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A Review on Advances in Mapping Landslide Susceptibility

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ABSTRACT

This article addresses various aspects of assessing landslide hazard zonation, reflecting the growing interest in this field in recent years. Numerous technical papers in literature delve into this subject, and this paper provides a summary review and classification of the main global approaches. The initial categorization distinguishes between qualitative and quantitative methods. Qualitative methods rely on the expertise of experts, with susceptibility/hazard assessments derived directly in the field or by combining various index maps. In contrast, quantitative methods, the second group, are more formally rigorous. This group includes statistical analyses (bivariate or multivariate) and deterministic methods, which analyze specific sites or slopes using geo-engineering models. These analyses can be either deterministic or probabilistic. The article explores quantitative methods, including the relatively recent application of Neural Networks to engineering geology problems.

KEYWORDS: Landslides,

1. INTRODUCTION

Landslides frequently occur in steep areas and poses a significant natural threat. The issue of landslides has been heightened in recent years due to the expansion of urban areas , rising traffic volume, and the widening of roads from single lanes to dual lanes[1]. Landslide as defined by [2] is the downslope movement of under gravitational influence of material soil and rocks. From year 2005 to 2016 a total of almost 56000 people were killed in more than 4700 different non-seismic landslide events , with Asia representing major contribution in these numbers. Analysis shows that landslide events triggered by anthropogenic activities are increasing due to Construction activities in mountainous terrain[3].

The likelihood of a slope collapse happening is determined by a combination of geo-environmental variables, which is referred to as landslide susceptibility. . Assessing landslide susceptibility is a crucial step in environmental planning to mitigate the risk of disasters to human life and property[4].

Different techniques are utilized in the past for assessing landslide hazard which are broadly grouped into; Quantitative & Qualitative methods. Qualitative or heuristic (i.e AHP, Fuzzy Logic) method are mainly subjective or descriptive and are essentially based on experience of expert decision maker. On other hand quantitative method(Frequency Ratio, Logistic regression) used numerical values or expression of correlation between pre-conditioning causative

factor(Topographic, Geographic, Hydrological, Climatic and Anthropogenic) and past inventory of landslide is required in this method[5].

Deterministic methods are also employed for assessing and determining factor of safety against slope failure for a specific slope in a small area. Because of requirement of comprehensive geo-technical data deterministic approach isn't utilized for assessing landslide susceptibility[6].

Hence Statistical or probabilistic model in combination with GIS environment are used for assessing landslide over large areas[4].

2. VARIOUS MODEL APPROACHES FOR MAPPING SUSCEPTIBILITY

Basically Speaking, methodologies used throughout literature for landslide hazard assessment can be categorized into qualitative, Semi-quantitative & quantitative. Different methods have been adopted and developed which can be summarized in fig. 1.

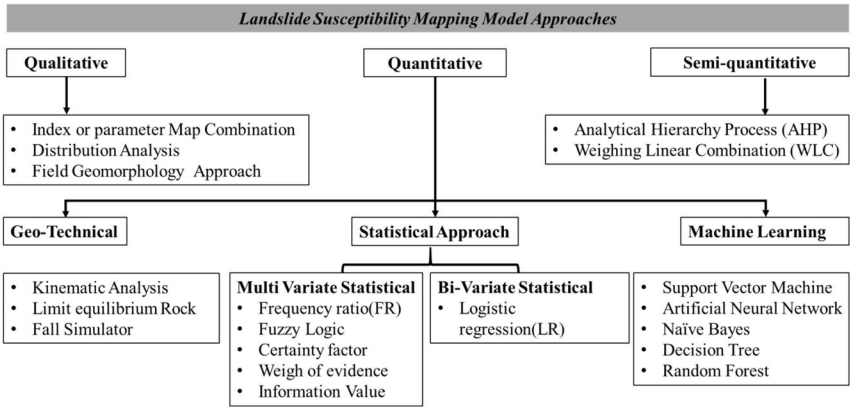

Figure 1: Various Methods Approaches For landslide Zonation

2.1 Data Driven or Quantitative Method:

Identifying of relationship between influential factors and the incidences of landslide is the core concept followed in quantitative methods[7]. A numerical interpretation is used to identify the relationship. Quantitative methods can be subdivided into statistical analyses, whether bivariate or multivariate, and deterministic methods. The latter involve detailed examination of specific sites or slopes using geo-engineering models[8]. Deterministic quantitative methods, often expressed in terms of the factor of safety, primarily rely on engineering principles associated with slope stability, such as the limit equilibrium method[9]. Data-driven models can be further classified into three categories: statistical, probabilistic, and machine learning.

