Evaluation of quantitative Landslide Susceptibility Zonation (LSZ) method for Nilgiri District

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Abstract: Landslide susceptibility zonation (LSZ) in Nilgiri district is the catastrophic natural disasters occurring annually. Inventory map from past occurrence were created and used for LSZ quantitative methods Spatial Multi criteria Evaluation (SMCE) and Artificial Neural Network (ANN). Predictors causing landslides, identified namely rainfall,soil, lineament, geomorphology, geology, drainage, road, railway, land use/land cover, slope and aspect were used as parameters grouped into four factors namely hydrological, anthropogenic, geology and geomorphological in the form of thematic maps. Two statistical approaches namely SMCE and ANN were used to calculate the weights and ratings. GIS was used to prepare landslide hazard zonation map after overlaying the several layers with weights. The hazard zonation map was classified five zones namely very low, low, moderate, high and very high. Landslide hazard maps were validated, using field check and Receiver Operating curve . The LSZ maps of both the methods were compared with the real land with respect to blocks, it showed that ANN method best and also 92% accuracy and forfeited SMCE method.

Key words: LandslideSusceptibility Zonation– Spatial Multi Criteria Evaluation method–Artificial Neural Network – Receiver Operating curve – Field check - Nilgiris district

1. Introduction:

The outward and downward mass movements of soil and rock sliding along slopes causes debris flows termed as landslides (Varnes 1984; Cruden 1991). The landslide is considered as a universal hazardous environmental degradation tagged to mountainous terrains of every country in low to high magnitude ranges (Gao&Maro 2010). Landslides are annually occurring incident that cause damages to slopes and amenities in Nilgiris district.. They have occurred at toes, heel of steep slopes, along roads and railway lines, barren lands, during unprecedented rainfall(Thennavan et.al 2020). Government agencies namely Survey of India, Southern railways, Department of Horticulture, Department of soil and water conservation separately with regard to their necessity.

Impact of urbanisation on landuse was studied Aleotti and Chowdhury, 1999. Therefore, developing a good method for recognizing potential landslide area is important. It is known that the temporal and spatial distributions of landslides are complex and non-linear.Basics of GIS was explained by Elangovan (2006).

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2. Study area:

The study area chosen for this study is a hilly terrain region situated in the northern part of Tamil Nadu state in the Western Ghats ranges known as is the Nilgiri district. for administrative purposes, the district has been divided into four blocks confined geographically by 76o 14'-77o 02' East Longitude and 11o 10' - 11o 42' North Latitude. It covers an area of 2457.50 Km2, of which more than 5% is forest (Vasanthakumar et al 2008; Soil Atlas 1998). The district receives rainfall from both Southwest and Northeast monsoons with an average annual rainfall of 1857.00mm. It is widely connected with the other states through roadways (major road NH67) and railways (from Mettupalayam to Udhagamandalam).

As a summary of landslide occurrence at Nilgiri district from various sources - Seshagiri et al 1982, The geotechnical cell funded by Hill Area Development Programme (HADP) and southern railways, Coonoor. Heavy rainfall downpour for a continuous period causing increase in pore water pressure in soils on slopes prompts landslides. improper drainage, poor maintenance of natural drains,cutting of slopes and manmade activities have profoundly caused landslides in Nilgiri district. In this research four factors namely hydrological, Geomorphological, geological and anthropogenic are considered mapping eleven parameters namely geology, geomorphology, soil, land use and land cover, distance to lineament, distance to road, distance to railway, distance to drainage, rainfall, slope and slope aspect are considered for preparing LSZ map.

3. Landslide Susceptibility Zonation Mapping

The word susceptibility stands for 'state or fact of being likely or liable to be influenced or harmed by a particular thing'. Delineating any area into susceptible zones with regard to its effect of disaster is known as landslide susceptibility zonation (LSZ). Kanungo et al. (2009) defines LSZ as the division of land surface into near-homogeneous zones based on ranking these according to degrees of actual or potential hazard due to landslides. LSZ can be studied in two forms, namely quantitative and qualitative. Many methods are available for predicting landslide susceptibility, the accuracy depends on the parameters considered and the methods of analysing the data.Landslide studies do not get completed without framing landslide inventories since it is the key requirement (van Westen et al 2006). In this paper landslide inventory map based Spatial Multi Criteria Evaluation (SMCE) and Artificial Neural Network(ANN) methods are compared to choose the best method for prediction of LSZ for the Nilgiri district.

