Data Mining Approach For Landslide Susceptibility Mapping For Kundhapallam Watershed, Nilgiris, TamilNadu

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Abstract:

There is a growing awareness regarding the need for greater harmony between the development of anthropological activity and the evolution of the natural environment. For this purpose the researchers have shown increasing interest in the natural hazard assessment and mitigation. A landslide represents one of the most morpho-dynamic processes that affect steep lands, urban and industrial development. The aim of this study is to apply fuzzy logic to landslide susceptibility mapping in Kundhapallam Watershed, Nilgiris, Tamilnadu using a geographic information system. The fuzzy set theory has then been implemented to determine the membership values for each category of the thematic layer. Weights of each thematic layer are calculated from the fuzzy numbers generated by the membership function and finally the instability score is calculated using the weights. It is inferred that the Data Mining Approach performs quite satisfactorily and is enabled to cope with large uncertainties, varying expert's judgments and societal issues raised by hazard evaluation.

Keywords - Landslide susceptibility, Membership Function, Fuzzy Logic

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Introduction

There is a growing awareness regarding the need for greater harmony between the development of anthropological activity and the evolution of the natural environment. For this purpose the researchers have shown increasing interest in the natural hazard assessment and mitigation. Scientists define Landslide hazard either as the probability that a reasonably stable condition may change abruptly or as the probability of occurrence of a potentially damaging phenomenon within a given area and in a given period of time. Since this hazard involves not only loss of human life but also causes economical burden to the society it becomes essential to develop a suitable model to evaluate the susceptibility of landslides. There are a number of different approaches for Landslide Susceptibility, hazard zone mapping, including direct and indirect heuristic approaches and deterministic, probabilistic and Statistical approaches. This purpose of the study is to assess the landslide susceptibility of the Kundhapallam watershed using fuzzy theory.

Study area:

Kundhapallam watershed lies in the Nilgiris district of TamilNadu which is a hilly district located on the fragile environment of Western Ghats with an elevation ranging from 300 m in the Mayor Gorge to 2634 m above MSL at Doddabetta peak. Kundhapallam watershed has a geographical area of 12 sq.km and is bounded by 76° 35’ 30” and 76° 37’ 30” East longitude and 11°14’15”and 11°16’15”North latitude.

It is a free basin consisting of an area of about 1753 ha. It also consists of forest plantation (4.04%), Shola lands (6.35%), Uplands i.e., Land with or without scrubs (9.38%), water bodies (3.03%), Grass land (1.59%), Mixed land cover (5.34%) and built up area (2.16%). The climatic features of the Kundhapallam watershed are, wind velocity – 5.4 Km/hr, relative humidity – 77%, annual rainfall – 1300 -2000 mm, maximum temperature – 24.3° C (summer season), minimum temperature 6.0° C (winter season).

Methodology:

Landslide hazard zonation can be generally classified into two basic groups: Direct method and Indirect method. In the direct method of landslide susceptibility hazard mapping the degree of hazard is determined by the mapping geomorphologist, based on his experience and knowledge of the terrain conditions. In indirect hazard mapping either statistical models or deterministic models are used to predict the susceptibility of the area to landslides. The objective of this paper is to focus Soft Computing approaches such as knowledge-based system fuzzy set theory, neural networks and genetic algorithms. This method produces satisfactory results even when both heterogeneity and uncertainty exist in the data.

Fuzzy logic is a special many-valued logic addressing the vagueness phenomenon and developing tools for its modeling via truth degrees taken from an ordered scale. It is expected to preserve as many properties of classical logic as possible. Fuzzy logic is a superset of conventional logic that has been extended to handle the concept of partial truth-values between “completely true” and “completely false”. In fuzzy logic the degree to which a member belongs to a set is expressed by the membership function MF. The membership function can take any value between 0 and 1. The logic behind fuzzy is to describe the vagueness of entities in the real world, where belonging to a set is really a matter of degree. In this study initially the major factors are given weight using expert knowledge.

A. Thematic mapping and weighting using fuzzy logic:

As for the preparation of thematic maps the data are collected from various sources like Survey of India Toposheet (SOI) No.58A/11 of scale 1:50,000 of 1972, IRS-1C LISS III +PAN merged satellite data , field data and various other sources were used.Base map was prepared from the Survey of India Toposheet. It gives the boundary of the study area. There are 12 villages and they fall on the eastern region of the watershed. The river Kunda is flowing from east to west.