Statistical model such as weigh of evidence[10] ,evidential belief[11], information value[12], frequency ratio[4]and certainty factor model [13] are frequently utilized landslide zonation. Multi variate analysis logistic regression[9] is most widely used thorough literature. In addition, advance machine learning model have been used recently including support vector machine [14], artificial neural network[15], and random forest [16]. A general scheme of steps followed in quantitative method in GIS software can be shown in fig. 2.

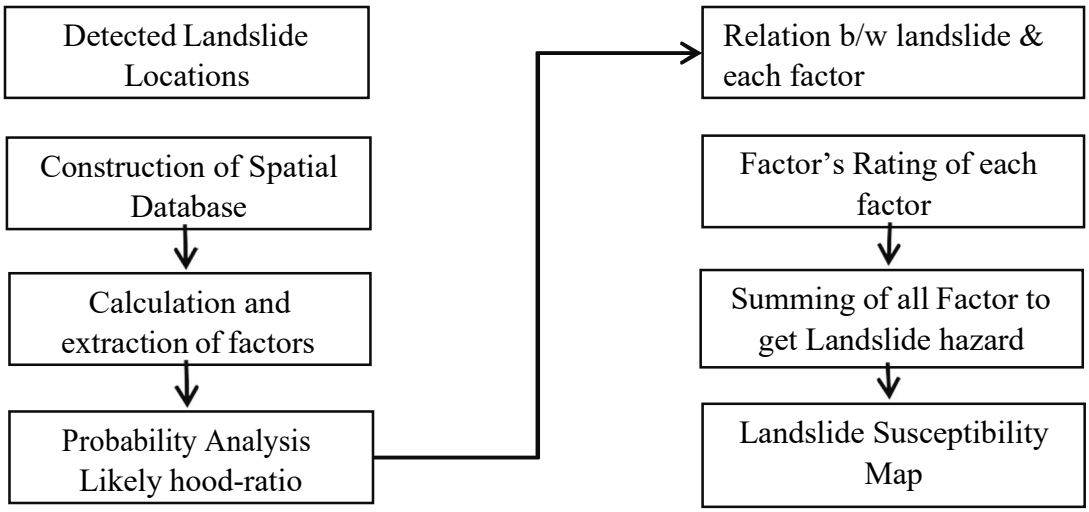

Figure 3: General Methodology Followed in quantitative method

2.2 *Qualitative methods:*

Broadly speaking, qualitative approaches rely entirely on the judgment of the individuals conducting susceptibility or hazard assessments. Input data typically come from on-site evaluations, often supplemented by aerial photo interpretation. These methodologies are also referred to as Expert Evaluation Approaches[17], can be divided into two categories index parametric maps combination and field investigation of geomorphology characteristic. A method proposed by Amadesi and vianello (1978) involve following steps as shown in fig. 3 to evaluate susceptibility map by overlaying structural maps with lithological map and slope map, which s then refined by first considering land use and then geomorphology map.

2.3 *Semi-quantitative methods:*

A qualitative method usually entails the straightforward process of conducting landslide inventories to identify locations or sites with pertinent geological and geomorphological characteristics susceptible to instability. However, certain qualitative approaches incorporate the idea of ranking and weighing, possibly transitioning into a semi-quantitative nature[9]. Examples of qualitative method are Analytical Hierarchy Process (AHP) develop by satty (1980) used by [10] and Weighted Linear Combination (WLC) by [18].

