Landslide Susceptibility Mapping using GIS based Statistical Models and Remote Sensing in Tropical Environment

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***Abstract*— Most shallow landslides are occurred by heavy rainfall on hill slopes which result in large casualties and huge economic losses in mountainous regions. Slope failure in hills occurs as soil resistance decreases in the presence of the stress acting which is been developed due to reasons such as increase in soil moisture content, changes occurred in land use causing slope instability and many more. Landslides occurred by rainfall can possibly be foreseen in real time by jointly using rainfall intensity-duration and information of land surface susceptibility. Terrain analysis applications using spatial data such as aspect, slope, flow direction, compound topographic index along with information derived from remotely sensed data such as land cover**

The project presents GIS based spatial data analysis for landslide susceptibility mapping in parts of Nandi hills. Six important causative factors for landslides were selected and corresponding thematic data layers were prepared in GIS. The input data were collected from the topographic maps, satellite image, field data and published maps. Numerical weights for different categories of these factors were determined based on a statistical approach and then integrated in GIS environment to arrive at landslide susceptibility map of the area. The landslide susceptibility map classifies the area into five classes of landslide susceptible zones i.e., very high, high, moderate, low and very low. An attempt was also made to validate the map with the existing landslides of the area. The results of the analyses also showed that the Geographical Information System (GIS) technology provides a powerful tool to do spatial analysis and to model landslide hazard

Keywords—GIS, Slope failure, environment, landslide.

INTRODUCTION

The Earth consists of atmosphere, hydrosphere, and lithosphere. These layers are subject to different processes due to mutual interaction or self-interaction. Interactions can lead to various phenomenon, weathering, erosion, floods, hurricanes, landslides, earth quakes, volcanoes, tectonic movements, etc., which can lead to natural hazard. Natural hazards are an integral component of life on Earth

Natural disasters are grouped as:

Hydro-meteorological disasters: avalanches/landslides, droughts/famines, extreme temperatures, floods, forest/scrub fires, windstorms and other disasters, such as insect infestations and wave surges

Geophysical disasters: earthquakes, tsunamis and volcanic eruptions. The number of recorded natural hazards has increased in the last 50 years with the greatest increase in frequency attributed to hydro-meteorological disasters, with a lesser increase attributed to biological disasters and a slightly lesser increase attributed to geological disasters. The pressure for infrastructure development to meet the need of rapid urbanisation and global competition has led to expansion of construction activities even in hilly terrains and has catapulted frequency of landslides to dramatic proportions in recent decades. Landslide refers to the movement of a mass of rock, debris, or earth down a slope or any down slope movement of soil and rock under the direct influence of gravity. This includes various types of slope failures, like, earth and debris flows, slumps, slides, and soil and rock fall. Landslide is a phenomenon of a mass movement of landform and which is characterized by moderately rapid to rapid (> 30 cm per year) down-slope transport, by means of gravitational stresses, of a mass of rock and regolith that may or may not be water saturated. Landslides are one of the normal landscape building processes in undulating terrain and are common in Himalayas and Western Ghats regions in India. It includes any detached mass of soil, rock, or debris that moves down a slope or a stream channel. They are classified according to the type and rate of movement and the type of materials that are transported

Two types of forces are at work: 1.driving forces combine to cause a slope to move, and 2. friction forces and strength of materials act to stabilise the slope. When driving forces exceed resisting forces, landslides occur. It is one of the common natural hazards with devastating effects. They become a problem when they interfere with human activity resulting in damage to property and loss of life, evident from recent episodes in Ooty (Tamil Nadu) and Kerala. In order to minimise the losses due to landslide, it is necessary to identify and analyse the most

important determining factors leading to slope failures. They occur as “on-site” hazards and “off-site” hazards, and should be distinguished to effectively plan for future hazard situations

On-site hazards occur on or near the development site and are typically the slower moving landslides that cause most of the property damage in urban areas. They include features called slumps, earth flows and block slides

Off-site hazards typically begin on steep slopes at a distance from homes or developments, and are often rapidly moving

Figure 1.1 depicts a typical landslide that has occurred in the Nandi hills region due to heavyrainfall

1 DIFFERENT TYPES OF LANDSLIDES

Landslides are classified and described on the basis material and types of movement. Materials wise classification is on based on the size of predominant material present in the slide i.e, rock,debris and earth.

