IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 3, Issue 1 Ver. I (Jan - Feb. 2015), PP 16-20
www.iosrjournals.org

A Survey on Landslide Susceptibility Mapping Using Soft Computing Techniques

Sonam Lhamu Bhutia[1], Prof. (Dr). Ratika Pradhan[2], Prof.(Dr) M.K Ghose[3]
[1](, Dept. of Information Technology, Sikkim Manipal University, India)
[2](Dept. of Computer Applications, Sikkim Manipal University, India)
[3](Dept. of Computer Sciences, Sikkim Manipal University, India)

Abstract: *Landslide is a common phenomenon especially in tectonically fragile and sensitive mountainous terrain which causes damage to both human lives and environment. The complex geological setting of the areas in the mountainous region makes the land highly susceptible to landslides. Hence, landslide susceptibility mapping is an important step towards landslide hazard and risk management. The accurate prediction of the occurrence of the landslide is difficult and in the recent years various models for landslide susceptibility mapping has been presented. GIS is a key factor for the modeling of landslide susceptibility maps. This paper presents the review of ongoing research on various landslide susceptibility mapping techniques in the recent years.*

Keywords: *Artificial Neural Network , Fuzzy Logic, GIS, Landslide, Susceptibility Mapping, Support Vector Machine*

I. Introduction

Landslides are among the great destructive factors which cause lots of fatalities and financial losses all over the world every year [4]. It has been estimated that, on an average, the damage caused by landslides in the Himalayas costs more than US$ one billion, besides causing about 200 deaths every year, which amounts to 30% of such losses occurring world-wide [5]. Hence, it is important to predict landslide susceptibility of landslide prone areas and thus the study of landslide susceptibility mapping has become one of the major areas of research.

The objective of landslide susceptibility map is to predict the areas where the slope failure is most likely to occur. According to Brabb. E.E landslide susceptibility is defined as the likelihood of a landslide occurring in an area on the basis of local terrain conditions. It is the degree to which a terrain can be affected by slope movements, i.e., an estimate of "where landslides are likely to occur" [7].There are various factors on which the accuracy of a landslide susceptibility map depends, they are (i) Modeling assumptions i.e. the likeliness of the landslide to occur in future under the same conditions that has led to landslide occurrences in the past. (ii) Landslide inventory map (iii) quality of relevant thematic and environmental data, including maps showing morphological, geological, and land use conditions prone to landslides [16]. (iv) Modeling approach adopted for the susceptibility assessment. However, the techniques adopted for landslide susceptibility mapping can be broadly classified into direct and indirect techniques or, into qualitative and quantitative [6] though the accuracy of each method depends upon the various parameter selection.

In direct mapping, the geomorphologist, based on his experience and knowledge of the terrain conditions determines the degree of susceptibility directly [9]. In indirect mapping, statistical or deterministic models are used to predict the landslide prone areas, based on the information obtained from the interrelation between landslide conditioning factors and landslide distribution [9]. Qualitative methods are a relatively subjective approach that represents the prone levels of a landslide in descriptive expressions based on decisions of experts [10][11][12][13][14].Quantitative models use a numerical assessment of the relationship between slope instability and other controlling factors [15]. Quantitative methods depend closely on mathematical models [17].

Although both quantitative and qualitative approaches, have their own advantages and disadvantages, however, quantitative approach is widely preferred over the qualitative approach because of its feature of non-dependence over human judgments and over the recent years, GIS has been extensively used along with these approaches as it facilitates the production of landslide maps, reducing the time and resources required for their compilation and systematic update[18] thereby solving problems related to the production, update and visualization of landslide maps [18].

Quantitative approach can broadly be classified into three categories viz. deterministic analysis, statistical methods, and artificial intelligence techniques. These techniques rely mostly on the mathematical models and less on human judgments unlike the qualitative approach and thus tend to give a comparatively more accurate result. However, there is no universally accepted method of producing landslide susceptibility maps [18].

