# Landslide hazard zonation and evaluation using GIS and remote sensing: A Review

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**Abstract -** *Landslide is a significant natural hazard in mountainous terrain countries all around the world. Such disasters cause for the loss of hundreds of millions of dollars and thousands of death to all record each year. Scientific studies will help to minimize risks posed by sudden landslide hazard occurring in different corners of the world. The objective of this review focus on the study of methodologies used in previous research articles related to landslide hazard zonation. Geological maps were used as a source for lithology, soil and land use was processed from Landsat +ETM satellite. Slope and elevation were derived from Digital Elevation Model (DEM) collected from ASTER satellite. LHZ maps were generated using a raster calculation. Results categorize study areas into four compartments, based on their raster calculation processed using GIS environment. 30% of study areas under the review articles were found a no hazard area and only 21% were considered as high hazard.*

***Keywords;*** *Landslide, hazard zonation, Geographical information system, Remote sensing*

## 1. INTRODUCTION

Any disaster threat, which hamper natural process and accompanied by deleterious effect on humans and ecosystem can be considered as a natural hazard. Natural threats can be divided based on their types and effect on the biosphere and natural ecosystem. This include geological, which is highly deteriorating the earth surface, water related disaster (hydrological) and metrological hazards are among the classifications. Many geological disasters are felt when they cause a massive economical loss. Landslide Hazard Zonation (LHZ) divide the geographical locations in to compartments based on their exposure to land slide incident by studying crucial driving factors for insatiability[1].

Weather related hazards predominantly wind and heat driven disasters are the most common ones under the meteorological disasters [2]. This review article constituent related research articles made since 1990 up to current status i.e. 2018, highlighting the slow developments of LHZ techniques and mechanism to map land slide vulnerable areas.

Heat waves affect the USA and south Asian countries frequently hurricanes and freezing rain are also considered as metrological hazards. Landslide is the most popular hazardous disaster which is caused by natural and anthropogenic reasons in many countries [3]. Massive deforestation, excessive overgrazing, quarrying, resource wastage are the main man made causes for a landslide hazardous disaster [4]. It is difficult to forecast and predict most of the natural hazardous disasters but it's possible to study the pattern and deduce and design preventive measures. Even though is not possible to eliminate, if the hazard is well understood and appropriate measures are taken by the concerned body, the magnitude of the loss both economically and naturally can be minimized [5]. Previous studies have been done in assessing the risk of the hazard and develop mechanisms to minimize the risk and cope up with the disastrous effect. It is possible to develop an action plan and minimize the risk if appropriate studies and information collected before the disaster happen [6]. Such risk minimization strategy is called landslide hazard zonation, which is accompanied by of different methods and analysis.

Landslide disaster refers to any mass wasting including wide range of ground movement, deep- seated rock failure, rock falls, debris flows and mud flows. There are different driving factors for this incident like, slope imbalance, from mountain to coastal areas or even submarine landslides[7]. Gravity is a primary factor for landslide including other reasons which cause slope instability, which expose slope to lose its maintenance. Trigging factors may be also heavy rainfall which wash away soil of the certain geographical location and make the areas prone to disaster decreasing the shear strength of slope material will exacerbate the suitability of the areas to more vulnerable condition [8]. The following are among the natural causative factors for land slide

I. Glacier evaporation and melting down
II. Availability of more than adequate ground water in a certain areas
III. Hydrostatic pressure on earth fractures
IV. Poor vegetative coverage and inadequate soil management
V. Soil erosion by rivers and waves of water
VI. Chemical pollution of ground water
VII. Massive earthquakes destabilizing slope by soil liquefaction

VIII. Volcanic disasters

Heavy prolonged rain fall take the lion's quotient for causing landslide disasters passage of cyclones, tsunami, and thunderstorm are also driving reasons. Duration, intensity and chemical composition of the rain fall will highly determine the magnitude of the land slide[9].

### 1.1 Land slide prevention mechanisms

It's possible to prevent the land slide hazard by following simple strategies including:

**Plant vegetation**: Planting small shrubs and plants on the slope is an alternative mechanism. As plants and shrubs grown on the slope their root hold together and prevent the soil erosion which in turn hinder land slide. Some selected plant species with a good ability of holding soil to their root can be selectively planted in campaign.

**Retaining Walls**: Retaining walls are also a good mechanism, Proper drainage facility by constructing wooden or concrete retaining walls will save soil erosion which in turn hinder landslide incidence

**Preventing soil erosion**: building gutters will prevent landslide by diverting water discharge which is a potential soil erosion factor. If diverting the water is not suitable for the condition it is possible to build small dams and minimize the speed of the water runoff over the slope. As velocity of water on the slope determine the amount of soil eroded, constructing small dams will help to save eroded soil by minimizing the speed of the water runoff

**Altering the Slope Gradient**: altering the slope gradient of the vulnerable areas is a simple tricky mechanism to minimize land slide damages.

