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Application of Remote Sensing and GIS in Landslide Mapping and Management

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Abstract: ***Landslide is most decisive nature hazard in hilly area. In India Himalaya and Western Ghats region have many hot spots of landslide. Reason of landslide is natural as well as man-made. In recent years the frequency of landslide is increase and main reason behind it, is rapid development of infrastructure like roads, dams, canals and building in hilly areas so the natural ecosystem of the hilly area is disturbed and frequent occurrence of climatic events also main reason behind it. For the complete landslide hazard management and mitigation, complete assessment of the hilly area is most important, and also find out factors which decisive for creating instability in the region. For the multidimensional study of hilly region particularly landslide hazard approach, there is a need of multidisplinary studies which include geology, hydrogeology and, geomorphology etc. and also need of different government agency and stakeholders also. From all point of view identification and mapping of landslide hot spots in hilly area is fast task in landslide management and mitigation for that purpose spatial-temporal data of various elements is required. In inaccessible hilly area Remote sensing images provide many useful information of land use land cover and change in terrain of this area. GIS provide tools of spatial data analysis and quarries and DEM models helps in landslide mapping and management. In this paper author explain the role of Remote Sensing and GIS in landslide mapping and management.***

Keywords: Landslide, GIS, Remote Sensing Image, DEM models.

1. Introduction

Landslide defined as the rapid downward and outward movement under the influence of gravity, of a mass of rock, earth or artificial fill on a slope. Landslide is occurred due to natural processes as well as anthropological activities. Both of them play a major role as the triggering factor in the occurrence of landslide.

Hazard refers to the probability of occurrence of an event within a specified period of time and within a given area of potentially damaging phenomena, e.g., landslide. Landslides, defined as the movement of a mass of rock, debris or earth down a slope (Cruden, 1991).

Reason of landslide is natural and man- made also. Natural reasons are angle and degree of slope, intense rainfall, earthquake shaking, weathering and erosion, rate of percolation of water in soil on hill slope, change in water level, rapid stream erosion etc., and man-made are infrastructure development like road, canal, building on the slop of hills. Deforestation and changing land use pattern in hilly area increase the rate of soil erosion these are the important factors of landslide occurrence.

In disaster management like landslide includes three phases of disaster management, pre-disaster, during disaster and post- disaster. In all this three phases of disaster management remote sensing and GIS play very important role. The remote sensing is an important factor in detecting landslide because it is not always easy to access the place of mishap by comminuting to the place. The use of remote sensing is very important at all the time. The remote sensing based landslide studies mainly deals with the dictation, mapping, monitoring and the GIS has the application potential to integrate a variety of data sets at different scales to generate landslide hazard zonation map which is very beneficial for the management at the time of disaster and also for the development activities (Arya et al. 1994).

Landslide Hazard Zonation (LHZ) is defined as a method of dividing the land surface into homogenous zones and assigned a numerical extent of landslide hazard. It is include those areas that are, or could be, affected by landslide, assessing the probability of such landslide occurring within a specified period of time (NDMA).

Social and economic losses due to landslides can be reduced by means of effective planning and management. In the past two decades, significant developments in processing power, remote sensing (RS), and geographic information systems (GIS) have made it easier to prepare landslide susceptibility maps (Achour and Pourghasemi, 2020, Abhijit S. Patil, Sachin S. Panhalkar,2023). These advances have revolutionized the field of landslide studies (Lee, 2019; Shano et al., 2020; Patil et al., 2020; Pradhan et al., 2020, 2021; Coco et al., 2021; Hodasova and Bednarik, 2021, Abhijit S. Patil, Sachin S. Panhalkar,2023).

Reason of Landslide:
Landslides occur when the slope (or a portion of it) undergoes some processes that change its condition from stable to unstable. This is essentially due to a decrease in the shear strength of the slope material, an increase in the shear stress borne by the material, or a combination of the two. A change in the stability of a slope can be caused by a number of factors, acting together or alone. Natural causes of landslides include:

- Increase in water content (loss of suction) or saturation by rain water infiltration, snow melting, or glaciers melting.
- Rising of groundwater or increase of pore water pressure (e.g. due to aquifer recharge in rainy seasons, or by rain water infiltration).

a) Increase of hydrostatic pressure in cracks and fractures.
- Loss or absence of vertical vegetative structure, soil nutrients, and soil structure (e.g. after a wildfire).
- Erosion of the top of a slope by rivers or sea waves.
- Physical and chemical weathering (e.g. by repeated freezing and thawing, heating and cooling, salt leaking in the groundwater or mineral dissolution).
- Ground shaking caused by earthquakes, which can destabilize the slope directly (e.g., by inducing soil liquefaction) or weaken the material and cause cracks that will eventually produce a landslide.
- Volcanic eruptions.

b) Changes in pore fluid composition.
c) Changes in temperature (seasonal or induced by climate change).

Landslides are aggravated by human activities, such as:
1) Deforestation, cultivation and construction;
2) Vibrations from machinery or traffic.
3) Blasting and mining.
4) Earthwork (e.g. by altering the shape of a slope, or imposing new loads);
5) In shallow soils, the removal of deep-rooted vegetation that binds colluvium to bedrock.
6) Agricultural or forestry activities (logging), and urbanization, which change the amount of water infiltrating the soil.
7) Temporal variation in land use and land cover (LULC): it includes the human abandonment of farming areas, e.g. due to the economic and social transformations which occurred in Europe after the Second World War. Land degradation and extreme rainfall can increase the frequency of erosion and landslide phenomena. (https://en.wikipedia.org/wiki/Landslide#Causes)

Role of Remote Sensing and GIS in Landslide:
Mitigation of disasters on account of landslides can be successful only with detailed knowledge about the expected frequency, character and magnitude of mass movements in an area. For forecasting occurrence of landslides in near future in an area, comprehensive knowledge of causative factors of land sliding is necessary.