1.1 Deterministic Approach

The deterministic or physically based models are based on the physical laws of conservation of mass, energy and momentum [21]. This approach is based on numerical expression of the relation between controlling factors and landslide. It focuses on site investigation based on soil thickness, soil strength, underground water pressure, slope geometry etc. and analysis using deterministic distributed model approach which helps us understands landslide location and timing.

As this approach requires a detailed geotechnical and hydro geological data, it can only be used for the small and relatively homogenous areas.

1.2 Statistical Approach

This approach does the prediction of future landslide areas by measuring the combinations of variables that have led to landslide occurrence in the past [24]. Landslide susceptibility mapping uses either multivariate or bivariate statistical approaches [23].

1.2.1 Bivariate Statistical Analysis: In bivariate statistical analysis, each causal factor map is combined with the landslide distribution map and weighting values based on landslide densities are calculated for each causal factor class. The most commonly used techniques for bivariate statistical analysis are, weights of evidence, information value, and frequency ratio.

1.2.1 Multivariate Statistical Analysis: In multivariate statistical analysis, the weights of causal factors controlling landslide occurrence indicate the relative contribution of each of these factors to the degree of hazard within a defined land unit [17]. The most commonly used techniques for multivariate statistical analysis are logistic regression, discriminant analysis & cluster analysis.

1.3 Soft Computing Techniques

At times, some of the landslide contributing parameters cannot be modeled because of the complex nature of the landslide phenomena [18]. Hence, application of new techniques that are concerned with or represent the nonlinearity of landslide susceptibility assessments becomes of utmost importance.

The main focus of this paper is to present recent developments of various techniques that use soft computing techniques for landslide susceptibility mapping using GIS.

II. Related Work

Over the recent years, soft computing techniques for land-slide susceptibility mapping have gained significant importance as these techniques are concerned with the use of nonlinear models that can be applied to the multi-source data analysis and classification with respect to landslide [18]. There are various soft computing techniques that can be use, however, some of the commonly used soft computing techniques that have been discussed here are fuzzy logic, artificial neural networks and support vector machines.

2.1 Artificial Neural Networks

Biswajeet Pradhan proposed a model for land-slide susceptibility mapping using artificial neural network using the back propagation algorithm. Five different training samples were selected to train the ANN in order to avoid bias effect in the final results. Here, nine geological and geomorphological factors including, topographic slope, topographic aspect, topographic curvature, distance to drainage, lithology, distance to faults, soil texture, landcover and normalized difference vegetation index (ndvi) were taken into account to predict the landslide susceptible areas. The results of the landslide susceptibility maps were validated using the existing landslide location data with the aid of receiver operating characteristics (ROC) approaches. This approach gave a minimum accuracy of 82.92% and a maximum accuracy of 92.59%. The ROC curve explains how well the model and attributed predict the landslide and thus assist the area under curve (AUC) to make the predictions more accurately [27].

Isik Yilmaz proposed models for landslide susceptibility mapping using Frequency Ratio, Logistic Regression, Artificial Neural Networks and then a comparative study of all these three models were made.

Here, eight geological and geomorphological factors including, geology, faults, drainage system, topographical elevation, slope angle slope aspect, topographic wetness index(TWI) and stream power index(SPI) were taken into ac-count to predict the landslide susceptible areas. The validation of these models was done using area under curve (AUC) values. The ideal range of values ranges from .5 to 1. The model that used artificial neural network using feed forward back propagation algorithm gave highest accuracy with an AUC value of 0.852[28].

2.2 Fuzzy Logic

Mohammad Parsa Sadr et.al proposed a model for landslide susceptibility mapping using hybrid Analytic Hierarchy Process and Fuzzy logic. Here, causative factors that were taken into account were vegetation, geomorphology, Tectonic and Lithology. The validation of the results were done using area under curve (AUC) o and receiver operating characteristics (ROC) approaches. In this study, the AUC value was found to be 0.782 which indicates that the prediction precision of the acquired map was 81.02 %.as compared to the ideal value of 100% [29].

