Comparative Study of Data Driven Landslide Hazard Zonation Techniques

[1]Rohan Kumar

[1] School of Chemical Engineering and Physical Sciences, Department of Petroleum Engineering, Lovely Professional University, Phagwara, Punjab.

Abstract:

Landslide hazard zonation (LHZ) mapping of Tehri reservoir rim region has been carried out using two data driven methods namely: landslide frequency ratio and binary logistic regression. Ten terrain parameters namely, soil cover, aspect, slope angle, lithology, relative relief, land use land cover, drainage buffer, road buffer, reservoir buffer and photo-lineament has been selected to carry out LHZ mapping of Tehri reservoir rim. Area under curve technique has been used to assess the accuracy achieved from the two methods. Landslide frequency ratio method gave 72% accuracy and logistic regression method resulted in achieving 82% accuracy.

Introduction

Tehri reservoir region is located in Lesser Himalaya. Construction of Tehri Dam at the confluence of Bhagirathi and Bhilangana river resulted in development of 70 km long reservoir. The valley in which reservoir has developed, supports forest vegetation, crop land, villages, roads and other infrastructures. The area is represented by rugged and undulating terrain. The Tehri reservoir area is also witnessing rapid infrastructure development namely, road construction, housing, irrigation canals etc. The reservoir water varies between elevation 830 m (which is the maximum reservoir water altitude) and elevation 740 m (Dead storage) during the monsoon and dry periods[1]. Reservoir water level variation leads to wetting and drying of the valley slopes and consequently the valley slopes fail at many places. Due to transient pore water pressure that are induced by the reservoir water variation, valley slopes fail at many places. Such failures can be seen around the periphery of reservoir in terms of road subsidence, landslides, terrace failures and sink holes.

Many methods are used for mapping of landslide probable atreas namely: qualitative, quantitative, semi-quantitative, process based and deterministic methods. Among them, data driven methods (such as quantitative, process based, semi-quantitative) uses landslide inventory to arrive a numerical estimate of landslide probability. Complete landslide inventory involves the present and historical information of landslide incidences with their types and landslide area. Incomplete landslide inventory data is not feasible for the LHZ mapping. Based on a comprehensive landslide inventory, quantitative and computational process based techniques can be applied to delineate landslide probable zones. These are landslide inventory driven techniques, in which landslide density, in factor classes, are considered, which further leads to the characterization of the factor classes pertaining to their significance in landsliding. Quantitative methods such as frequency ratio, weights of evidence (WofE), binary logistic regression and discriminant analysis vary in their conceptual models but all are based on landslide density in factor classes. On the other hand, advancement in computation technology, data mining approaches have led to use of several approaches for the purpose of LHZ mapping and these commonly include landslide inventory information. Artificial neural network (ANN), support vector machines (SVM), decision tree (DT), Naive Bayes (NB) models and Adaptive neuro-fuzzy interface system (ANFIS) model[2-9] The upper hand of these models lie in capability of handling large input data with fast learning capacity.

In the present study, two landslide inventory-based methods namely, landslide frequency ratio and binary logistic regression method (BLR) was used to produce LHZ maps. Arc GIS, SPSS and Matlab 2010 software were used to perform the above-mentioned analysis.

Data used: Remote sensing multispectral data belonging to Landsat 8, ASTER and World View-2 sensor and ancillary data (such as Survey of India toposheet, Geological map, Soil map) were processed in GIS platform to extract ten landslide causing factors namely, soil cover, geology, photo-lineament, LULC, slope angle, topographic aspect, relative relief, drainage, reservoir buffer and road buffer.

Method

LHZ mapping using Frequency ratio

Landslide frequency ratio is based on landslide density, present in each factor class. The frequency ratio value of each factor class reflects their significance in landsliding. It is rooted in the principle of conditional probability, that implies frequency ratio >1 is an indicative of strong relationship of factors/class in landsliding whereas <1 reflects weaker relationship of factors with landslide occurrences. In this study, frequency ratio value of each factor class was normalized in a range of 0 to 1 and arithmetically added to produce landslide hazard estimate on pixel by pixel basis also called landslide hazard index (LHI). LHI was reclassified in following landslide hazard zones: very low hazard, low hazard, moderate hazard, high hazard and

