and statistical approach (Lee and Touch,2006) [11] were applied for estimating the landslide susceptibility area. Landslide susceptibility map is reduced the landslide hazard and is used for land cover planning. The frequency ratio model was better than logistic regression model (Lee and Biswajeet,2007). Fuzzy membership functions and factor analysis (Gemitzi et al,2011) [8] were used to assess the landslide susceptibility using various factors. The spatial data were collected and processed and create a spatial database using GIS [4] and Image processing techniques. The landslide occurrence factor was identified and processed. Each factor weight was determined and calculated the training using back-propagation (Biswajeet and Lee ,2010;Prabu and Ramakrishnan,2009) [2][17].

Thematic Layers Preparation For Factors Influencing Landslides

For this study, map data were selected based on three key attributes: relevance, availability and scale. The relevance refers to the main causative factors of landslide in the study area. The availability refers to relevant factors that are readily available to be used for developing a slope instability map. The scale attribute is an important consideration and refers to the map scales of different causative factors of landslides that will be employed for creating a slope stability map. Landslide occurrences are attributable to the resisting strength of the soil or rock forming the slope against gravity and a landslide results when the balance is tipped in favor of gravity. This balance can be changed by both natural and man-made circumstances. The elements that affect slope stability and landslides are numerous, varied and interact in complex and often subtle ways. Besides manmade factors are summarized, reviewed and divided natural factors influencing landslide into six groups: i.e. rainfall, slope, geomorphology, geology, landuse/ landcover and soil. Six relevant factors are selected as inputs for the models of landslide susceptibility mapping in this study. The Landslide factors thematic layers are prepared from the LISS III+ PAN images using ArcGIS Tool. Maps relevant to landslide occurrence were constructed in a vector format spatial database using the ArcGIS software.

Description of The Study Area

The main objective of the study is the analysis of landslide susceptibility model using data mining classification approach in mountainous regions Nilgiri District, Tamilnadu. There are four Panchayat Unions in this District. The four Municipalities are Udhagamandalam (ooty), Coonoor, Gudalur and Nelliyalam. There are 11 special village panchayats in this district. Udhagamandalam (Ooty) is considered as study

area for landslide risk analysis and its represented in Fig. 1. Geographically, the study area is located between latitudes 11°41' North, and longitudes 76°70 East. The study region is about 879 km^2.