Dieu Tien Bui , Biswajeet Pradhan et.al. proposed a model for landslide susceptibility mapping using Adaptive Neuro-Fuzzy Inference System (ANFIS). Here, ten causative factors were taken into account which comprised of slope aspect, curvature, lithology, land use, soil type, rainfall, distance to roads, distance to rivers, and distance to faults. A total of six ANFIS models with the hybrid training algorithm and six different membership functions (Gaussmf, Gauss2mf, Gbellmf, Sigmf, Dsigmf, Psigmf) were used. The validation of the model was done using area under the curve (AUC). The model with Sigmf has the highest AUC value of 0.848 [30].

2.3 Support Vector Machine

Hamid Reza Pourghasemi et.al proposed a model for landslide susceptibility mapping using support vector machine (SVM). Here, fourteen causative factors were taken into account which were slope degree, slope aspect, altitude, plan curvature, profile curvature, tangential curvature, surface area ratio (SAR), lithology, land use, distance from faults, distance from rivers, distance from roads, topographic wetness index (TWI) and stream power index (SPI). Here, six different types of kernel classifiers such as linear, polynomial degree of 2, polynomial degree of 3, polynomial degree of 4, radial basis function (RBF) and sigmoid were used for landslide susceptibility mapping and the validation of these classifiers were done using success rate and relative operating characteristics curve (ROC) by comparing the existing landslide locations with the six landslide susceptibility maps. The validation results showed that success rates for six types of kernel models vary from 79.3% to 87.8% [6].

Dieu Tien Bui et.al has given a comparative study of three approaches namely the support vector machines SVM, decision tree DT, and Na¨ıve Bayes NB models for spatial prediction of landslide hazards. The landslide susceptibility indexes were calculated using SVM, DT, and NB models. Here ten causative factors namely slope angle, slope aspect, relief amplitude, lithology, soil type, land use, distance to roads, distance to rivers, distance to faults, and rainfall were taken into account. Using these factors, landslide susceptibility indexes were calculated using SVM, DT, and NB models. The validations of these models were done using success-rate and prediction-rate. Models derived using Radial basis function (RBF) kernel SVM showed the highest prediction with AUC value of 0.961[31].

Table 1: Comparative Analysis of Soft Computing Techniques

Techniques	Advantages	Disadvantages
Artificial Neural Network	It allows a nonlinear relationship between the landslide and main susceptibility factors. They are independent of the statistical distribution of the data and thus specific assumptions with the multivariate data distribution were not required.	This technique demands the conversion of data to other format such as ASCII which again needs to be reconverted so that it can be incorporated with GIS. It also takes a longer execution time with heavy computing load.
Fuzzy Logic	With the application of fuzzy logic, the model will have tolerance towards imprecision of data. Fuzzy logic method, because of the subjective degree of membership, leads to high prediction.	The choice of fuzzy operator should be done very carefully as it creates a huge impact, make the best prediction. In the areas that involves high mathematical description, the computing power poses as one of the restrictions for complete mathematical restriction.
Support Vector Machine	This method can easily make use of large input data with fast learning capacity and is well suited to nonlinear high- dimensional data modeling problems. It also provides promising perspectives in the landslide susceptibility mapping.	Efficiency of this technique depends on the choice of the kernel function parameter. Although Support Vector Machine (SVM) is a widely used classifier, it poses a very high algorithmic complexity.

III. Conclusion

In the recent years, soft computing techniques have been gaining popularity because it provides a predictable and better solution. However, it is observed that every soft computing technique have their own advantage and disadvantages. Thus it would be ideal to have a hybrid model of these techniques. This hybrid models are becoming one of the major areas of research as models try to get the benefits of the various techniques used and at the same time it also tries to remove the individual disadvantages of each of the techniques by combining them on common features.

References

[1]. Ghosh, J.K, Suri, S "A knowledge based system for assessment of landslide hazard". In Proceedings of the Indian Geotechnical Conference, vol. 1, pp. 393–396. IGS, Ahmedabad (2005).

