Analysis of Landslide Susceptibility to Different Land Use Patterns in a Part of Kodaikkanal, Tamilnadu

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Abstract--- Landslides are one of the common natural hazards in mountainous area, resulting in loss of life and property. Landslides in Tevankarai stream sub-watershed is the object of study. This is studied with particular reference to land use pattern using statistic data of landslide occurrences as primary data, combined with engineering analogy method and ground investigations to find the characteristics its spatial distribution in the study area. The study uses sensitivity coefficient to assess the effect of each land use category on landslide susceptibility. The study shows that the most vulnerable category of land use is the construction land, consisting of settlements and communications, followed by agricultural lands, consisting of cropland and plantations. The study emphasizes the need for land use planning.

Keywords--- Landslide, Land use pattern, Kodaikkanal, Sensitivity Co-efficient

I. INTRODUCTION

SLOPE failures are one of the most destructive natural hazards. They consist of landslides, rockfalls and mudflows. They present a significant limitation to development in mountainous terrains. The assessment of landslide hazard and risk is therefore a subject of major interest for geo-scientists and land managers of mountain regions. The increased pressure of development and urbanization on environment and the awareness of the significance of the socio-economic impacts of landslides can be the major cause of this growing interest [1]. A reliable assessment of landslide hazard requires a detailed determination of temporal occurrence of landslide, which is a very difficult task and hence landslide susceptibility is more frequently assessed [2]. Landslide susceptibility is defined as the proneness of an area to landslides [3] and a landslide susceptibility map depicts the distribution of potential unstable slopes based on a given set of geo-environmental conditions [4], classifying the land surface into zones of different degrees of susceptibility [5]. The landslide susceptibility map is of crucial importance in the economic planning of urban areas and engineering structures [6]. It is a vital tool in helping the land planners to develop areas around the slopes that are likely to fail, to assess the hazard that a proposed use of land will affect the stability of an area, and to develop and review and mitigation options [2]. Geographic Information Systems (GIS) proves to be a basic tool for landslide susceptibility mapping owing to its efficiency in spatial data management and manipulation for spatial analysis [1], [7], allowing the frequent updating of susceptibility assessment procedures.

Kodaikkanal is a hill town situated in the western spur of the Western Ghats. It is one of the major tourist attractions in South India. Natural environment with weathered rocks and high annual rainfall makes the region vulnerable to geologic hazards. The area experiences rapid urban development with land clearing for housing and commercial establishments. Over the past decade, there is a significant increase in building density accompanied by large scale construction of urban infra-structural facilities, power facilities and exploitations of agricultural land. The numbers of landslide incidences keep increasing every year especially in the road section connecting the plains and the hill town. Anthropogenic interference is observed to be the most important factor causing landslides in this region. A natural geomorphic watershed boundary encompassing the town and its surrounding is selected for the study – the Tevankarai stream sub-watershed. An attempt is made to study the effect of the different land use categories and their impact on the landslides.

II. STUDY AREA

A. Geographical Position

The Tevankarai stream sub-watershed is a part of Dindigul District in Tamilnadu, located in the Western Ghats, set at the divide of the Tevankarai stream and Gundar river covering an expanse of 63.44 km². It is bound by latitudes 10°13’23” and 10°19’23”N and longitudes 77°27’8” and 77°33’48”E (Fig. 1).

B. Topographic Condition

This region is a gentle valley - nearly 87 % of the slopes have a gradient less than 35. The elevation is higher in the southern part of the basin and decrease towards the north and rises again in the north north-east. Few notable peaks are Mamumdi Malai Peak, 2195 m in the South and Perumalai Peak, 2337 m in the North - North East. The drainage pattern is mostly denticratic and the sub-watershed has a drainage density of 4.688 km²/ km².

C. Geological Condition

Bedrock geology is monotonous - charnockite in varying degrees of weathering with limited soil cover ranging between nearly bare areas in the north and north-eastern parts to
maximum thickness up to 3.1 m in the southern parts.

There are weathered charnockite in the upper most layers to a depth of 2.5 m. The study area is a typical hill terrain dominated by denudational landforms. The prominent features include pediments, valley fills, fracture valleys, structural controlled valleys and structural hills and valleys. Valley fills and pediments are evident in the study area. The cliffs, which are very few in number, are also noted. They are isolated and steeper; mostly with very little or no vegetative cover is the most vulnerable terrain feature in the study area. Valley fills, found in pockets of the study area are depositional features.

