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Different Techniques for Landslide Zonation Mapping and Landslide Assessment: A Review

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Abstract

Assessing the hazards of landslides and zonation mapping of the landslides is important in managing the hazards and risks of landslides. For the past few decades many hazard assessments and zonation mapping techniques have been carried out by the researchers. This paper presents the review of researches carried out in the past years on landslide hazard assessment and zonation mapping techniques.

Keywords: Artificial Neural Network (ANN), Digital Elevation Model (DEM), Geo Information systems(GIS), Information Value Model(IVM), Standardized Discriminant Function Coefficient (SDFC)

1. Introduction

Landslides are the movement of rocks, debris and soil along the downward slopes due to gravitational pull. It is a natural calamity where the social and natural environment is disturbed and damaged. The damage and risks can be prevented if the landslide is recognized before the occurrence. Hence, there is a need for hazard assessment at various spatial scales of land slide. In the last few decades the study on landslides by researchers has given many observations and results. Assessments carried out for landslides on the land surfaces with spatial data, instable slopes and insufficient data has given observations and results that multivariate methods can give accurate predictions for spatial data, Physical methods can give good results for areas with improper data and decision making approaches can assess the causes for landslides occurring due to instability of the slopes. In the recent years the advancement in Geo-spatial technologies has helped landslide assessments. The Geographical Information System (GIS) tools uses satellite data and imagery to assess, detect, monitor and give future predictions of landslides. The Various tools in Remote Sensing and GIS have given accurate results and future predictions in the landslide assessment.

The present paper reviews some of the techniques used for hazard assessment of landslides. The aim of this article is to discuss the techniques in landslide hazard zonation mapping methods and application of Remote Sensing and Geographical Information Systems.

1.1 Landslide Assessment and Landslide Zonation Mapping Methods

Land sliding is one of the natural disasters which is hazardous and causes damage to natural and social environment. Landslide hazard assessment and hazard zonation technique is an important method in assessing the landslide risk management. Landslide zonation is way of partitioning the land area into regions and giving priority to these regions according to the level of susceptibility of landslides. There is a lot of research done in the last few decades, and several techniques have been

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identified for Land slide hazard zonation mapping. Some of the approaches that have been developed are inventory based mapping, statistical approaches, bi-variate and multivariate statistical approaches, probabilistic assessment, deterministic approach, fuzzy logic and decision making approach.

2. Techniques for Landslide Assessment

2.1 Inventory Based Approach[1]

It is one of the basic qualitative methods of land slide hazard zonation mapping, it is also known as distribution approach. In this technique, the spatial and temporal patterns of landslide distributions are represented in the landslide inventory maps, which portray type of debris movement, rate of debris movement, type of displaced material etc. By field survey, history data, satellite imagery and aerial photo interpretation, landslide data is obtained. Landslide distribution and the land slide severity maps are created which provide basis for landslide susceptibility methods. N Casagli[2] has tested this method in the Virginio River Basin, Italy.

2.2 Bi-Variate and Multivariate Statistical Approaches

Landslides are temporal, dynamic, spatial and discrete in nature. Land sliding starts at a spatial point and the control on further occurrence depends on the surface and subsurface spatial variables present at that point. The landslide hazard zonation mapping approaches have taken a change to statistical approach from the traditional heuristic method, statistical approaches simplifies process of assigning weights and give better results which can be reproduced. In the statistical methods there are two variants the bi-variate method and multi-variate method. The bi-variate method compares the factors causing landslides to the existing landslides. Based on landslide severity and distribution the weights are assigned to the landslide causing factors. Bayesian Model, Frequency Analysis approach, Information Value Model (IVM) are a few bi-variate methods applicable for hazard zonation mapping.

2.2.1 Bayesian Approach

In the Bayesian approach the prior probability of occurrence of landslide is considered to assess the posterior probability based on the relative evidences and this method is called the weight of evidence method. In the weight of evidence method the landslide causing factors are considered as training values which can derive possible predictions of the further occurrences of landslides. The Bayesian approach-Weights of Evidence method has been used for prediction of the susceptibility of the landslides from last three decades (Blahut et. al. 2010). This method has been used to prepare a landslide hazard zonation map of part of Bhagirathi valley, Uttarakhand by John Mathew, V. K. Jha and G. S. Rawat[3]

2.2.2 Frequency Ratio Approach[1]

In the statistical method under the bi-variate approach, we have frequency ratio approach for assessing the occurrence of landslides. The observations and relationships between landslide distribution and factors causing landslides give the predictions on the relationship between the location of the landslides and the factors responsible for the susceptibility of landslides. The Frequency ratio for each factor that is responsible for causing landslide is estimated depending on its relationship with the factors that causes further occurrences of landslides. The Susceptibility Index (SI) of the landslide is calculated by adding the frequency ratio values of each factor. Using frequency ratio model, the spatial relationships between the location of landslide occurrence and each of causative factors were derived by K. Solaimani et.al.[4]

2.2.3 Information Value Method[1]

This method is also a bivariate approach here the predictions of the occurrence of landslides are made depending on the relationships between the susceptibility of landslide and the factors related to it. In the considered mapping unit the information values are determined for each landslide related factor on the basis of susceptibility of landslide. Shraban Sarkar et. al. (2013)[5] applied this method to the parts of Darjeeling to find the landslide susceptibility.

