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Landslide Susceptibility Modelling of Central Highland Part of Chaliyar River Basin, Kerala, India with Integrated Algorithms of Frequency Ratio and Shannon Entropy

Suraj P.R.*, Melvin Babu, Manoharan A.N., Archana Krishnan N., Shruthi Mayya K. and Niveditha P.

Department of Geology, Government College, Kasaragod-671123 (KL), India
*(*Corresponding Author, E-mail: sprbhoomi@gmail.com)*

Abstract

An integrated landslide susceptibility analysis is carried out for the central highland region of the Chaliyar River Basin in Kerala, India using bivariate statistical methods, namely the Frequency Ratio (FR) and Shannon Entropy (SE). The study addresses the complex nature of landslides, influenced by natural as well as anthropogenic factors, with specific focus on assessing the landslide likelihood of the study area. The methodology involves a systematic approach of collecting the inventory data, identifying various landslide causative factors and developing their corresponding thematic maps, spatial analysis of landslide occurrence and causative factors using GIS software and generation of Landslide Susceptibility Model (LSM) employing FR and SE algorithm, followed by model validation. Various causative factors considered for the study include slope angle, slope aspect, slope curvature, elevation, lithology, drainage density, land use and land cover (LULC), Topographic Wetness Index (TWI) and Normalized Difference Vegetation Index (NDVI). The FR and SE algorithm enable the spatial classification of the study area into four landslide susceptibility categories namely Low, Moderate, High, and Very High. Validation of both the LSMs was carried out using Landslide Density Index (LDI) and Area Under the Curve (AUC) methods. LDI demonstrate a positive fit for both the models, which is indicative of reliability of the susceptibility predictions of the study area. A slightly higher AUC value of SE model is an indication of a high accuracy rate of SE model over FR model. This research brings out a robust methodology for predicting and identifying the landslide risks of the study area. The outcomes of this study will help in developing effective strategies to manage the landslide hazards in geologically vulnerable areas.

Keywords: Landslide Susceptibility, Landslide Conditioning Factors, Frequency Ratio, Shannon Entropy, Landslide Density Index (LDI), Area Under the Curve (AUC)

Introduction

Landslides, recognized as profoundly calamitous natural events, unleash deleterious consequences on both the physical and human spheres (*Bui et al.*, 2020). Beyond the immediate physical devastation, these occurrences cast an enduring economic and social impact over human habitats (Hong *et al.*, 2017). Global statistics from 1995 to 2014 depict a staggering toll of 3,876 reported landslides, resulting in 11,689 injuries and 163,658 fatalities (Haque *et al.*, 2019). India is highly vulnerable to landslide and related disasters. Recent studies show thatNorthwest Himalayas contribute 66.5% of landslides, followed by the Northeast Himalayas (18.8%) and the Western Ghats (14.7%) in India (Martha *et al.*, 2021). The peculiar geographical location of Kerala makes the state a highly vulnerable to landslide and related natural disasters. In 2018 monsoon season alone, 4,728 cases of landslide occurrences were reported from the state (Hao *et al.*, 2020). These figures underscore the imperative to identify high-risk landslide zones and implement proactive measures for prevention and mitigation to safeguard communities globally as well as locally.

Recently, researchers are widely using the Machine Learning algorithm in landslide susceptibility modelling such as support vector machine, multivariate adaptive regression spline, boosted regression, classification and regression trees, quadratic discriminant analysis, artificial neural networks, maximum entropy, random forest, and generalized linear model (Ali *et al.*, 2022). At the same time, various bivariate and multivariate statistical methods are still widely employed in Landslide Susceptibility analysis and hazard zonation (Mengistu *et al.,* 2019; Hamza and Raghuvanshi, 2017; Girma *et al.*, 2015) because of its simplicity. The bivariate approach, grounded in inductive logic, state that if a situation holds in all observed cases, it holds universally (Dai and Lee, 2001). Frequency Ratio (FR) analysis, a common method among bivariate statistical approaches, correlates responsible causative factor classes with the spatial distribution of past landslides (Chimidi *et al.*, 2017; Hamza and Raghuvanshi, 2017; Girma *et al.*, 2015; Lee and Min, 2001). Shannon Entropy (SE) method, another bivariate statistical approach, assesses the extent to which various factors influence landslide development,

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