3.1 Inventory Map

In order to centralise the past landslide occurrence data and get accurate picture of landslide locations and reasons for the slide an inventory map is necessary. A total of 1556 landslide locations were recorded, of which more than 800 locations are repetitively susceptible to landslides (Jaiswal et al 2011). Reliability of data depends on its quality and abundance of data available (Glade, 2001).The Vagueness in historical data leads to incomplete description of landslide. Thus, persistence of morphological signature is necessary to maintain accuracy of location and are checked in the field as shown in Figure 1, but the accuracy of data may not be hundred percent Jaiswal et al. (2011).

The landslide inventory form is designed using Csat programming language to storedatabase table using SQL including data integrity. Spatial coordinates of the locations were used as an interplay between database table and GIS software. The landslide inventory map has been prepared using 406 identified locations out of 520 and the remaining is used for validation.

A. Old landslide debris renovated B.Old scar found at Mallikorai after 2008 landslide C. Reactivated landslide person

Fig 1. Identification of old scars of landslides in field

3.2 Spatial Multi Criteria Evaluation (SMCE)

SMCE is a way of producing policy-relevant information semi-statistical approach stemming from spatial decision problems by decision makers Sharifi et al. (2004) and is approached as map of evaluation tables. All eleven parameters are grouped into four sub criteria and each sub criteria is mapped with the relevant parameters asmain indicators.as shown in Figure 2 .The four factor sub criteria are hydrological, anthropogenic, geology and geomorphology. Based on the actual causative factors quoted in various reportsthe main indicators are distributed among the subcriteria depending upon their interrelationships. The weights of the thesemain indicators are found using bivariate analysis namely Landslide Frequency Ratio (LFR) and that of subcriteria using statistically method namely Analytical Hierarchy Process (AHP) Saaty (1990) Pourghasemi et al. (2014) and evaluation is done by ranking of sub criteria and main indicators , and finally transforming into one table of maps Sharifi&Rodrguez (2002)Shanthi et.al (2012).

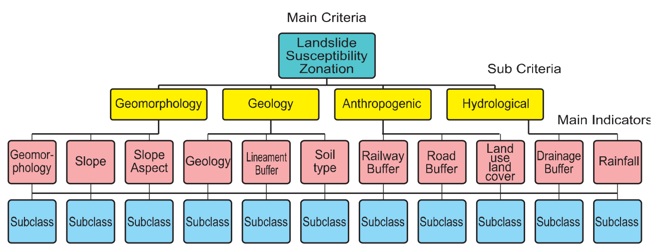


Fig 2: Hierarchy of developing the problem using SMCE

3.3 Artificial Neural Network (ANN)

Artificial neural network is a "computational mechanism able to acquire, represent, and compute a mapping from multivariate space of information to another, given a set of data representing that mapping" (Padhan 2010). Landslide associated database constructed from the thematic maps of the 11parameters considered for landslide study is taken as input data. A model is generated using back propagation-learning algorithm and S-shaped sigmoid function as the transfer function and weights for the parameters are derived as outputs (Pradhan et.al 2010). Later,using these weights of the parameter LSZ map is generated.

Landslide analysis using ANN performed in two stages as shown in the figure 3, namely, pre-processing and processing.