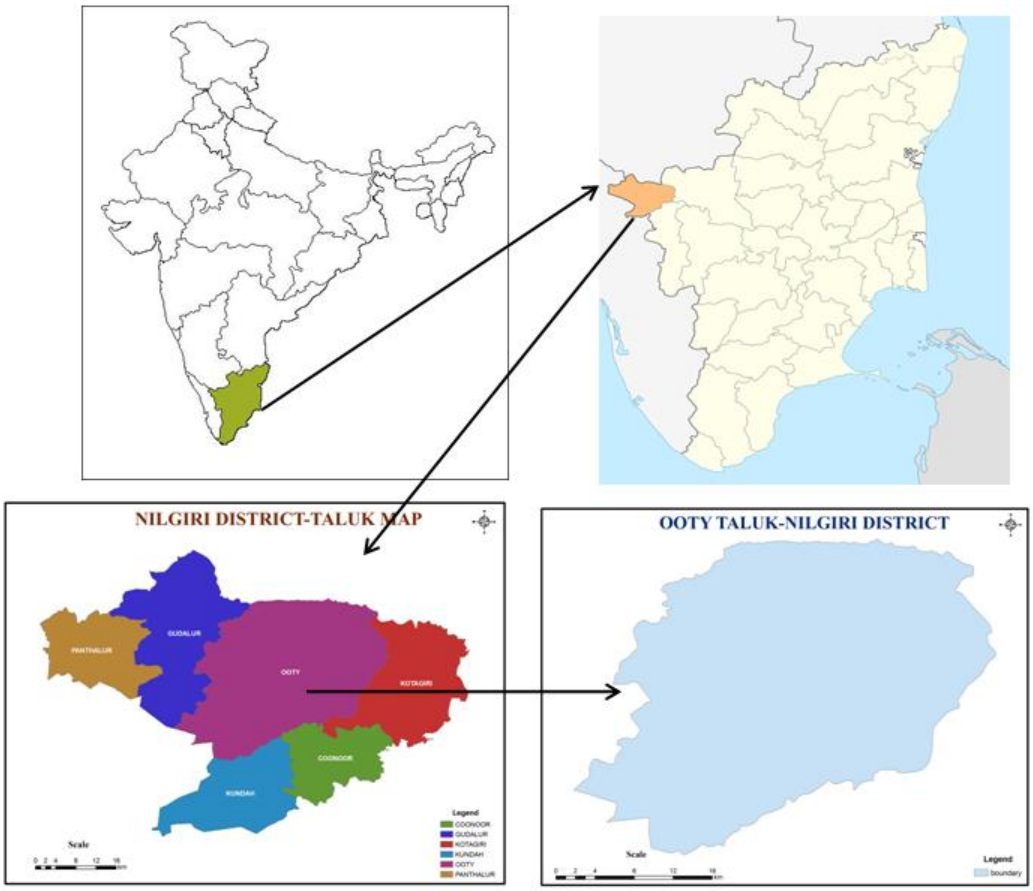

Figure 1: The Study Area (Ooty) for Landslide Risk Analysis

Landslides occur frequently in this area and seriously affect local living conditions. For example, several landslides in the November 2009 caused severe damages. More than 39 people lost their lives, and many houses, roads and other infrastructures were destroyed. Moreover, Heavy Rainfall occurs every year to increasing the risk of landslide. The landslide demolished nearly 300 tinned roof mud huts. Therefore, the present study of landslide hazard in the Ooty,Nilgiri District [25], Tamilnadu province is very useful for obtaining more insight in the relevant processes and parameters controlling landslide.

Rainfall

Nilgiri district receives the rainfall from both the southwest and northeast monsoon. One part of Nilgiri district receives the southeast monsoon and another part of the Nilgiri district receives the northwest monsoon. Southeast monsoon covers the Gudalur, Panthalur and kundhataluk. Northeast monsoon covers the Ooty, Coonoor

and Kotagiritaluks. In this region rainfall plays a major role because most of crops was depending the rainfall only 6% crop have been covered under the irrigation. Nilgiri receives the high rainfall when comparing to the other district but the ground water is low because of the topography. In 2009 November the district received 547 mm rainfall, which is the highest rainfall in past thirty years in the November. Due to the heavy rainfall the district affected from road damaged, soil erosion and landslide. There are 30 rainfall stations in the district. The ooty rainfall map is shown in Fig. 2.