Certain determination factors need to be considered in LHZ process. Lithology is the main factors causing landslide, which the rock type of the susceptible area influencing tremendously the hazard occurrence. These helps to predict the potential effects and to reduce the probability of occurrence by mapping the hazardous area. Chauhan confirms that the occurrence of landslide happened in highland areas and the influence of man-made activities are one of the potential causes of these disasters. The effect of hydrological processes is also the main prominent factor.

Geo and Lee reported that climate, precipitation, bedrock and soil conditions along with slope highly influence landslide occurrence, and the areas affected in the past will have a more quotient in causing similar disastrous hazard [10]. In the inventory data analysis the papers identifies 50 different past landslides from field studies are collected and these data are processed by the help of GPS [11] . Landslide hazard zonation is worked in different highland areas because most of the methodology of landslide hazard zonation technology show advancement with technology. The nature of the susceptible area determines the risk assessment approach because parameters causing the landslide will not be the same in all risky geographical locations [12]. The mechanism to cope up with the risk may be varying according to the key factors that are driving the disaster. Appropriate study mechanism will follow distinct methodologies in studying landslide zonation. Even though most of the landslide occurrence shares similar parameters, only one determinant factors may not be applicable in landslide zonation [13]. Approaches in landslide zonation can be categorized under direct and indirect methodologies. The direct method may consist inventory landslide and heuristic methodologies. In direct methodology, the expertise and cartographer on the areas determine the decision unlike the indirect one. Heuristic methods are focusing on quantitative and number based analysis based on landslide inventory to identify the geological and geomorphologic properties. Most of the studies use different methods to understand the pattern of previously recorded landslide. These methods are; GIS based statistical & probability approach, inventory of past landslide, bivariate approach, deterministic approaches [14]. In these approach all the methodologies are used based on the 6 causative factors calculation of hazard index equations. As the studies describes that all the data are taken from topographical and satellite images, metrological reports, digital elevation model data, Google earth images and the DEM 30m resolution utilized to extract slope, aspect, elevation of the study area by using ASTER satellite.

## 2. Hazard mapping / Assessment Techniques/

### 2.1 Statistical Approach

[15] Komac and Zorn reports that, the exposure of certain area for the landslide in the past is highly influential in determining the occurrence for the future. Statically approach uses landslide frequency and GIS as the main input to deduce the occurrence. The basic principle is that based on previously recorded landslides and it will be helpful to guess its occurrence scientifically. Variables causing landslides will be applied in calculating and analysis of landslide hazard zonation. There are wide ranges of multivariate techniques available, as may be seen from the different statistical method and factor analysis is done by using data squeezing which compress large files to smaller, more manageable, number of factors. [10] These study uses multivariate statistical methods of logistic regression methods and probabilistic methods, there are 14 probabilistic factors and 9 logistic regression factors are taken and calculating from different databases. For logistic regression methods the dependent variables must be input as 0 or 1. Factors analysis will help to distinguish the most important factors from the junk data set (Ransom 1991). This methods are the most common approaches which are used in different literatures [11] Showed that by using this

approaches it is possible to spot the areas on the map to easily understand and study the effect of different land slide causing factors like, slope, elevation, curvature, land-use, ground water surface traces. By using those causative factors, it uses the tool raster calculator in ArcGIS, total pixels occupied by each factor also identified. [13] These studies also identifies different methodologies that has a fruit full application. Other literatures like Landslide inventory, statistical (bivariate & multivariate statistics), geotechnical approach, but the study mainly focused on the probabilistic methods of weighted overlay method.

### 2.2 Deterministic approach

This approach gives a detailed and explanation about the effect and the magnitude of the landslide. It quantitatively represent the process, the severity and degree of the landslide by comparing determine factors in land slide hazard zonation. Deterministic approach utilized hydrological and slope data as input in zonation. Hydrological models in application today may be either two or three dimensional, the data generated in this models will be further processed by GIS operations. Slope stability models calculate the safety factors for a slope in two or three dimensions. This approach is difficult to manage for a number of reasons, like amount and sampling density of required physical parameters which is highly costly [16].

### 2.3 Artificial Neural Network

Artificial neural network is a mathematical model simulating the biological neural networks and incorporating the four mathematical algorithms. These models has three simple rules. Multiplication, summation and activation. In this model, factors will have different weights and the mathematical model will consider their weight during the mathematical calculations.

In artificial neural network inputs with different weights will be multiplied by individual weights and the artificial neural network will be the sum of each input [17].

Artificial neural networks consists of more than one neural networks which can solve complex real life problems by processing information. A single neural network can also easily analyze and gives a detailed reading for simple problems. For a complex and complicated tasks neural networks can be interconnected in a process called topology. Various artificial neural networks may have distinct kind of architecture. McCulloch and Pitts (1943) were the first to prepare artificial neural network model.