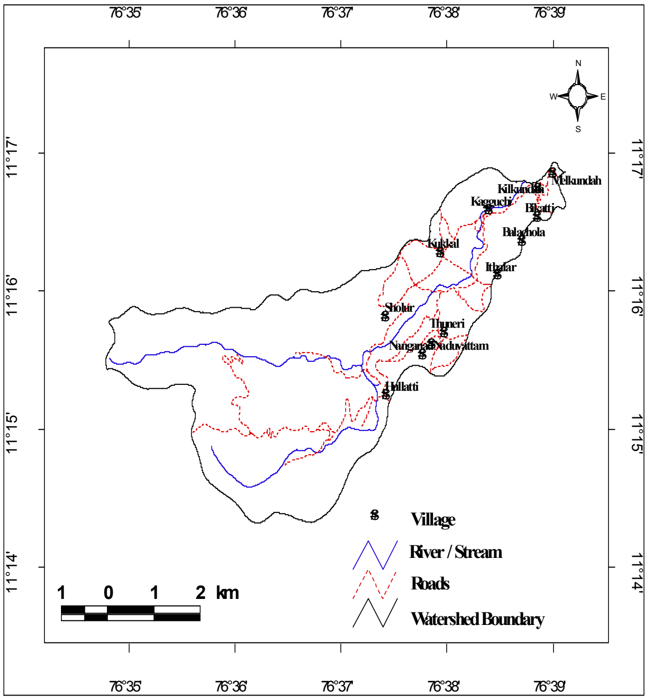

Fig: 1 – Base map

The factors considered for analysis are the following: Slope, Lineament, Geology, Soil type, Drainage, Landuse, Run off. The following table 1 gives the weight of the factors used for analysis of landslide susceptibility. Slope is an important factor in the analysis of landslide. As the slope increases the probability of the occurrence of landslide increases, because, as the slope angle increases the shear stress of the soil increases. The slope class was categorised as 0°-13° as moderate slope, 14°-15° as steep slope, 16°-17° as very steep slope and 18°-19° as high slope. The Land use map shows the different types of land cover pattern present in the study area. The watershed area is characterised by the dense forest, degraded forest, agricultural land, forest plantation, grass land, horticultural plantation, land with or without scrub, open forest and villages. The horticulture plantation is found as the major landuse in the watershed.

The watershed is entirely covered by charnockite. The drainage density for the study area was categorized into four zones (very high, high, medium and low). Majority of the watershed falls under high density category. The runoff is high for the entire watershed, with very high runoff in agricultural land which leads to severe erosion. Absence of low runoff is noted in the study area. The runoff lineament density is categorised into four classes as very high, high, moderate and low. After the preparation of the thematic maps, Weights are assigned to the individual factors using the expert knowledge. The following table gives the weights of the factors.