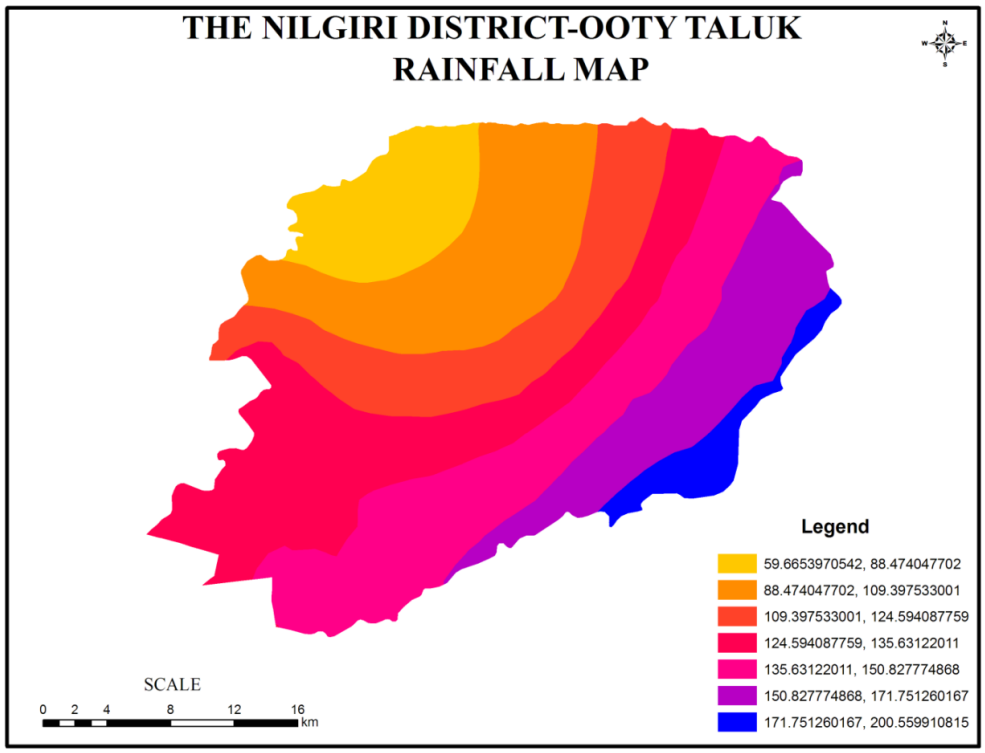

Figure 2: Rainfall Map

Naduvattam, Upper Bhavani, Governorsola, Masinagudi, Anaikatty, Valve wood estate, Kallatti and udagamandalam are the eight rainfall stations located in OotyTaluk. 59.67-88.47 mm, 88.47-109.40mm, 109.40-124.59mm, 124.59-135.63 mm, 135.63-150.82mm, 150.83-171.75mm and 171.75-200.56 mm rainfall classes are there in ooty. Here the maximum and minimum rainfall is 59.67-88.47 mm & 171.75-200.56 mm.

Slope

Slope is the important layer in the analysis of landslide. Slope represented as rise or fall of the land surface. Rising slope is climbing from the foot of a hill towards the top portion and falling slope is climbing the downhill. When the slope angle increased, chance to get landslide occurrence. The high amount of value indicates the higher or steeper degree of slope. Slope failure is a complex that occurs in many scales for

many reasons. The slope movement is fast in particular areas that have previously experienced landslide activity. Usually failure occur downward movement to the surface and stress exceeds the strength. Clayey rock fills, creep under the loads, leaching, weathering, cracking and pressure factors are decrease the shear strength. This shear stress relates to the mass material and slope angles. If the slope angle increase, the stress also increases and the stability reduces. The slope categories are represented in Fig. 3.

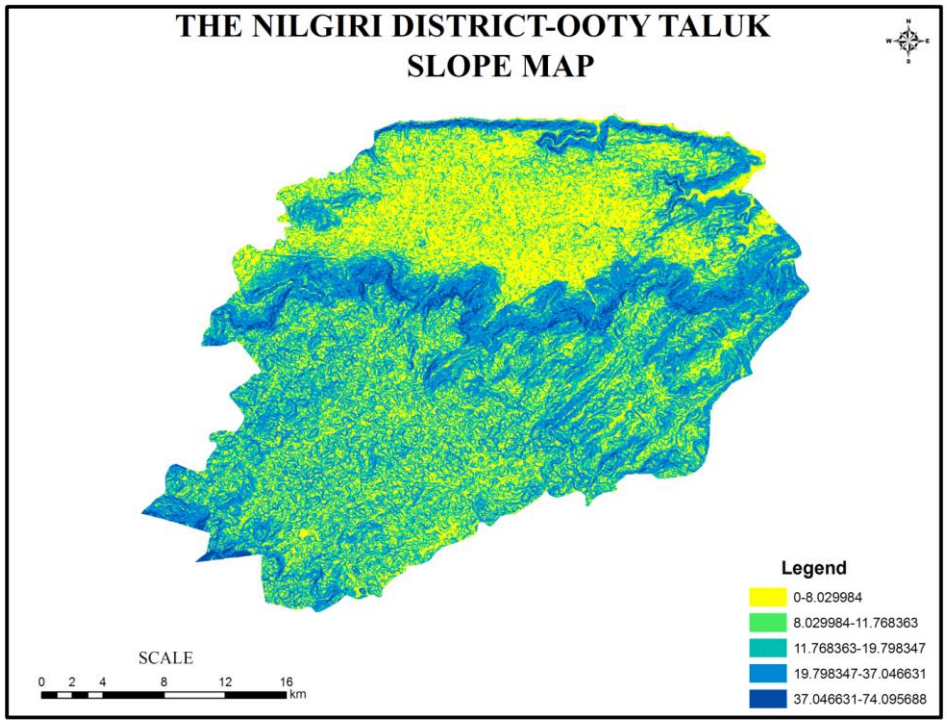

Figure 3: Slope Map

Ooty is the head quarters of the nilgiri district. The higest value of the slope was present in the middle of the Ooty 19.80-37.05 and 37.05-74.10 occupied with 222.06 and 27.56 sq km. The upper most area 0-8.03 of the ooty situated in the direction of north and areawise 231.91 sq km. The largest area of ooty 253.64 sq km occupied in the classes of 11.77-19.80.142.58 sq km area covered by 8.03- 11.77 slope percentage.