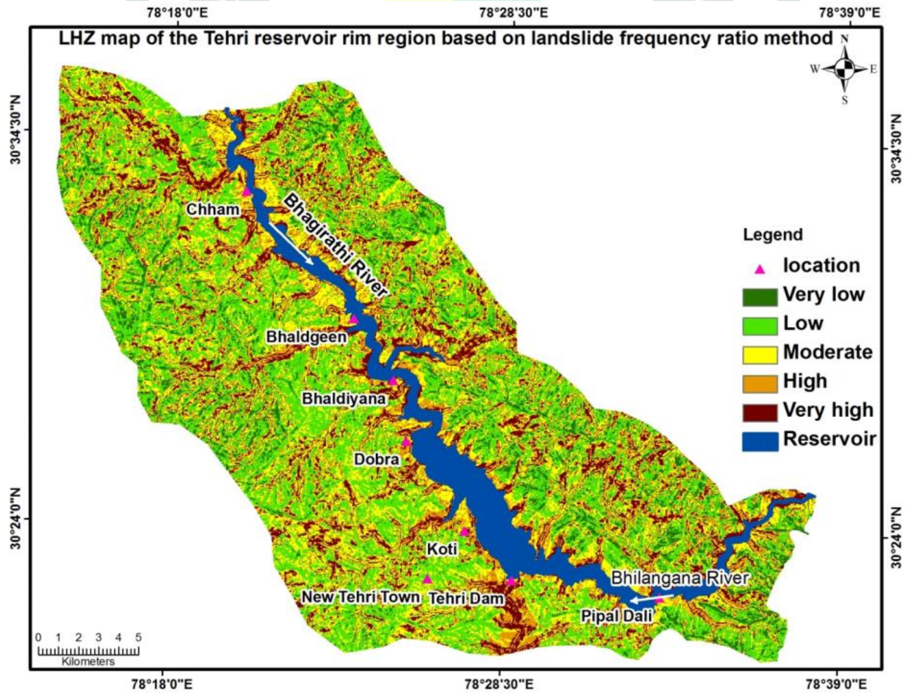

Figure 1: LHZ map created using landslide frequency ratio method

very high hazard zone by selecting threshold values. Threshold values were chosen subjectively. Further, area under curve (AUC) was generated for the validation of the method.

LHZ mapping using BLR method

In the present study, estimation of LHZ was computed using BLR model, that is founded on multivariate principle. BLR utilizes dependent variable (landslides) in

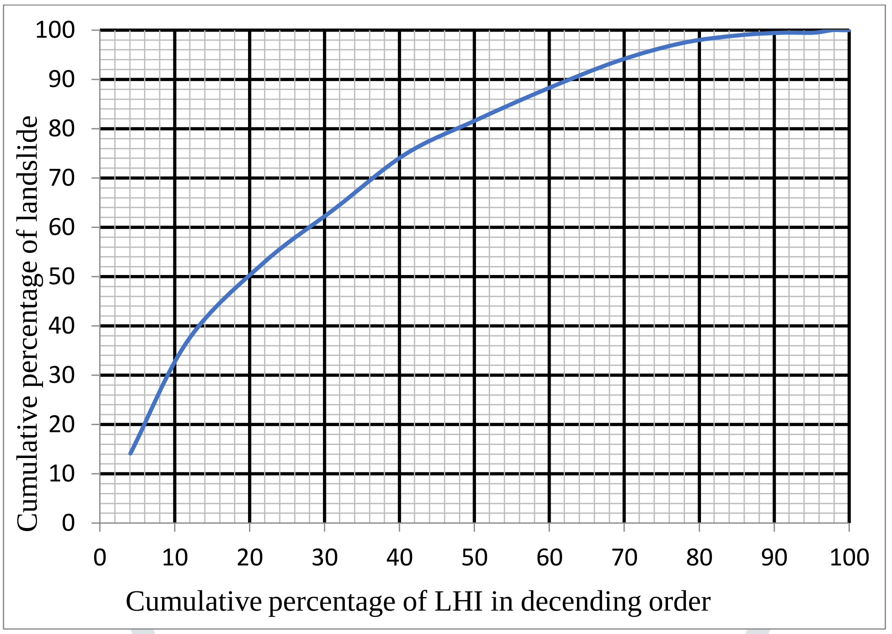

Figure 2: AUC curve developed for frequency ratio based LHZ map

binary form. BLR model excludes those landslide causing factors, that are not significant in contributing[10]. Many authors have reported about the advantage of BLR model in attaining higher accuracy for Himalayan terrain. BLR model prioritize significant landslide contributing factor, estimate the relative contribution of factors, omits the insignificant factors and estimate hazard probability for each mapping unit.