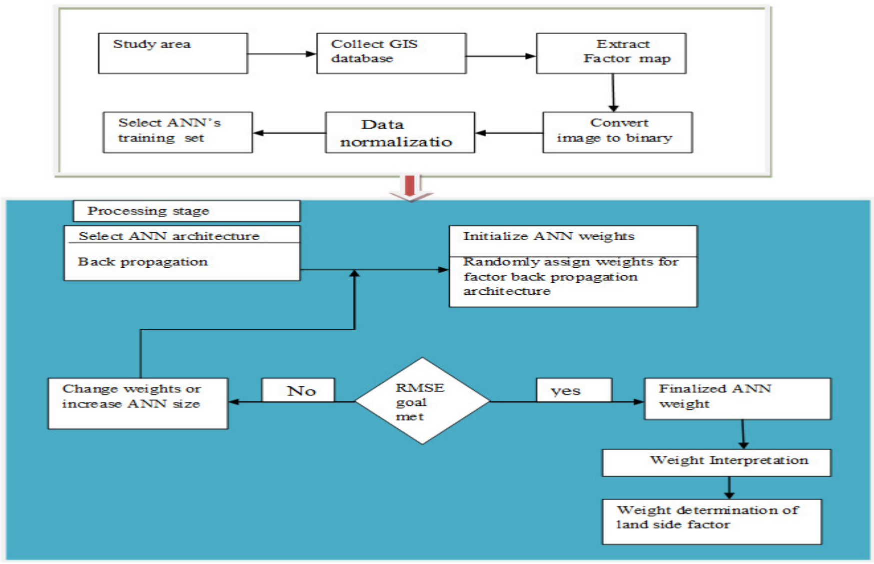


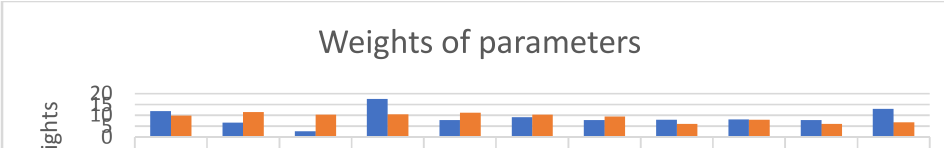
Fig 3 Schematic diagram of the process of calculating weight of the parameters using ANN

ANN method developed by Hines (1997) using MATLAB was used after changing few parameters for landslide mapping Here back propagation neural network method was used. The database created using GIS was used for input.

The study area is divided into 10mx10 m grid. This grid was converted into ASCII format to use it further in ANN program.t is found that 4,85,01,300 cells available in the study area .In this 3%of the areas have experienced landslides.

3.4 Preparation of LSZ Map

The weights of the parameters determined using SMCE and ANN methods as shown in Figure 4. GIS was used to prepare LSZ map using weighted overlay process. Adiscrete grid theme was created by combining multiple input parameters in the form of thematic maps.



	Geomorphology	Geology	soil	land use land cover	Lineament buffer	railway buffer	road buffer	Drainage buffer	rainfall	Slope	Slope Aspect
SMCE	11.91	6.699	2.664	17.43	7.780	9.104	7.756	7.918	8.021	7.837	12.87
ANN	9.875	11.55	10.30	10.35	11.23	10.23	9.464	5.973	7.942	5.942	6.808

Fig4 Weights of the parameters using SMCE and ANN

The LSZ map of the ANN model shown in Figure 5&6.Cleary pictures that all the five categories of classification of LSZ are widely spread over the entire Nilgiri district. This is due to the advantage of analysis using Matlab and also analyzing in terms of pixel rather than area as done in the other three methods.

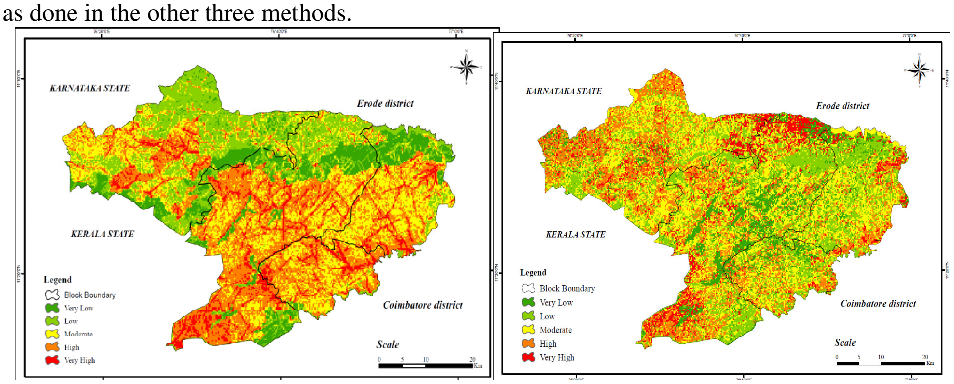


Fig 5LSZ map of SMCE and ANN

4. Validation of LSZ Maps

It is necessary to evaluate the uncertainties, robustness and reliability of the model(Corominas et al. 2013). The most commonly used method is Receiver Operating Curve (ROC) Zweig & Campbell (1993). The area under the ROC curve (AUC) is used to assess the overall quality of a model Hanley (1982). Performance of the model will be good if more area is considered..Out of 520 landslide locations identified 406 is used for LSZ analysis and the remaining 114 locations are used for validating. The figure 6 shows all the two models using ROC and field verification.