[2]. Nagarajan, R, Mukherjee, A , Roy A, Khire M, "Temporal remote sensing data and GIS application in landslide hazard zonation of part of Western Ghat, India." Int. J. Rem. Sens. 19(4), 573–585 (1998).

[3]. Fu Yixiang1, Yuan Tao2 & Gao Lan3 "The prediction of local landslide based on GIS and neural networks ", The Geological Society of London 2006.

[4]. H. Shahabi1, B.B. Ahmad2, and S. Khezri3 "Land-slide Susceptibility Mapping Using Image Satellite and GIS Technology". International Journal of Engineering Research & Technology (IJERT), Vol. 1 Issue 6, August - 2012 ISSN: 2278-0181.

[5]. Naithani A. K "The Himalayan Landslides" Employment News, 23(47), 20-26 February, 1-2, (1999).

[6]. Hamid Reza Pourghasemi1, Abbas Goli Jirandeh2, Biswajeet Pradhan3 et.al. "Landslide susceptibility mapping using support vector machine and GIS at the Golestan Province, Iran", J. Earth Syst. Sci. 122, No. 2, April 2013, pp. 349–369 c Indian Academy of Sciences.

[7]. M. H. Vahidnia1, A. A. Alesheikh2 et.al. "Landslide Hazard Zonation Using Quantitative Methods in GIS", International Journal of Civil Engineering. Vol. 7, No. 3, September 2009.

[8]. Brabb, E.E ". Innovative approaches to landslide hazard and risk mapping, Proceedings of the 4th International Symposium on Landslides", 16–21 September, Toronto, Ontario, Canada (CanadianGeotechnical Society, Toronto, Ontario, Canada), 1:307–324, 1884.

[9]. C. J. Van Westen, N. Rengers And R. Soeters "Use of Geomorphological Information in Indirect Landslide Susceptibility Assessment". Natural Hazards 30: 399–419, International Institute for Aerospace Survey and Earth Sciences, Enschede, the Netherlands, 2003.

[10]. Sarkar S , Anbalagan R "Landslide hazard zonation mapping and comparative analysis of hazard zonation maps", Journal of Mountain Science, Vol. 5, pp. 232-240, 2008.

[11]. Sarkar S, Kanungo D.P, Patra A.K , Kumar P "GIS based spatial data analysis for landslide susceptibility mapping", Journal of Mountain Science, Vol. 5, pp. 52-62, 2008.

[12]. [Wang M, Qiao J et.al. "GIS-based Earthquake-Triggered Landslide Hazard Zoning Using Contributing Weight Model", Journal of Mountain Science, Vol 7, pp 339–352, 2010.

[13]. Pradhan B "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, pp. 1244–1256, 2010.

[14]. Pradhan B, Chaudhari A, Adinarayana J, Buchroithner M.F "Soil erosion assessment and its correlation with landslide events using remote sensing data and GIS: a case study at Penang Island, Malaysia", Environmental Monitoring &Assessment Vol 184 (2), pp 715–727, 2012.

[15]. Nader Saadatkhah, Azman Kassim ,Lee Min Lee "Qualitative and Quantitative Landslide Susceptibility Assessments in Hulu Kelang area, Malaysia.", Bund.C, . Vol. 19 , 2014.

[16]. M. Van Den Eeckhaut et.al. ". Combined landslide inventory and susceptibility assessment based on different mapping units: an example from the Flemish Ardennes, Belgium", Nat. Hazards Earth Syst. Sci., 9, 507–521, 2009.

[17]. Paolo Magliulo, Antonio Di Lisio, Filippo Russo "Comparison of GIS-based methodologies for the landslide susceptibility assessment", DOI 10.1007/s10707-008-0063-2. Received: 2 July 2007. /Revised: 11 February 2008 / Accepted: 23 October 2008 # Springer Science + Business Media, LLC 2008.

[18]. Murat Ercanoglu "An Overview on the Landslide Susceptibility Assessment Techniques", 1st WSEAS International Conference on ENVIRONMENTAL and GEOLOGICAL SCIENCE and ENGINEERING (EG'08) , Malta, September 11-13, 2008.