Results and Discussion

LHZ mapping using landslide frequency ratio: In this study, a landslide frequency ratio method for estimating landslide probable area was applied. LHZ (Figure 1) was computed by assuming that the future landslides can be predicted by quantitative relationships among past landslides and the terrain factor classes. Validation was performed on the basis of AUC. The curve (Figure 2) shows that 33% of the landslides fall under the initial 10% of high LHI classes and more than 50% landslides fall under initial 20% of high LHI classes, which further indicate the prediction capability of the frequency ratio based LHZ method. AUC value can be converted into percent prediction accuracy which in the present case is 72%. Bar chart method was also utilized in this case by using the whole landslide data. Percentage of landslides in each LHZ class was arranged along with the percent domain of LHZ classes and a bar chart was generated.

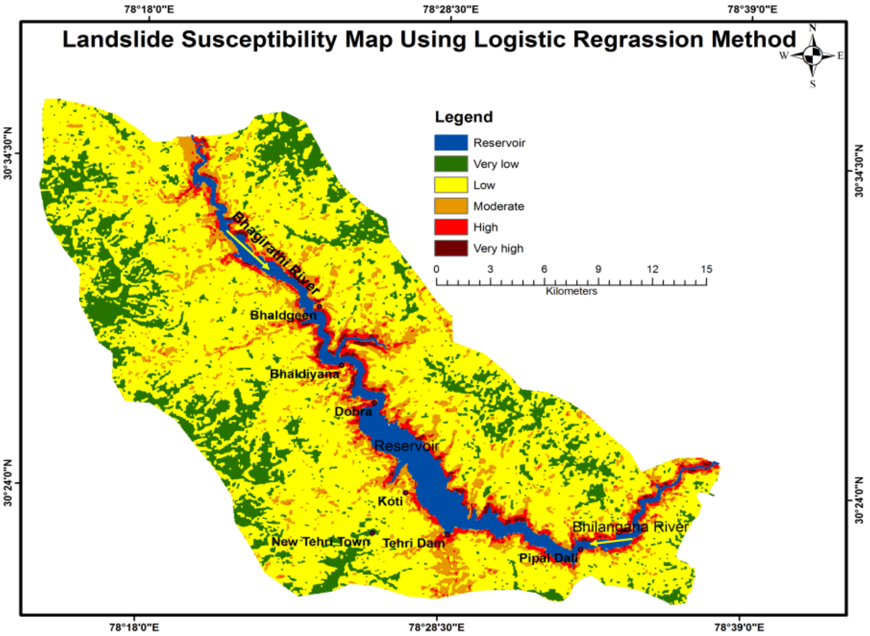

Figure 3: LHZ created using binary logistic regression method

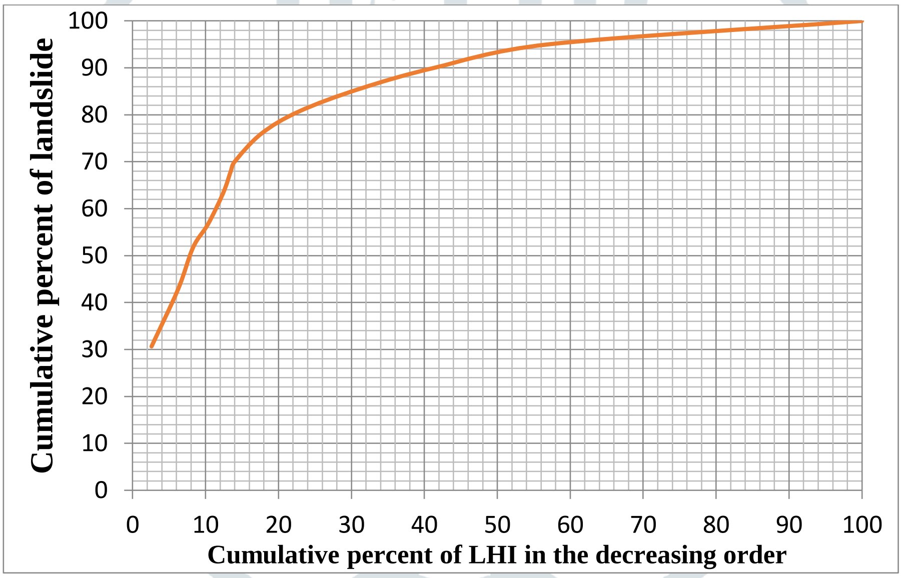

Figure 4: AUC showing prediction capability of the BLR method

LHZ mapping using BLR model: The present study provides insight about the significance of the independent variables used for the LHZ map (Figure 3) and the capability of BLR method in predicting landslide susceptible zones in the Tehri reservoir rim region. 65 independent variables belonging to 13 different classes were subjected to BLR analysis and have reflected the significance of variables in landslide occurrences. 25 variables are found to be significant, whereas rest are terminated. Based on these significant variables LHZ map (Figure 3) was prepared. The LHZ map has provided critical evaluation of the regions surrounding the reservoir in view of the slope instability. Validation was performed using AUC technique which resulted 83% accuracy (Figure 4).

Conclusions:

Landslide Hazard Zonation map of the slopes bounding the Tehri reservoir has been carried out using landslide frequency ratio method and BLR method. Frequency ratio method and BLR method has given 72% and 83% accuracy respectively in identifying landslide hazard zones. Frequency ratio method gave comparatively lower accuracy in comparison to BLR method. So it can be concluded that BLR method is more suitable for LHZ mapping in highly undulating terrain like Himalaya. This study can be carried out at larger scale (like 1:10000 to 1: 5000) and hazard probability can be estimated more finely.

Reference:

[1] P. Samui, "Slope stability analysis: A support vector machine approach" Environ. Geol., vol. 56, pp. 255-267, 2008.

[2] H. Saito, D. Nakayama and H. Matsuyama, "Comparison of landslide susceptibility based on a decision-tree model and actual landslide occurence: the Akaishi mountains, Japan" Geomorphology, vol.109, pp. 108-121, 2009.

[3] S. Wan, and T.C. Lei, "A knowledge-based decision support system to analyze the debris-flow problems at Chen-Yu-Lan river, Taiwan" Knowledge-Bases Sys., vol..22, pp. 580, 2009.

[4] B. Pradhan, "Remote sensing and GIS-based landslide hazard analysis and cross-validation using multivariate logistic regression model on three test areas in Malaysia" Adv. Space. Res., vol. 45, pp. 1244-1256, 2010.

[5] Y-K. Yeon, J-G. Han, and K.H. Ryu, "Landslide susceptibility mapping in Injae, Korea, using a decision tree" Engg. Geol., vol. 116, pp. 274–283, 2010

[6] I. Yilmaz, "Landslide susceptibility mapping using frequency ratio, logistic regression, artificial neural networks and their comparison: a case study from Kat landslides (Tokat-Turkey)" Comp. Geosci., vol. 35, pp. 1125–1138, 2009.

[7] A.S. Miner, P. Vamplew, D.J. Windle, P. Flentje and P. Warner, "A comparative study of various data mining techniques as applied to the modeling of landslide susceptibility on the Bellarine Peninsula, Victoria, Australia" In: Geologically Active, Williams, A. L., Pinches, G. M., Chin, C. Y. and McMorran, T. J. (eds.), CRC Press, New York, NY, USA, pp. 352, 2010.

[8] D. Tien Bui, B. Pradhan, O. Lofman and I. Revhaug "Landslide susceptibility assessment in Vietnam using support vector machines, decision tree, and Naive Bayes models" Mathematical Prob. Engg., vol. 12, pp. 1-26, 2012.

[9] S. Chauhan, M. Sharma, M.K. Arora and N.K. Gupta, "Landslide susceptibility zonation through ratings derived from Artificial Neural Network" Int. J. Appl. Earth Observ. Geoinf., vol. 12, pp. 340–350, 2010.