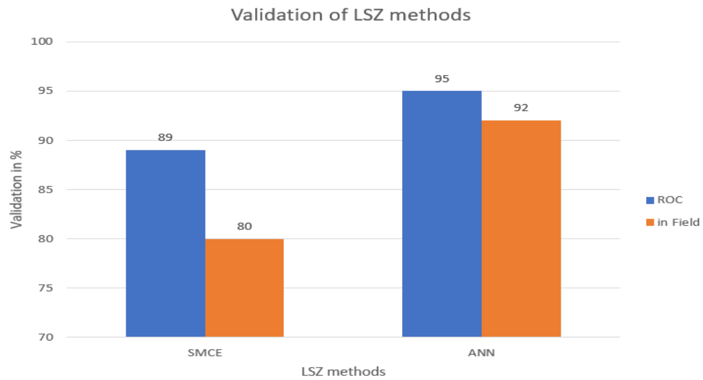


Figure 6 Validation of SMCE and ANN methods

5. Conclusion

Out of two LSZ methods, ANN showed closer range between the predicted and field observed values. It is further fortified by Receiver Operating Curve (ROC) validation that area under the curve (AUC) value is 0.95, indicating 95% reliability while SMCE is only 89%. Since ANN has proved its edge overSMCE as given in Table 1.

LSZ methods/ Category	Very Low	Low	Moderate	High	Very High
Coonor block					
SMCE	2	5	33	32	28
ANN	12	22	30	20	16
Udhagamandalam block					
SMCE	10	25	20	25	20
ANN	12	25	27	20	16
Kothagiri block					
SMCE	15	10	40	25	10
ANN	6	24	30	28	12
Gudalur block					
SMCE	12	35	25	15	13
ANN	5	15	35	25	20

Table 1 Comparison of LSZ methods for various blocks at Nilgiris district

Hence both the validation through ROC and field showed ANN model to be best suited for LSZ mapping.

References

[1]. Varnes, DJ 1984, 'Landslide hazard zonation preview of principals and practice', International association of engineering geologists, commission on landslides and other mass movements on slopes, Natural hazards, vol. 3, pp. 176-176.

[2]. Cruden, DM 1991, 'A simple definition of a landslide', Bulletin of Engineering Geology and the Environment, vol. 43, no. 1, pp. 27-29.

[3]. Gao, J &Maro, J 2010, 'Topographic controls on evolution of shallow landslides in pastoral Wairarapa, New Zealand, 1979-2003', Geomorphology, vol. 114, no. 3, pp. 373-381.

[4]. Aleotti, P & Chowdhury, R 1999, 'Landslide hazard assessment: summary review and new perspectives', Bulletin of Engineering Geology and the Environment, vol. 58, no. 1, pp. 21-44.

[5]. 'Soil Atlas 1998, Nilgiri district, Soil Survey and Land use organization, Department of Agriculture Tamil Nadu'.

[6]. Vasantha Kumar, S &Bhagavanulu, DVS 2008, 'Effect of deforestation on landslides in Nilgiris district - A case study', Journal of the Indian Society of Remote Sensing, vol. 36, no. 1, pp. 105-108.

[7]. Seshagiri, D, Badrinarayanan, S, Upendran, R, Lakshmikantham, C & Srinivasan, V 1982, 'The Nilgirislandsldies', GSI Miscilaneous Publication No 57.

[8]. Kanungo, D, Arora, M, Sarkar, S & Gupta, R 2009, 'Landslide Susceptibility Zonation (LSZ) Mapping–A Review', Journal of South Asia Disaster Studies, vol. 2, no. 1, pp. 81-105.

[9]. van Westen, CJ, Asch, TWJ &Soeters, R 2006, 'Landslide hazard and risk zonation—why is it still so difficult?', Bulletin of Engineering Geology and the Environment, vol. 65, no. 2, pp. 167-184.