The movement based classification is divided into six types as falls, topples, slide, spread, flow,complex. These types of landslides are resultant of the temporal conjunction of several factors.Landslides are classified by causal factors and conditions, and include falls, slides and flows, which are described below. There are many attributes used as criteria for identification and classification including rate of movement, type of material and nature of movement

A combination of characteristics can also contribute to an increased risk of landslide hazards. Types of landslides are as follows

Falls: Falls are abrupt movements of rocks and boulders i.e., masses of geologic materials that become detached from steep slopes or cliffs. Movement occurs by free-fall, bouncing, and rolling on separation along discontinuities such as fractures, joints, and bedding planes. Gravity, mechanical weathering, and the presence of interstitial water strongly influence falls..In falls, material is detached from a steep slope or cliff and descends through the air by free fall or by bouncing or rolling down the slope. Rock fall, the most common type, is a fall of detached rocks from an area of intact bedrock

Topples: The end-over-end motion of rock down a slope. Under the actions of gravity and forces exerted by adjacent units or by fluids in cracks toppling occurs. Toppling failures are distinguished by the forward rotation of a unit or units about some pivotal point, below or low in the unit.

2 FOREST AND HILL MISS MANAGEMENT

Forest logging, fire and cultivation on hill slopes are considered the most important in triggering shallow landslides

The causal factors that contribute to landslides in an area are (i) preparatory and (ii) triggering factors. These mainly consist of Fissured Materials- Loose soil, rock and fragmented materials. Mass discontinuities- Adversely oriented slip control, bedding lineaments, faults, etc. Water and soil erosion of the slope toe- Due to streams or human anthropogenic activities .Intense short period rainfall- Heavy rainfall for a shorter duration on a weak plane. Prolonged high precipitation- High rainfall, dam construction and alteration in river course. Loading of the slope at its crest- Construction on the top of slope, heavy earthmoving equipments, etc. Shrink and swell of expansive clay- Soil of layer or clay loamy with high permeability and porosity. Water leakage- Seepage of water from any construction or natural resources

Understanding of these factors in a region helps in adopting at stabilisation approaches. Landslide can be triggered by various factors. The relationship of them can be expressed as: Landslide = f (hydrology, geology, land use and land cover, slope morphometry, anthropogenic activity, natural hazards).

3APPLICATION OF GIS AND REMOTE SENSING LANDSLIDE HAZARD ZONATION

Landslides often cause damage for property and people. To reduce the losses due to landslides over the long term identification of unstable slopes to aid in mitigation of landslide hazards is the integral part of land management. Landslide hazard zonation is a process of ranking different parts of an area according to the degrees of actual or potential hazard from landslides .The evaluation of landslides is a complex task as the occurrence of the landslide is dependent on many factors. The process of zonation of landslides comprises of preparation of maps showing the status of causality factors in the study area with the help of aerial photographs, satellite imagery, topographic maps and geographical maps

The geological data of lithology and structure can be extracted from the remote sensing data or by the digitizing the map. The lithological units can be mapped by a panchromatic or multispectral or radar data. Over the same lithology, the spectral response may be quite variable,being a function of several factors

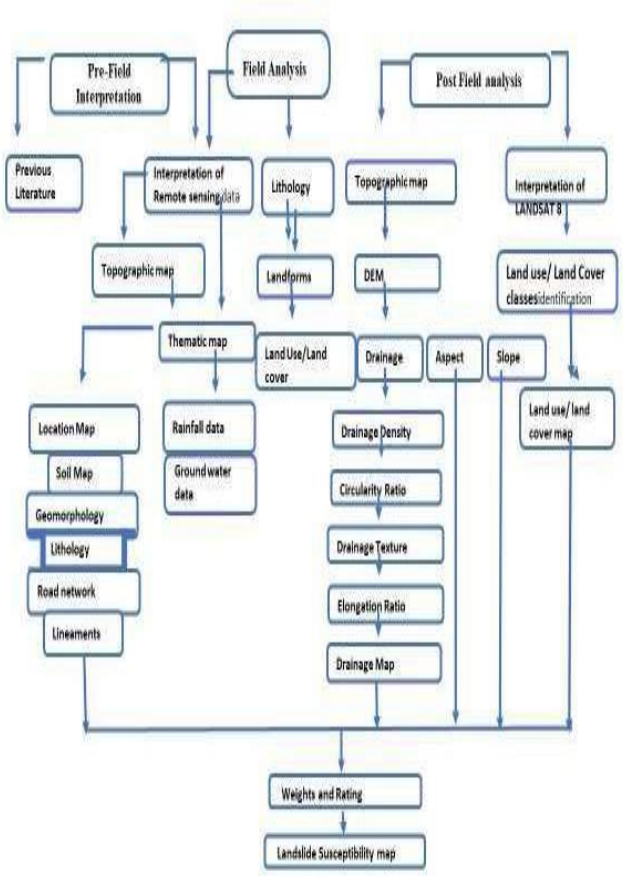
The factors that have to be accounted for deducing the lithological information are a) general geological setting, b) weathering and landform, c) drainage, d) structural features, e) soil, f) vegetation and g) spectral characteristics. These parameters are also interdependent, and interpretation is generally based on multiple convergence of evidence; however, even single parameter could be diagnostic in a certain case. The structural units like folds, faults, lineaments and bedding can be identification depends on resolution and dimension of the discontinuities