D. Climatic Condition

The climate is influenced by altitude - in general of temperate type. Annual rainfall is high; averaging to 1670 mm. Maximum rainfall is recorded in the months of October and November and minimum in January and February. Weathering prevails in this climate, causing soil and rocks to erode. Soil erosion and slope failures are dominant.

III. DATA AND METHODS

A. Data Resource and Processing

Land use map is prepared from the aerial photographs (Task No. 1307 A; Run Nos. 39 (Photos 37 – 41), 41 (17 – 30), 43 (16 – 29), 40 (37 – 48), 44 (7 -19); Year: 1985) and updated using the satellite imagery (IRS ID-LISS III; Path: 101 and Row: 066; Toposheets: 58F7,8,11,12; Years: 2003 and 2006) and is also verified in the field during field investigations. The land use map is classified as cropland, plantation, settlements, forests, scrub, barren- fallow land and water-bodies. Road map is extracted from 1: 25,000 Survey of India topographic maps. The result of the analysis is shown in Table 1. The total area of study is 63.44 km², including agricultural land, consisting ocropland and plantation (73.50% of total area), construction land, consisting of settlements, communications and water conservancy facilities (12.73 % of total area), forests and unused land (13.77 % of total area).

land use categories is done using a temporal validation data-set consisting of 36 landslide locations mapped in 2009. The sensitivity co-efficient calculated using the validation data-set mimics the analysis. This observation also holds true on field inspection of the region to verify the results of the analysis.

IV. METHODS

Different land use patterns produce diverse influences on slope instability (i.e) landslide susceptibility of various land use patterns is different [8]-[11]. Sensitivity co-efficient (SCL) is the most common quantification to evaluate landslide susceptibility to different land use patterns [12]. Sensitivity co-efficient is calculated as:

\[
SCL_i = \ln \left( \frac{N_i}{A_{Li}} \right) / \left( N/A_T \right) 
\]

where SCL_i - sensitivity co-efficient of landslide susceptibility to different land use types (i)

\[N_i\] - number of landslides in different land use categories

\[A_{Li}\] - area of each land use type in the study area

\[A_T\] - total area of study
The SCL$_i$ is used to assess the effect of different land use categories on landslide susceptibility. The higher the SCL$_i$, greater is the susceptibility to landslides. The results of the analysis are verified in the field by using a validation data-set.

The sensitivity co-efficient (Table 1) of the training and validation data-set shows that the construction land consisting of the settlements and communications (roads) is the most susceptible category (i.e) induces landslide susceptibility to a greater extent, followed by agricultural land consisting of cropland and plantations. The sensitivity co-efficient reinforces the fact that anthropogenic interference, particularly in the form of rapid urban expansion is the key to slope instability problems.

Validation of the sensitivity co-efficient for the various land use categories is done using a temporal validation data-set consisting of 36 landslide locations mapped in 2009. The sensitivity co-efficient calculated using the validation data-set mimics the analysis. This observation also holds true on field inspection of the region to verify the results of the analysis.

V. CONCLUSIONS

Slope instability is a common problem in the Western Ghats. Land use pattern is one of the most important factors that dictate the degree of susceptibility to landslide. Each type of land use has a specific influence on the slope stability of the area. The effect of each land use category is studied in this paper using sensitivity co-efficient. The study points out that construction land, in particular settlements and roads are the most susceptible land use categories, followed by agricultural land (cropland and plantations). The result of the analysis pictures the fact that the area experiences rapid unplanned urban development. This unprecedented and irregular urban sprawl upsets the fragile geomorphic balance of the hill-town, increasing the frequency of landslides along the roads connecting the hill-town and in the sub-urban region where there is a tremendous increase in the building density. The study shows that land use planning and regulation are need of the hour to save the hill town from slope instability related problems.

Table 1: Land Use Pattern in Tevankarai Stream Sub-Watershed

<table>
<thead>
<tr>
<th>Land use</th>
<th>Pixels in Land use Category</th>
<th>Training Data-Set</th>
<th>Validation Data-Set</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Landslide Pixels</td>
<td>SCL$_i$</td>
</tr>
<tr>
<td>Unused Land</td>
<td>Scrub</td>
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<td>9</td>
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<tr>
<td>Agricultural land</td>
<td>Forest</td>
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<td>Cropland</td>
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<td>Plantation</td>
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<td>Construction land</td>
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REFERENCES