2.2.4 Fuzzy Logic Method[1]

This method is also a bivariate method. In this method each land slide causing factor depending on its association with the factors responsible for the landslide susceptibility are represented by a value that is between the binary values.

From the represented values the hazard zonation maps are generated by integrating the values using Gama operator or by algebraic Sum in the fuzzy logic. Champatiray et.al. (2007)[11] applied this method to landslide susceptibility assessment in Garhwal Himalayas.

2.3 Multi-Variate Statistical Analysis

In this method the landslide area for each pixel are calculated and the prediction of the presence or absence of landslide in that area is obtained by the application of multivariate statistical method. A few multivariate methods are Logistic regression model, Discriminant analysis, Artificial Neural Networks (ANN).

2.3.1 Logistic Regression Analysis[1]

Logistic regression method is a multivariate method which can be used for predicting the occurrence or nonoccurrence of landslides. This method determines the relationship between occurrence and nonoccurrence of landslides and the factors for it like slope angle, slope aspect, lithology and land use. It then generates a model for the landslide susceptibility. Lee[9] have applied this model for land slide hazard zonation mapping.

2.3.2 Discriminant Analysis Method[1]

In this technique the maximum difference between the landslide causative factors and non-causative landslide parameters are determined and weights are assigned to these factors, discriminant analysis determines the maximum difference for each independent variable between landslide causing and non-causing factors (Lee et.al. [6] (2008)). For the regions affected by landslides and regions which are free from landslides the slope values are classified and significance of each value is represented by computing Standardized Discriminant Function Coefficient (SDFC). Each variable in discriminant function gives the prediction of instability of slopes. Gorsevski Paul et.al.[6] used this method to map land slide hazards using GIS.

2.3.3 Artificial Neural Networks Approach[1]

The factors responsible for causing or triggering landslides are all interrelated. There is a nonlinear relationship between several landslide causative factors. Considering the complex relationship between various factors causing landslides the accurate landslide susceptibility assessment can be obtained using neural networks. Neural network algorithms can be used to give knowledge rules for assigning weights for the known and unknown variables. To reduce the errors, weights can be readjusted for the each variable. Biswajeet Pradhan[17] has applied this technique on different sites.

2.4 Probabilistic Approach[1]

In probabilistic approach, the spatial distribution of landslides is compared with various explanatory factors within probabilistic framework (Kanungo et.al. 2009)[15]. It includes Bayesian probability, certainty factor, favorability function etc. Based on probability distribution function the strong relationship between thematic data layer and landslide distribution is converted into a value which tells the probability of the occurrence or nonoccurrence of landslides. Sharma et al have applied this method for land slide assessment using GIS[16].

2.5 Physical Approaches

Physical approaches are used for land areas with insufficient data or for areas which do not have long term data. The land slide hazard assessment for such areas can be made by understanding the physical and mechanical processes responsible for the susceptibility of landslides. The physical approaches mainly consider the ground water data, slope values and the rainfall data. These models can be applicable to the areas with incomplete landslide inventories. Kuriakose et.al.[18]

2.6 Remote Sensing and Geo Information Systems in Landslide Hazard Zonation Mapping

The geo information systems can collect data from remote locations, store large amount of data, display data in the required form, analyze different situations, manipulate large amounts of spatially referenced data, and compute fast and produce effective results. Geo information systems and remote sensing technology can be employed for landslide hazard assessment and analysis .The data on land slide effects and characteristics like slope instability, lithology and land use/land cover data before and after occurrence of landslides can be can obtained from satellite images taken before and after the occurrence of landslides and the data can be used to predict future occurrences. Images before and after occurrence of landslides helps to know how the landscape changed after a land slide

event ,the factors that would have caused the landslides and also the method identified for regeneration and recovery after the event. Using Digital Elevation Model (DEM) the thematic data layers such as slope angle, slope aspect, curvature etc. can be extracted to generate spatial information data layers related to landslide hazards (Balasubramani and Kumaraswamy[22]).

3. Conclusions

In land slide assessment, landslide hazard zonation is an important task. Occurrences of Landslides depend on several factors which may be different from one location to the other. Land slide assessment involves determining weights for landslide causative parameters. Based on the way the weights are assigned for various causative factors, several land slide assessment techniques have evolved. In Heuristic and semi quantitative techniques, assigning of weights involve subjectivity therefore there is no accurate validity of assessment. Objective methods are used to determine weights for the landslide causative factors in Quantitative methods, In decision making approaches various tools are used for assigning weights for the landslide causative factors and pair wise comparison is made. With high resolution satellite data, imagery and field data, the GIS tools and techniques can be used to obtain accurate and improved landslide hazard zonation maps for the landslide assessment.

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