Geomorphology

Earth Surface structure and the representation of the landforms referred in Geomorphology. The process of geomorphology is better understanding of the physical geography. The study of the model represents the slope angles, decreases and increases of the landform and ridges. Some of the landforms are in different rounded shape because of the causes of erosion in landforms. Recently the geomorphology

study was broken down into the various studies of geomorphologic processes. The process considered about easy observed and measured into interconnected with the modern technology. The geomorphologic process are involved moreover in erosion, depositional or both. Erosion process concerns the earth surface by wind, water and glacier. The depositional process involved in eroded the material by wind, water and glacier.

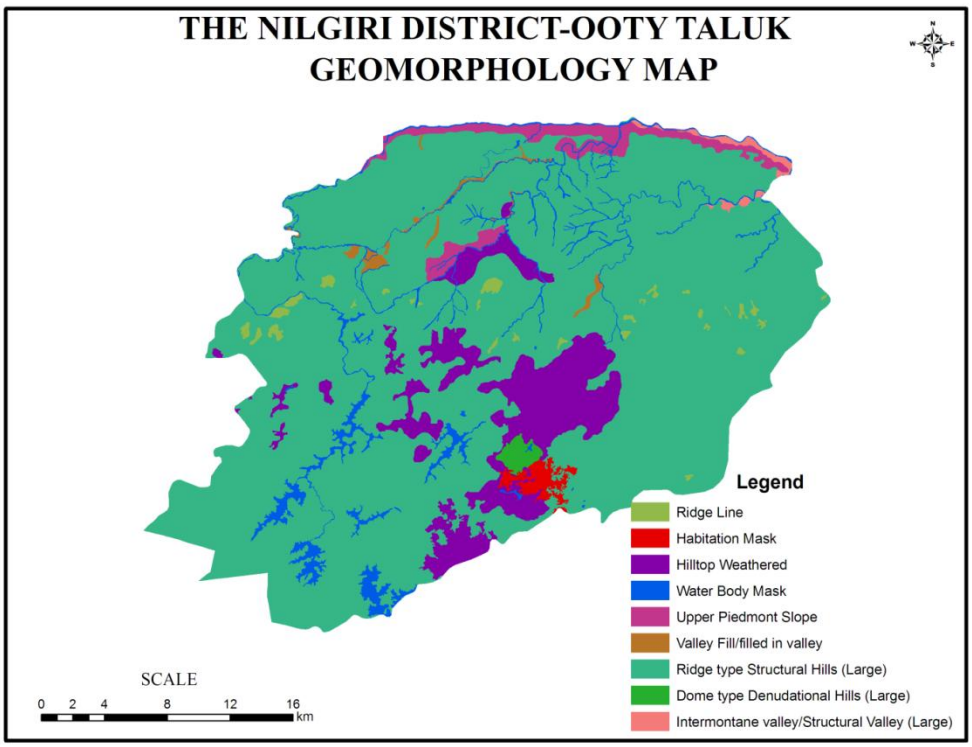

Figure 4: Geomorphology Map

The geomorphologic process is a fluvial process for the rivers and streams. This process engaged with the flow of the water, erosion of the channel, and shape in the landform and merging with the some other rivers. The geographical features are identified using the satellite images through the process of interpretation. The Geomorphology features for the ooty is classified as Ridge Line, Habitation Mask, Hilltop Weathered, Water Body Mask, Upper Piedmont Slope, Valley Fill/filled in valley, Ridge type Structural Hills,Dome type Denudational Hills and Intermontane valley/Structual Valley as shown in Fig. 4.

Geology

Geology is the study of Solid feature of the earth. It provides a history of the Earth plate information. In India, the oldest rock of Gneiss and Schist rocks are found and the rocks are classified in two systems based on the Precambrian rocks in India. The classified systems are Dharwar system and Archaean. The separate systems of Nilgiri

contain Charnockites assortment from granites to gabbros. The study area of Nilgiri's contains Gneiss, Schist and Gneiss Mixed, Ultra basic rocks, Charnockite Group also felsites. Coonoor and Kundha whole area were covered by Charnockite group and partially it was covered in Ooty, Kothagiri, Gudalur and Panthalur. On the top of the Gudalur, Panthalur, Kothagiri and Ooty area were covered by Gneiss. The geology map of the study area is shown in Fig. 5. The map is prepared based on GSI.