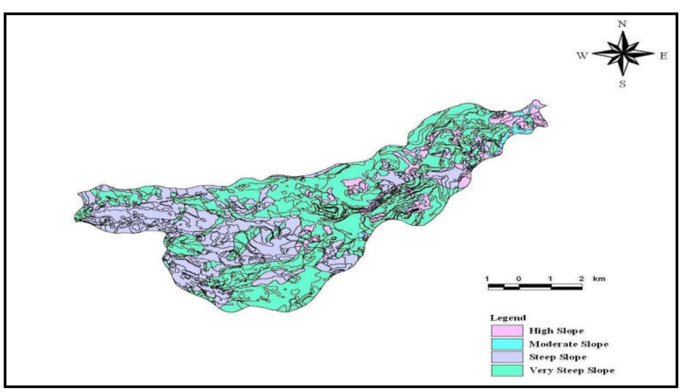

Fig: 2 – Slope map

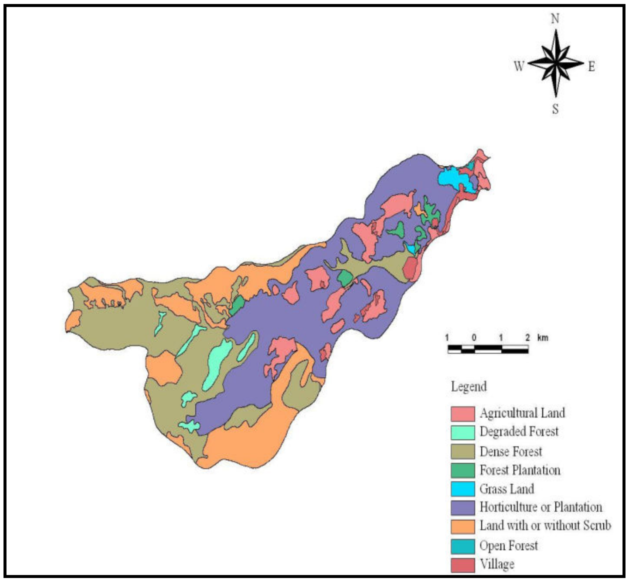

Fig: 3 – Land use map

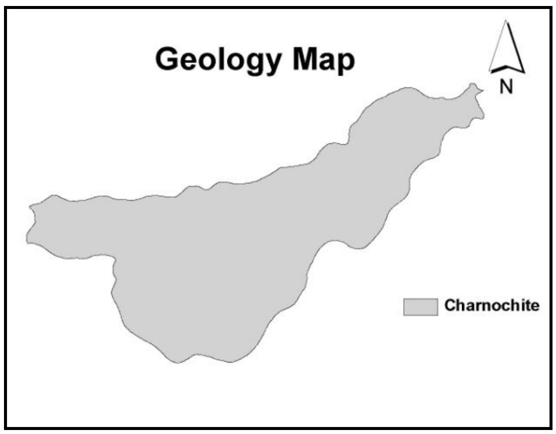

Fig: 4 – Geology map

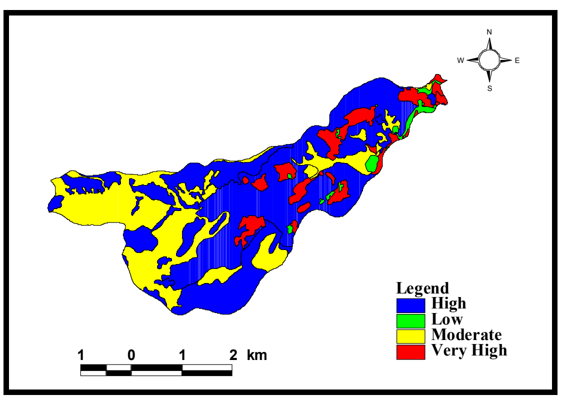

Fig: 5 – Drainage map

Table 1
Weightage for thematic maps

S.No	Factors	Weights(W)
1	Slope	0.2
2	Geology	0.15
3	Landuse	0.25
4	Drainage	0.2
5	Run off	0.2

The linquistic variables used for weighting the sub classes of the main factors are converted into fuzzy numbers. The conversion of the linquistic variables into fuzzy numbers is done by using the trapezoidal membership function. The trapezoidal membership function is shown below. a,b,c and d are the real numbers. The fuzzy number is nothing but (a,b,c,d).

$$\mu_{\tilde{A}}(x)=\begin{cases}\frac{x-a}{b-a} & a<x<b\\ 1 & b\le x\le c\\ \frac{x-d}{c-d} & c<x<d\\ 0 & x\le a \text{ or } x\ge d\end{cases} \quad (1)$$

Table 2
Linquistic variables and Fuzzy numbers

Linquistic Variables	Fuzzy Numbers
Very Low	(0,0,0,3)
Low	(0,3,3,5)
Low Medium	(3,5,5,7)
High	(5,7,7,10)
Very High	(7,10,10,10)

The fuzzy numbers are used by a group of experts to weight the subclasses of the factors. Then the aggregate fuzzy weight is calculated for each subclass of the factor. The aggregate fuzzy weight W is defined as:
W(s) = (∑t=1 to n ast/ n, ∑ t=1 to n bst /n , ∑ t=1 to n cst /n , ∑ t=1 to n dst /n) (2)

Where t = Number of experts, s = subclass, W (s) = fuzzy aggragate weight of subclass. After the aggregate fuzzy weights are calculated the weight are defuzzified using the formula given below. The defuzzified weights is denoted as D(W(s)).
D(W(s)) = (as + bs + cs + ds) / 4 (3)

The defuzzified weights are then normalized using the formula given below. The normalized weight is denoted as NWs.
NWs = D(W(s)) / ∑s=1 to n D(W(s)) (4)

Where n = number of subclasses in the factor. The comprehensive weight is calculated by multiplying the weight of the main factor and the weight of the subclasses. The following table gives the normalized weight of each subclass and the comprehensive weight.

B. Calculation of Susceptibility Score:

The factor maps are created as raster map and the raster maps are overlayed in an ArcGIS environment. The total study area is divided into grids of 1000m X 1000m cells. The susceptibility score is calculated after the rastered factor layers are attached with weights and grid layers. For each grid cells, j, the susceptibility score, Sj, is equal to the sum of the comprehensive weights of each subclass corresponding to the factors Slope, Geology, Landuse, Drainage and Run off.