Hence, the identification of landslide-prone regions is essential for carrying out quicker and safer mitigation programs, as well as future strategic planning for an area. Therefore, the Landslide Hazard Zonation (LHZ) of an area becomes significant whereby the area is classified into different LHZ ranging from very low hazard zone to very high hazard zone (Arora et. al,. 2004). Landslide susceptibility mapping is of great value for landslide hazard mitigation efforts (Ercanoglu et al., 2004). Landslide hazard analysis focuses mainly on the spatial zoning of the hazard (Beek and Asch, 2004).

Remotely sensed data are used in solving various environmental tasks. This technology can be used as an effective aid in natural hazard investigation, as well as for the purpose of environmental planning. Terrain information, such as, land cover, geology, geomorphology and drainage could also be derived from it and existing thematic information can be updated to enable the quantification of human interference on the earth's surface. Geographic Information System (GIS), as a computer- based system for data capture, input, manipulation, transformation, visualization, combination, quarry, analysis, modeling and output, with its excellent spatial data processing capacity, has attracted sincere attention in natural disaster assessment.

Spatial and temporal thematic information derived from remote sensing, thematic maps and ground-based information needs to be integrated. Several researchers have envisaged remote sensing and GIS technologies for LHZ studies. Specifically GIS has the potential of performing Landslide Zonation using various thematic layers.

Mapping of landslide:
Several kinds of maps are used to depict danger from landslides. These maps might be as simple as a map that uses the locations of old landslides to indicate potential instability, or as complex as a map incorporating probabilities based on variables such as rainfall, slope angle, soil type, and levels of earthquake shaking. The following types of maps are used to describe and depict landslide hazards.

Landslide inventory maps show landslide locations and might show the dimensions and geographical extent of each landslide. One clue to the location of future landsliding is the distribution of past movement, so maps that show the location and size of landslides are helpful in predicting the hazard for an area.

Landslide susceptibility maps describe the relative likelihood of future landsliding based solely on the intrinsic properties of a locale or site. Some organizations use the term "landslide potential map" for maps of this kind. Prior failure (from a landslide inventory), rock or soil strength, and steepness of slope are three of the more important site factors that determine susceptibility.

Landslide hazard maps indicate the possibility of landslides occurring throughout a given area. An ideal landslide hazard map shows not only the chances that a landslide might form at a particular place, but also the chance that it might travel downslope a given distance.

Landslide risk maps show landslide potential along with the expected losses to life and property, should a landslide occur. Risk maps combine the probability information from a landslide hazard map with an analysis of all possible consequences (property damage, casualties, and loss of service).(https://www.usgs.gov/faqs/what-a-landslide-hazardmap#:~:text=Landslide%20hazard%20maps%20indicate%20the,travel%20downslope%20a%20given%20distance) .

Mapping the vulnerability of regions to landslides is a first, but crucial step in setting up a risk mitigation and adaptation strategy that also includes an early warning system. Vulnerability assessment is a useful adaptation planning tool for mitigating climate risks (IPCC 2014). The mapping of areas that are vulnerable to landslides is quite important, given the context of rapid changes in climate, especially patterns of rainfall, number of rainy days, a rapidly changing

landscape (land-use and land-cover changes), changes in conditions in the soil, natural geological and geomorphological processes, degrees of saturation and increasing human habitations in mountain habitats. In addition, the patterns of surface water behavior – flows and stocks – also need to be studied, particularly from the point of view of the extent of various controls on the flow of water – slope, fractures in the underlying rock and the patterns of precipitation.

2. Conclusion

Landslides, ground settlement and avalanche interfere greatly and persistently with mass activities. It occurs when hill side or valley side slopes falls using to specific geological, climatic and biotic factors. They are bringing about major disruptions of towns and cities, communication systems and large structure including dams and bridges. Slope plays a dominant role to create gravity force for wasting process like land sliding, soil creeping, slumping etc. Construction activities for development in hilly region have greatly enhanced the frequency of landslides. Mitigation of disasters due to landslides can be successful only with detailed knowledge about the expected frequency, character and magnitude of mass movements in an area. To forecast possibilities of the future landslides in an area, comprehensive knowledge of causative factors of land sliding is necessary. The wide applicability of geospatial technologies are using in solving various environmental tasks. This technology can be used as an effective aid in natural hazard investigation, as well as for the purpose of environmental planning. Drainage map, contour map, digital elevation model, slope angle map, land use / land cover map, relative relief map, thrust (buffer) map, photo lineament (buffer) map, geological map are basic requirement for landslide hazard zonation or for identification of landslide prone areas which can be delineated under GIS and remote sensing data. In mapping of landslide and Landslide Hazard Zonation (LHZ) remote sensing and imagers of different resolution and different frequency of hill are giver synoptic view of area which is played very crucial role in every phase of landslide management. Geographic Information System (GIS), as a computer- based system for data capture, input, manipulation, transformation, visualization, combination, quarry, analysis, modeling and output, with its excellent spatial data processing capacity, has attracted great attention in natural disaster assessment.

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