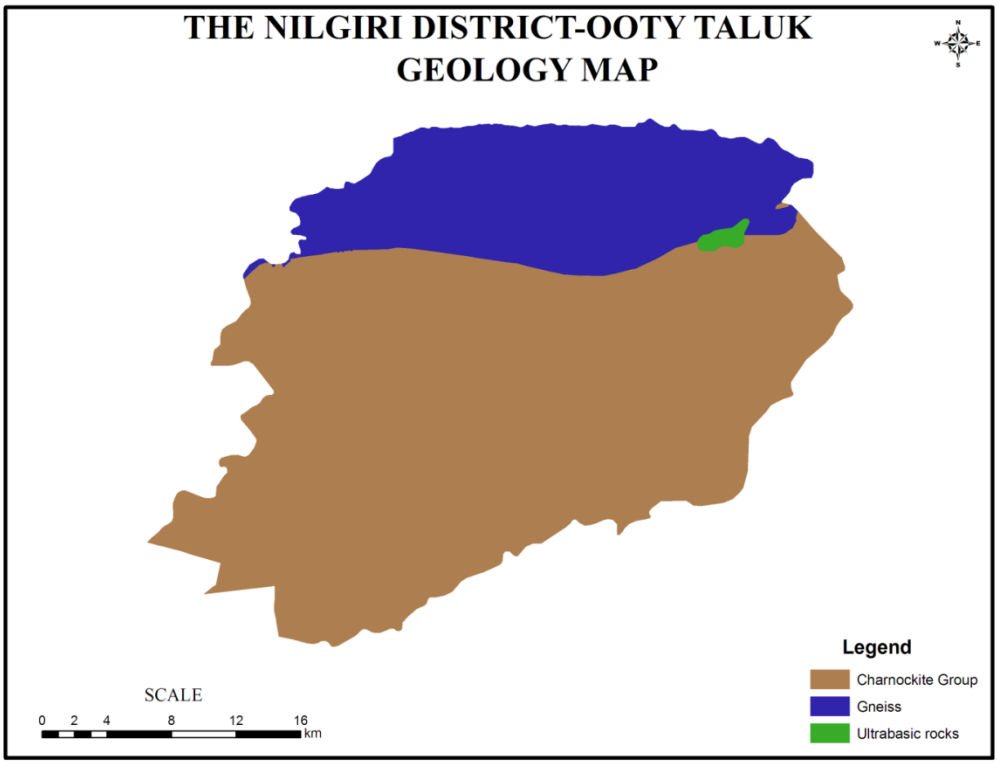

Figure 5: Geology Map

Land use / Land cover

Land cover it refers to what types of features are presented on the earth surface. It includes the Forest, vegetation, water bodies, etc. The land use is represented how humans are using the land, however humans are modify the land cover to land use for their own use, for instance forest they are modified into agriculture like that they are changing the features. Using the satellite imagery and field survey to interpreted the land use and land cover features. The change of land use and land cover plays an important role in climate change. If the changes are occurred continuously deforestation will happened to that place. The deforestation happens means soil strength will be loosening and it is creating a problem like land slip or landslide. In landslide studies the landuse/land cover layers are considered as a next importance to the slope. The deforestation of the human activities in land use/land cover the stability of the slope has been altered. The landuse/land cover maps have been classified as

Agriculture, Dense forest, Settlement, Scrub Forest, Industry, Tea plantation etc.., as shown in Fig. 6.