[10]. Jaiswal, P, Van Westen, CJ &Jetten, V 2011, 'Quantitative estimation of landslide risk from rapid debris slides on natural slopes in the Nilgiri hills, India', Natural Hazards and Earth System Science, vol. 11, no. 6, pp. 1723-1743.

[11]. Glade .T.,Albini. P., Frances.F.,(eds) 2001,'The use of historical data in natural hazard assessments-Advances of Technological and Natural Hazard Research, Kluwer, Norwell,pp.153-169.

[12]. Saaty, TL 1990, 'How to Make a Decision: The Analytic Hierarchy Process', Interfaces, vol. 24, no. 6, pp. 19-43.

[13]. Sharifi, A, Herwijnen, M &Toorn, W 2004, 'Spatial Decision Support Systems', Lecture Notes. The Netherlands: ITC, International Institute for Geo- Information Science and Earth Observation.

[14]. Pourghasemi, H, Moradi, H, Aghda, SF, Gokceoglu, C & Pradhan, B 2014, 'GIS-based landslide susceptibility mapping with probabilistic likelihood ratio and spatial multi-criteria evaluation models (North of Tehran, Iran)', Arabian Journal of Geosciences, vol. 7, no. 5, pp. 1857-1878.

[15]. Sharifi, MA & Rodriguez, E 2002, 'Design and development of a planning support system for policy formulation in water resources rehabilitation: the case of Alcazar De San Juan District in Aquifer 23, La Mancha, Spain', Journal of Hydroinformatics, vol. 4, no. 3, pp. 157-175.

[16]. Pradhan, B 2010, 'Remote sensing and GIS-based landslide hazard analysis and cross-validation using multivariate logistic regression model on three test areas in Malaysia', Advances in Space Research, vol. 45, no. 10, pp. 1244-1256.

[17]. Hines, ML & Carnevale, NT 1997, 'The NEURON Simulation Environment', Neural Computation, vol. 9, no. 6, pp. 1179-1209.

[18]. Hanley, JA 1982, 'The meaning and use of the area under a receiver operating characteristic (ROC) curve', Radiology, vol. 143, pp. 29-36.

[19]. D.S. Vijayan, D. Parthiban," Effect of Solid waste based stabilizing material for strengthening of Expansive soil- A review," Environmental Technology & Innovation, Volume 20, 2020, 101108, ISSN 2352-1864, https://doi.org/10.1016/j.eti.2020.101108

[20]. Elangovan. K, (2006). " GIS Fundamentals, Applications and Implementations ", New India Publishing ,New Delhi

[21]. Zweig, M & Campbell, G 1993, 'Receiver- operating Characteristic (ROC) plots: A fundamental evaluation tool in Clinical Medicine', Clin. Chem, vol. 38, no. 5, pp. 561-577.

[22]. Corominas, J, van Westen, C, Frattini, P, Cascini, L, Malet, JP, Fotopoulou, S, Catani, F, Van Den Eeckhaut, M, Mavrouli, O, Agliardi, F, Pitilakis, K, Winter, MG, Pastor, M, Ferlisi, S, Tofani, V, Hervás, J & Smith, JT 2014, 'Recommendations for the quantitative analysis of landslide risk', Bulletin of Engineering Geology and the Environment, vol. 73, no. 2, pp. 209-263.

[23]. Edison Thennavan, GanapathyPattukandanGanapathy, 2020," Evaluation of landslide hazard and its impacts on hilly environment of the Nilgirid District – a geospatial approach", Geoenvironmental disasters, 7:3 https://doi.org/10.1186/s40677-019-0139-3pp: 1 to 14.

[24]. M. Tholkapiyan, A.Mohan, Vijayan.D.S , "A survey of recent studieson chlorophyll variation in Indian coastal waters", IOP Conf. Series: Materials Science and Engineering 993 (2020) 012041, doi:10.1088/1757-899X/993/1/012041.

[25]. Shanthi S andElangovan K,2017," Comparison of Landslide Susceptibility Using AHP SMCE and GIS for Nilgiris District, India Indian", Journal of Geo Marine Sciences,Vol 46(II) PP 802-814.