4. PREDICTION OF LANDSLIDE USING REMOTE SENSING AND GIS

In order to minimise the damage due to landslides, it is required to identify the regions, which are susceptible to

landslides. This requires spatial and temporal data related to the region. Geospatial technologies such as Geographic Information System (GIS) and Remote Sensing (RS) help in the analysis of spatial and temporal data. Remote sensing provides the spatial data at regular intervals, while GIS helps in the analysis. GIS is the ideal tool for the analysis of parameters with a high degree of spatial variability. Landslide susceptibility is defined as the proneness of a terrain to produce slope failures and susceptibility is usually expressed in a cartographic way. A landslide susceptibility map depicts areas likely to have landslides in the future by correlating some of the principal factors that contribute to landslides with the past distribution of slopefailures

5 METHODOLOGY



6.SOFTWARE USED

IDRISI 3 for D.E.M, fusion of PAN & LISS-III, images raster analysis and image analysis and Arc View 3.2, MAPINFO 6.0 for vector analysis, ARCGIS ,QGIS

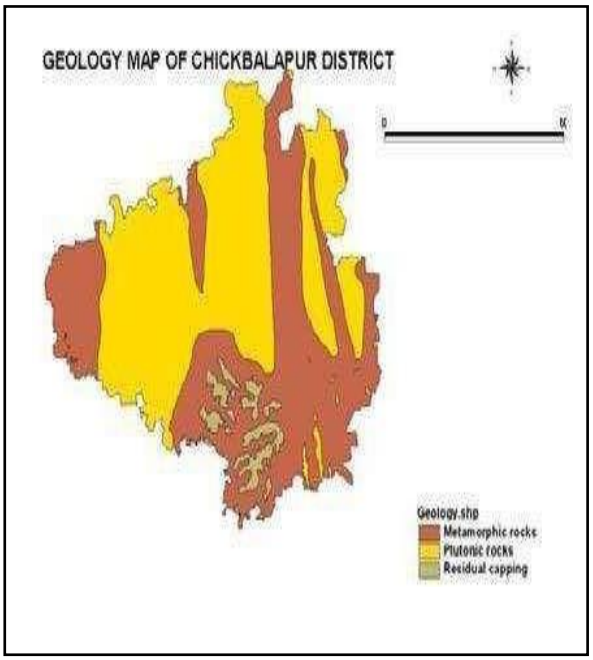
Landslide Occurred Area in 2022

Draining structures constructed in order to prevent rainfall

CONCLUSION

As per the landslide prone zone mapping, slides may occur due to infiltration of water in the unconsolidated material due to reservoirs and toe cutting of the hilly area for developmental activities. The study area with heavy rainfall of more than 4500 mm and instances of high intensity rainfall, which not only increases the surface flow in river basin but also induces a high piezometric head in the unsorted colluvium of clayey soil and metamorphic rocks. The area of study is having an abundance of wet surface due to heavy rainfall and surface water. The stability of the wet surface further reduces because of the existence of clayey soil due to its low porosity and permeability. Geological existence of metamorphic rocks along the lineament features increases hydrostatic pressures on the existing unconsolidated material, which trigger down slope movement. In the study area it is found that the slope excavation is mainly done in order to develop residential sites or build roads on sloping terrain as the area is having completely forested hilly terrain full and as a result now some slopes are much steeper than the pre-existing natural slopes. The added weight of fill placed on slopes can also result in an area prone for landslide hazards. Small landslides are common along roads, in either the road cut or the road fill. During the field visit it was found that most of the existing landslides are near the roads. Road associated landslides are good indicators of the potential impacts of excavation on new construction.

Contour Map



GEOLOGY MAP

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