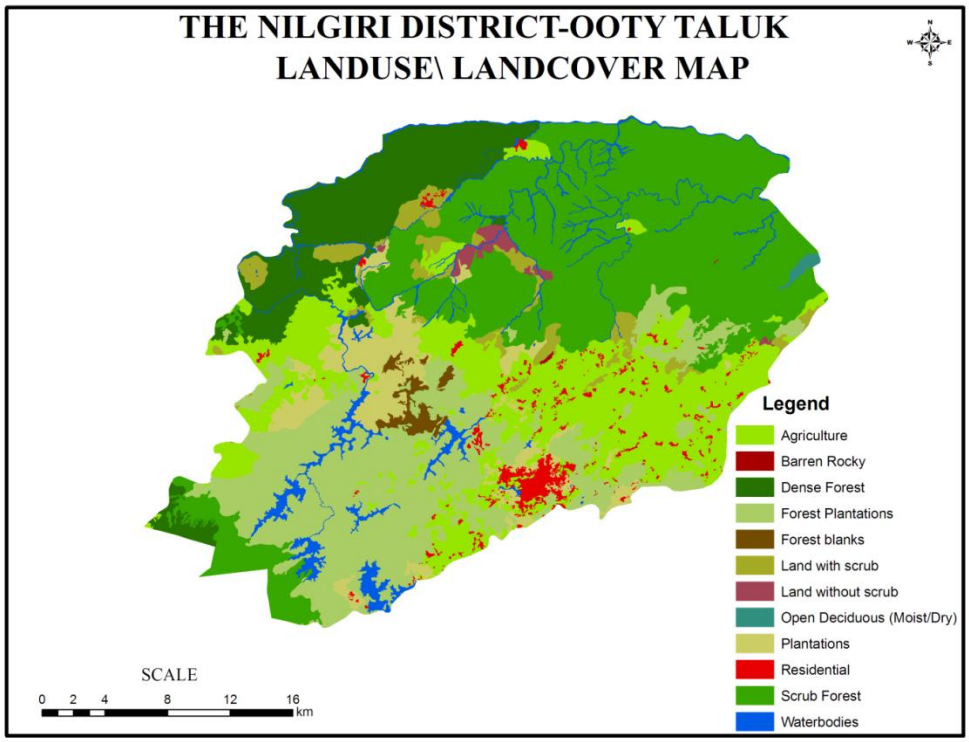

Figure 6: Land Use/ Land Cover Map

The economy of the Ooty is based on the agriculture and tourism. In this area scrub forest was covered in 282.59 sq km after that forest plantation and agriculture land was covered in 184.39 sq km and 175.54 sq km.Residential area in this area was occupied in 17.32 sq km. Forest blanks and land without scrub it was covered minimum in Ooty.

Soil

The soil is the mixture of organic remains, clay and rock particles that is normally black or dark brown. The plant grows on the top layer of the earth. It acts as mechanical and equilibrium behavior includes engineering, chemical and mineralogical properties of soil. Vital engineering property is shear strength and the stability of natural & constructed hill slopes are the fundamental property of the soil. It possesses loading, unloading and especially water content in which the value is not a unique. Generally soil measures described in the form of function such as surface, cohesion and internal angle of friction. Clay content is another noticeable property that the chemical and weathering product of soil given by the clay minerals.