### 2.4 Fuzzy logic methods

This concept is based on partial logic, in the classical set theory membership is defined as 1=true or 0=false. Fuzzy logic defines the instability factors as members of a set reaching from 1 represents the highest susceptibility, to 0, represents no susceptibility of land sliding, allowing different degrees of membership. In several articles fuzzy logic based applications are used to mapping of landslide susceptible areas [18].

### 2.5 Inventory past land slides

Inventory models are very useful in predicting and assessing the risk and hazard of landslide based on history of the area. Previous studies and reoccurrence of the disaster will give an immense way to study and understand the degree of its frequency in the future. More than two inventories can be used for the study as the pattern and the severity of the parameters vary according to the specified areas of study [19]. Landslide inventories give a clear look on the geographical condition and distribution of past movements, maps and size of landslide, which is key in assessing and risk management measures.

### Role of remote sensing in Landslide Inventory

Comprehensive landslide inventory is an input for landslide hazard and risk analysis. Inventory maps predict the type of landslide along with time and date of occurrence. Inventory approaches may use distinct approaches for prediction including digital stereo image interpretation to automatic classification or the combination of both. Multi temporal images also applied in inventory mapping. The stereo-images play a key role for landslide inventory mappings as it provides a 3 dimensional visualization opportunity in parallel with derivation of height information. The role of satellite images is very useful with higher resolution. Landslides are directly affecting the ground surface, so remote sensing application is very suited to slope instability studies.

### 2.6 Application of remote sensing and GIS in hazard mapping

All methodologies in landslide hazard zonation share one common intersect which is GIS and remote sensing which are very important to specifically study and asses the occurrence of landslide in a specific areas [20]. Current trends in LHZ study grabs more attention from geoscientists and engineering professionals. In old days, it was difficult and laborer because of a time and effort required for manual handling and data processing. Computer based applications will help to minimize the time and energy loss for LHZ mapping in addition to its accuracy and precision. GIS is a computer based technology designed to capture, store, manipulate, analyze and display diverse sets of spatial and geo reference data. Upcoming new developments on LHZ focus on early waring and pre disaster management [21].

GIS is a technological framework for aiding accurate data processing, management, integration and analysis and display. Currently GIS, is considered as ideal tool to work on LHZ (Carrara et al). Even though studies have been conducted on proposing variety of different GIS based LHZ methods for sustainable management, systematic comparison of different modeling in GIS based landslide probability don't get enough attention in the scientific community. LHZ mapping is a tool to identify those areas, which are vulnerable to landslide hazard based on important factors, and their past history of exposure for landslide [22].

Extremely dangerous places for data collection follow different procedures based on their specific topographical condition [23]. The authors uses different parameters for zonation including geological, topological, meteorological maps reported in published papers [11], [20], [24], [25]. Data analysis is usually processed by statistical, probabilistic and GIS accompanied by taking Digital Elevation Model (DEM), enhanced thematic mapping tools, satellite images and raster calculation. The highest ever record of extinction by land slide was recorded in the years from 1991 up to 1999. Studies also states that the susceptibility of these risk are overcome by using of mapping the risky place by using of logistic regression and probabilistic method and extract those information from geological, topographical, soil & forest maps and these data are constructed based on the knowledge of GIS, aerial photographs and field survey [10]. It is not difficult to spot a geographical location, which is highly prone to land slide. Most of the occurrence of landslide are predictable because they are related to mountainous landscapes and also frequently seen in coastal area [26]

## 3. CONCLUSIONS

Studies included in this review article used distinct ways to study the LHZ of specific areas. Specific factors are shortlisted as the main driving factors for land slide including, heavy rainfall, sloppy ways, and wet lands are among others. A methodology for study varied based on the geographical location and data type of data relevant for LHZ. GIS based statically approach was used along with inventory of past landslide for data related with topographical maps, satellite images and metrological data, on the other hand logistic regression method widely applied for filed survey, aerial photographs, and soil and forest maps. From the reviewed articles, it can be concluded that geology, land utilization also considered as determinant factors in studying LHZ of areas specially found in a sloppy and roadside locations.

According to literature review under this review article, the mechanism, cause and adequate understanding of the landslide are the precondition for effective landslide control management. Geological structure of the area is the foremost requirement for ideal risk managements caused by land slide. Hydro geological study as well as geomorphologic attribute, which may directly lead to a failure of the slope. Landslide control measures include two types of works

1. Prevention works and
2. Detention works

The former intends to stop or mitigate a landslide motion by changing the natural conditions, such as, topographical, geotechnical and water conditions at a landslide site, while the latter aims at detaining a part of the landslide motion or the entire landslide motion using structural control works.

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