Sj = ∑ k=1 to n wkj x NWsj (5)

Where, K = Major Factors

Results and Discussion:

Based on the suitability score, the landslide susceptibility levels are classified into four classes. The areas which are susceptible for landslide are calculated as given in the Table 4. The eastern region of the watershed is under high susceptible zone for landslide whereas the villages in the eastern side are under moderate susceptible zone for landslide. The dense forest which falls under the western region of the watershed is found to be having moderate susceptibility. The village Sholur is observed as low susceptible for landslide than other villages.

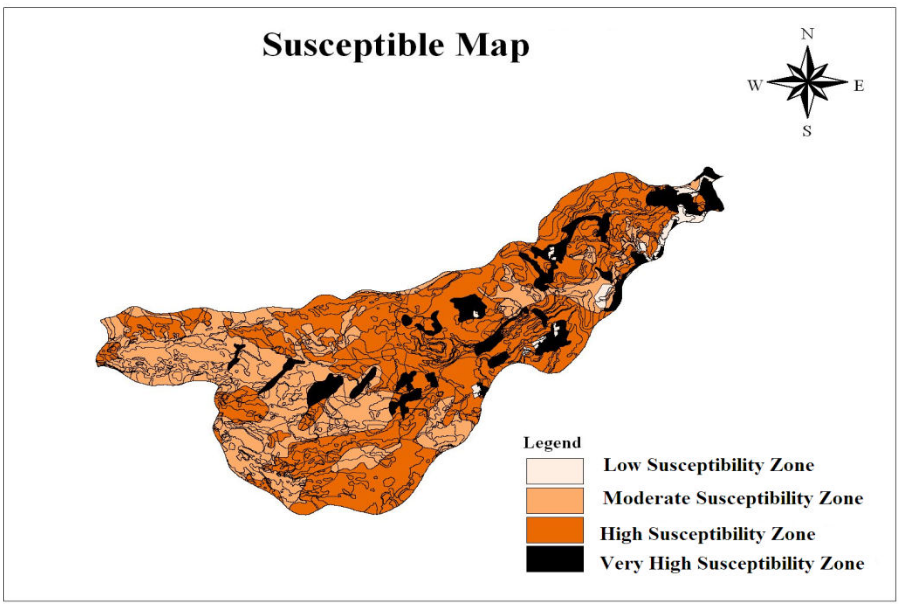

Fig:6 – Susceptible map

Table 3
Landslide Hazard Evaluation Factor System And Weights

S.No	Factors	Sub classes	Normalized Weights	Comprehensive Weight
1	Slope	moderate slope (0°-13°)	0.076	0.015
		steep slope(14°-15°)	0.155	0.031
		very steep slope(16°-17°)	0.317	0.063
		high slope(18°-19°)	0.451	0.090
2	Geology	charnockite	1	0.150
3	Landuse	Dense forest	0.037	0.009
		Degraded forest	0.069	0.017
		Agricultural land	0.069	0.017
		Forest plantation	0.069	0.017
		Grass land	0.141	0.035
		Horticultural plantation	0.201	0.050
		Land with or without scrub	0.069	0.017
		Open forest	0.141	0.035
		Villages	0.201	0.050
4	Drainage	low(< 0.004 Km/Km^2)	0.076	0.015
		medium(0.004 – 0.006 Km/Km^2)	0.155	0.031
		high(0.006 – 0.008 Km/Km^2)	0.317	0.063
		very high(> 0.008 Km/Km^2)	0.451	0.090
5	Run off	low(<0-250mm)	0.076	0.015
		medium(250-500mm)	0.155	0.031
		high(500-750mm)	0.317	0.063
		very high(750-1600mm)	0.451	0.090

- The very steep slope is found in eastern region, steep slope is observed in the western region, villages have moderate slope and high slope occurs in agricultural and grass land.
- The watershed is entirely covered by charnockite.
- Majority of the watershed falls under high drainage density category.
- The runoff is high for the entire watershed, with very high runoff in agricultural land which leads to severe erosion. Absence of low runoff is noted in the study area.

Table 4
Landslide susceptible area

Different categories	Area (%)
Zone of Very High and high susceptibility	92
Zone of Moderate Susceptibility	12
Zone of Low Susceptibility	2

Conclusion:

As a conclusion, knowledge derived models were useful for landslide susceptibility mapping considering the prediction accuracy. The integration of different factors in GIS environment using the fuzzy logic procedure proves to be an effective approach because of the fact that it can narrow down the potential susceptibility zones in a meaningful way for planning future developmental activities. In spite of a number of weaknesses in the database, the fuzzy logic modelling approach, combined with the remote sensing and GIS data, yields a reasonable accuracy for the landslide prediction.

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