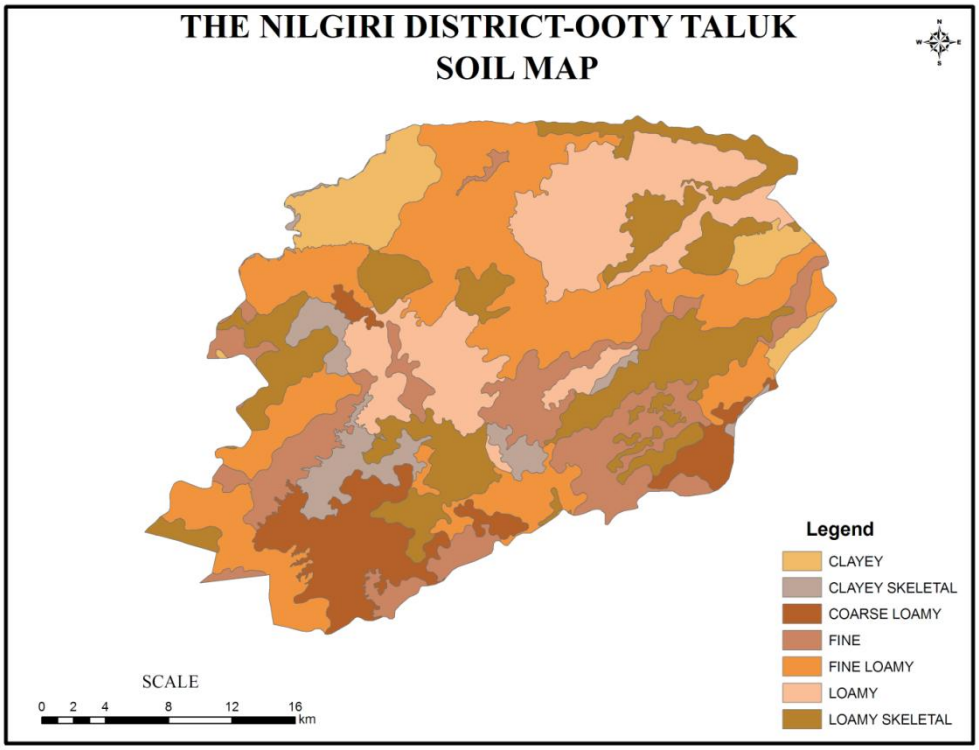

Figure 7: Soil Map

Here area is classified with six types namely Clayey, Clayey Skeletal, Coarse loamy, fine, fine loamy, loamy and loamy skeletal. The highest and lowest area is 260.92 and 40.16 sq km covered by Fine loamy and clayey skeletal soils. The next lower area is 55.03 sq km, which covered by clayey soil. The other soil area specifications are 78.24, 124.2, 147.08 and 174.02 sq km covered by coarse loamy, fine, loamy and loamy skeletal soils. The prepared soil map is shown in Fig. 7.

Decision Tree Classification Approach

To handle multiple attacks from intruders and eaves dropping, members authentication, integrity of data, multi-key exchange management protocol has to be adopted. The Key Management Protocol takes the responsibility of key generation [17] and distribution of distributed cluster [20] managed key protocol over multiple nodes.

Data mining [14] classification approach is used to predict the class label by using training data set. Classification approaches are categorized into Decision Tree, Back propagation Neural Network, Support Vector machine(SVM),Rule based Classification and Bayesian Classification. In the present scenario, landslide analysis study was done by using Neural Network but it is difficult to understand and tricky to predict. In this paper, Soft Decision Tree Classification approach is applied to analyze

landslide susceptibility [19] in the hill region. The performance of the proposed approach is measured with various parameters.

Decision Tree (DT) [15] approach is used to analyze the data in the form of tree. The Tree is constructed using the top-down and recursive splitting technique. A tree structure consists of a root node, internal nodes and leaf nodes. The root node contains all the input data. An internal node can have two or more branches and is associated with a decision function. A leaf node indicates the output of a given input vector. The objective of DT building is to find the set of decision rules that can be used to predict outcome from a set of input variables. DT has been applied successfully in many real-world situations for classification and prediction. The main advantage of DT is that DT models have the capability of modeling complex relationship between variables. They can incorporate both categorical and continuous variables without strict assumptions with respect to the distribution of the data. In addition, DTs are easy to construct and the resulting models can be easily interpreted. The main disadvantage of DTs is that they are susceptible to noisy data and that multiple output attributes are not allowed.

In general decision tree [18] classifiers have good accuracy. During the tree construction attribute selection measures are used to select the attribute that best partitions the tuples into distinct classes. Popular measures of attribute selections are information gain, gain ratio and gini index. The attribute with highest information gain is considered as splitting attribute.

$$Info\ (D) = \sum_{i=1}^{n} p_i \log_z p_i$$

$$Info\ (D) = \sum_{j=1}^{v} \frac{|D_j|}{|D|} X\ Info\ (D_j)$$

$$Gain\ (A) = Info(D) - Info_A(D)$$

The term acts as the weight of the j^{th} partition. $Info_A$ (D) is the expected information required to classify a tuple from D based on the partitioning by attribute A. the smaller the expected information required, the greater the purity of the partitions.

Gain (A) tells us how much would be gained by branching on A. It is the expected reduction in the information requirement caused by knowing the value of A. The attribute A with the highest information gain, (Gain (A)), is chosen as the splitting attribute at node N. This is equivalent to saying that we want to partition on the attribute A that would do the "best classification", so that the amount of information still required to finish classifying the tuples in minimal.

Experimental and Result Analysis

Today environment is more prone to various disasters. This paper focuses landslide disaster analysis using computational techniques. The needed toposheets and required maps are collected from the geological survey of India. Many number of factors

causes landslide in the hill region, but six factors are very important for landslide study such as rainfall, slope, geology, geomorphology, landuse/landcover and soil. The above said factors thematic layers are prepared from the LISS III+ PAN images using ArcGIS Tool. The sample landslide data is shown in table 1.