[19]. FaustoGuzzetti, Alessandro CesareMondinia et.al. ". Landslide inventory maps: New tools for an old problem", Earth-Science Reviews 112 (2012) 42–66, 23 February 2012.

[20]. Clerici A, Perego S, Tellini C and Vescovi P "), A GIS-based automated procedure for landslide susceptibility mapping by the Conditional Analysis method: the Baganza valley case study (Italian Northern Apennines)", Environmental Geology, 50, 941–961, 2006.

[21]. Van Westen, C.J. & Terlien, T.J "An approach to-wards deterministic landslide hazard analysis in GIS. A case study from Manizales (Colombia)", Earth Sur-face Process and Landforms 21: 853–868, 1996.

[22]. Daniel P. Ames, Nigel W.T. Quinn and Andrea E. Rizzoli et.al "Physically based landslide susceptibility models with different degree of complexity: calibration and verification. Giuseppe Formettaa, Giovanna Capparellia, Riccardo Rigonb and Pasquale Versacea", International Environmental Modelling and Software Society (iEMSs) 7th Intl. Congress on Env. Modelling and Software, San Diego, CA, USA, 2014-proceedings.

[23]. ZHU Lei et.al. ". GIS-based logistic regression method for landslide susceptibility mapping in regional scale", , Journal of Zhejiang University SCIENCE A ISSN 1009-3095 (Print); ISSN 1862-1775 (Online), Zhu et al. / J Zhejiang Univ SCIENCE A 2006 7(12):2007-2017.

[24]. Mehrdad Safaei et.al. "Deterministic Rainfall Induced Landslide Approaches, Advantage and Limitation", Electronic Electronic Journal of Geotechnical Engineering, Vol. 16, 2011.

[25]. HoangBac Bui , QuocPhi Nguyen , VanTrung Nguyen ", GIS-Based Weights-Of-Evidence Modeling For Landslide Susceptibility Mapping At Jaechon Area, Korea", , International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences 2008.

[26]. Ranjan Kumar Dahal, Shuichi Hasegawa et.al. ", GIS-based weights-of-evidence modelling of rainfall-induced landslides in small catchments for landslide susceptibility mapping", 54:311–324 DOI 10.1007/s00254-007-0818, , Environ Geol (2008).

[27]. Biswajeet Pradhan "An Assessment of the Use of an Advanced Neural Network Model with Five Different Training Strategies for the Preparation of Landslide Susceptibility Maps" 65-81, Journal of Data Science, 2011.

[28]. Isik Yilmaz "Landslide Susceptibility Mapping using Frequency Ratio, Logistic Regression, Artificial Neural Networks and their Comparison: A Case Study from Kat Landslides(Tokat Turkey), Computers & Geosciences 35, 1125 – 1138, 2009.

[29]. Mohammad Parsa Sadrm, Abbas Maghsoud, Bashir Shokouh Saljoughi "Landslide Susceptibility Map-ping of Komroud Sub-basin Using Fuzzy Logic Ap-proach" Geodynamics Research International Bulletin (GRIB), 2nd Article- P. XVI to XXVIII, Vol. (II)– No. 02, SN:05, Spring Issue 2014.

[30]. Dieu Tien Bui, Biswajeet Pradhan, Owe Lofman, Inge Revhaug, and Oystein B. Dick " Landslide Susceptibility Mapping at Hoa Binh Province (Vietnam) using an adaptive Neuro-fuzzy Inference System and GIS", Computers & Geosciences, Volume 45, Pages 199–211, August 2012.

[31]. Dieu Tien Bui,Biswajeet Pradhan,Owe Lofman and Inge Revhaug "Landslide Susceptibility Assessment in Vietnam Using Support Vector Machines, Decision Tree, and Naïve Bayes Models", Mathematical Problems in Engineering, Article ID 974638, 26 pages, Volume 2012 (2012).