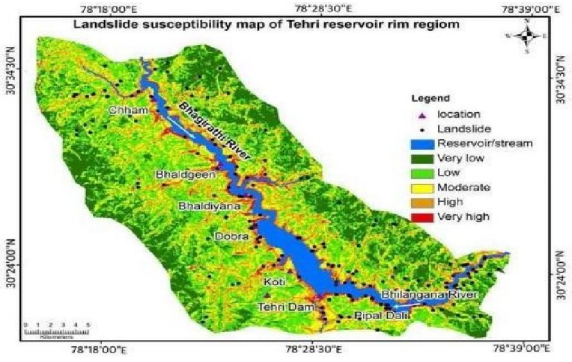

Figure 4: Landslide Susceptibility Zonation Mpa by AHP by [19]

3. DATA SOURCES & METHODOLOGY

3.1. Data Sources & Remote Sensing:

Different type of remote sensing technologies are used collect various data types in the past from different sources to develop landslide susceptibility maps in different regions thought the globe few of which can be summarized in the table given below;

Table 2: Data Sources used to collect relevant information

Data type	Remote Sensing	Source
Slope, Aspect,	ASTER DEM,	https://earthexplorer.usgs.gov/
Elevation, Curvature,	Alos Palsar	https://search.asf.alaska.edu/#/?dataset=ALOS
Relative Relief	SRTM DEM	https://search.earthdata.nasa.gov/search
Landslide inventory	SPOT-5 , Google earth,SPOT-1	https://earth.esa.int/eogateway/missions/spot-5
Land use/Land Cover, NDVI	Land Sat-08, Sentinal-2	https://landsat.gsfc.nasa.gov/satellites/landsat-8/
Soil Type	-	Geological Survey Department
Rainfall	-	Metrological Department
Road	SPOT-5 images	https://earth.esa.int/eogateway/missions/spot-5
Network/Drainage		
Density		
Distance from Fault	LISS-III	https://www.usgs.gov/centers/eros/science/usgs-eros-archive-isro-resourcesat-1-and-resourcesat-2-liss-3
Topographic Wetness	DEM	https://earthexplorer.usgs.gov/
index (TWI)		
Stream Power Index	DEM	https://earthexplorer.usgs.gov/
(SPI)		
Lithology		Geological Survey Department

3.2. Methodology:

Generalize step wise study used to develop landslide susceptibility map can be shown in the table below;

Table 3: Different step followed throughout the research for mapping susceptibility of landslide

S. No	Course of action	detail
1	Information on PastLandslide	Detect previously occurred landslide its spatial and temporal distribution

2	Identifying relevantfactors	Review and choose suitable geo-environmental data while taking into account the initial scale of the information.
3	Choosing Suitable mapping unit	Choosing an appropriate grid/Cell/pixel size in GIS depending on information of geometry of landslide i.e Point, Polygon.
4	Suitable quantitative/Qualitativ emodel	Depending upon the available resources and knowledge , the expected outcome and scope of study selection of suitable model.
5	Asses performance ofmodel fitting	Check the consistency and accuracy of the results obtain from statistical model by using proper metrics and techniques.
6	Check prediction Accuracy of the model	Select and utilize suitable methods to quantitatively estimate the uncertainty linked to model performance.
7	Develop protocol for landslide	Develop and design an appropriate protocol for landslide by involving the stake holders and the consideration of zonation based on susceptibility.

4. CONCLUSION

Through the literature review it is observed that there is significance diversity in landslide and relevant thematic data type, modeling approaches, study regions and criterion for assessing performance of model. Common quantitative approaches for susceptibility assessment are frequency ratio method, logistic regression, neural network analysis, and weigh of evidence analysis, with recent preference for machine learning techniques. No single model gains superiority over other, however certain model exhibit better performance in specific condition. A conclusion can be drawn that the expertise and knowledge of analyst in employing a specific classification model are crucial and greater concern is required regarding importance of multiple methods to develop diverse susceptibility assessment from same landslide and thematic data. There is still need for susceptibility assessment that should be carried out on large scale like on country level and continent because of wide spatial distribution of the hazard.

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