Table 1: Sample Landslide Data

Land use	Soil	Geomorphology	Geology	Rainfall	Slope	Zone
Agriculture	LOAMY SKELETAL	Ridge type Structural Hills (Large)	Ultrabasic rocks	135.63-150.82	11.76-19.79	Low
Agriculture	LOAMY SKELETAL	Ridge type Structural Hills (Large)	Gneiss	135.63-150.82	8.02-11.76	Low
Agriculture	LOAMY SKELETAL	Ridge type Structural Hills (Large)	Ultrabasic rocks	135.63-150.82	8.02-11.76	Very Low
Scrub Forest	LOAMY SKELETAL	Ridge type Structural Hills (Large)	Gneiss	135.63-150.82	0-8.02	Very Low
Scrub Forest	LOAMY SKELETAL	Ridge type Structural Hills (Large)	Ultrabasic rocks	135.63-150.82	0-8.02	Very Low
Scrub Forest	LOAMY SKELETAL	Ridge type Structural Hills (Large)	Gneiss	135.63-150.82	11.76-19.79	Low
Scrub Forest	LOAMY SKELETAL	Ridge type Structural Hills (Large)	Ultrabasic rocks	135.63-150.82	11.76-19.79	Very Low

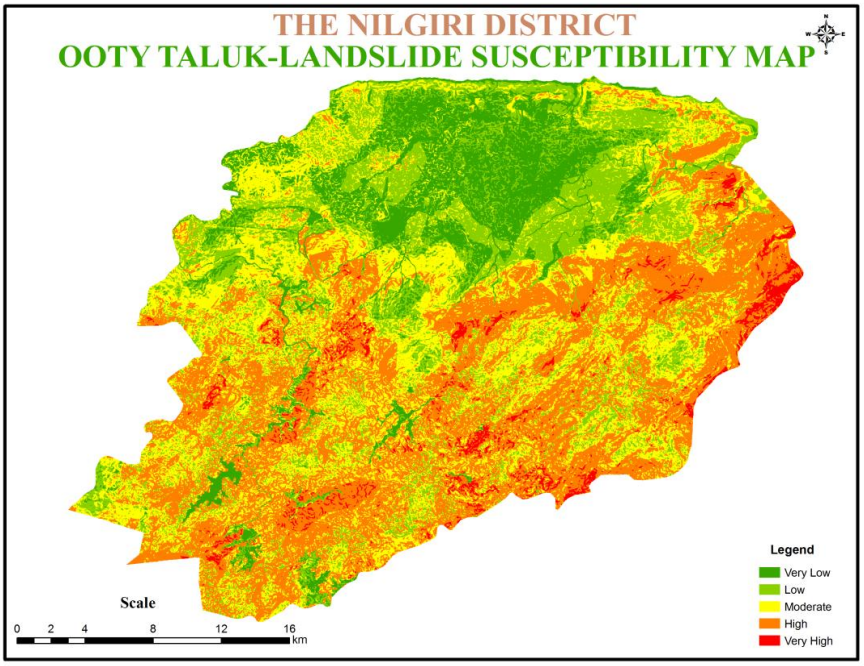

Figure 8: Landslide Susceptibility Map Using Decision Tree Classification Approach

Data mining classification approach Decision Tree is applied on the features which are extracted from the layers. The modeling of the Decision Tree has been developed in rapid miner data mining tool. The landslide risk is analyzed by using above said

approach and the result is shown in Fig. 8. The decision tree approach result is validated with field data. The accuracy of the proposed method is good than existing traditional approaches.

Conclusion

Disaster management and monitoring is important research domain. Predicting and analyzing disaster is complex task. In this paper, landslide risk is analyzed using GIS and data mining classification approach. The six important landslide induced factors such as rainfall, land use/land cover, Geomorphology, slope, geology and soil are considered for the analysis. Ooty, Nilgiri district of Tamilnadu is considered as study area. Remote sensing images and field data are used to prepare various thematic maps. The landslide risk model is built using decision tree classification approach. The performance of decision tree approach is compared with existing traditional GIS approaches. Decision tree approach is more suitable and accurate than traditional approaches. In future work, more spatial factor will be considered for landslide prediction. The decision tree approach will be improved by introducing weight to determine the splitting attribute for landslide risk study.

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