Landslide Disaster Management and Planning –A GIS based Approach

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Abstract

Landslide hazard zonation helps in identifying strategic points and geographically critical areas prone to landslides. In this study, a methodology has been developed to identify landslide prone areas using Photogrammetry with 3D GIS. A small area in the Kothagiri taluk of the Nilgiris district has been selected for this study. Orthophoto map was generated by ORTHOCOMP from aerial photograph on 1: 8,000 scale. The advantage of the high-resolution data helps in deriving 2 m contour, which is ideal to get the elevation and slope values of the terrain.

The products derived from DEMs are contour maps (2 m interval), slope maps, aspect maps, shaded relief maps and perspective views. The orthophoto map, topographic map, land-use/ land-cover map, slope map, soil map, geology, transportation network, and relative relief map have been utilized to generate various thematic data layers in GIS environment. In order to get the landslide prone areas, the triggering criteria should be assigned to each map layer. Depending on the threat posed by each category the Landslide Susceptibility Index, i.e., weightages were assigned. The data layers have been integrated in GIS environment by overlay analysis. The zonation map divides the study area into four zones of landslide vulnerability viz., very high, high, moderate and low. Arc view – 3D analyst was used especially for generating 3D view and getting slope and aspect information.

Overview

1. Introduction

In hilly regions, landslides constitute one of the major hazards that cause losses to lives and property. Landslide analysis is a complex analysis, involving multitude of factors and it needs to be studied systematically in order to locate the areas prone for landslides. Computer-based tool namely Geographical Information System (GIS) is found to be more useful in the hazard mapping of landslides.

One of the main advantages of the use of this technology is the possibility of improving hazard occurrence models, by evaluating their results and adjusting the input variables. Another aspect is the possibilities to store, treat, and analyze spatiotemporal data.

1.1 Objectives:

- To develop a spatial database for landslide analysis
- To delineate a Landslide Zonation Map using remote sensing and GIS
- To provide a decision support tool for hazard managers and planners

1.2 Study area : Study area is located in the Nilgiri district, covering part of the Kothagiri taluk which is a mountainous terrain in the north west part of Tamil Nadu. It is geographically located between 76° 14' 00" and 77° 02' 00" E longitudes and 11° 10' 00" and 11° 42' 00" N latitudes.

1.3 Data used

Data	Source
• Ortho photos (Scale 1:2500) :	Institute of Remote Sensing
• Contour Maps (2 m interval)	Institute of Remote Sensing
• Soil Map	Agricultural Engineering Department

1.4 Need for the study: Landslides in the hilly region causes loss of life and property, damage to natural resources and damage to roads, bridges, telephone / electric lines etc. This leads to immobility of goods and services leading to huge loss of revenue.

Field work of detecting the landslide by conventional methods is expensive and time consuming.

2. The Flowchart

The flowchart of the methodology is given in Figure 1.

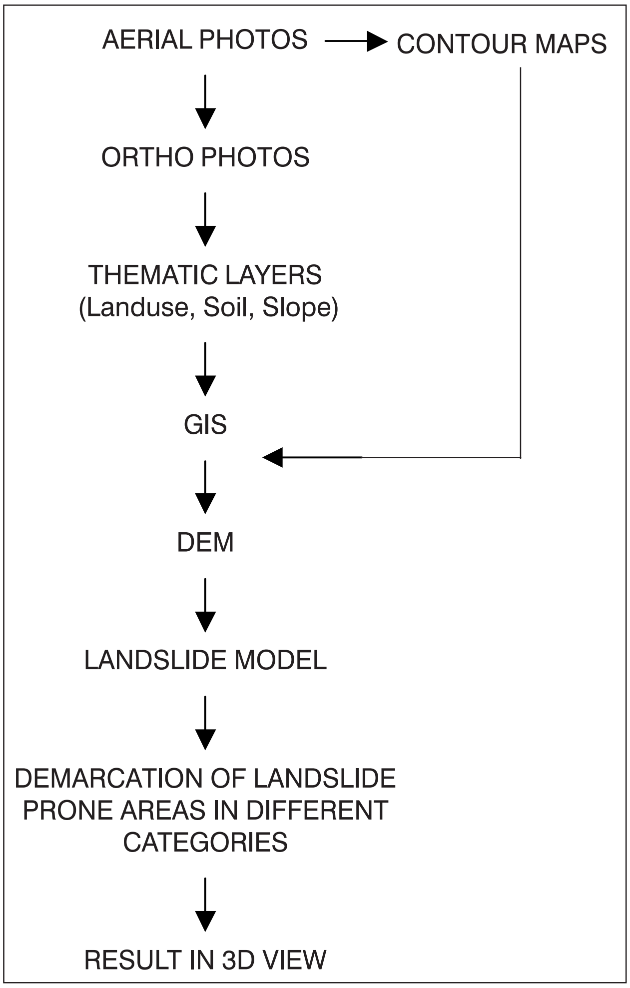

Figure1: Flowchart of Methodology

3. GIS Analysis

In order to generate the landslide prone areas a model has been developed in a GIS environment. Data in the form of thematic layers such as slope, soil and land use were input into GIS. Slope map has been derived from TIN (Triangular Irregular Network) model and land use map was delineated from orthophoto. The overlay analysis has been done. The assigning weights and criterion table 1 has been prepared as Look Up Table (LUT) and linked with union coverage. Finally the landslide prone areas zonation was delineated. The detailed method of analysis is discussed below.

3.1 Slope: Slope is a very important parameter in any landslide hazard zonation mapping. If the slope is higher then there is a chance of occurrence of landslide. Contour maps have been used for the preparation of slope map. Using the Arc view 3D analyst, the TIN model (Figure–3) for the study area is created from the digitized contour map (Figure-2). In the study area slope varies from 0° to more than 54°. The entire slope map is divided into four categories as follows:

> 54 deg	-	very steeply sloping
36 – 54 deg	-	steeply sloping
18 – 36 deg	-	moderately sloping
0 – 18 deg	-	gently sloping

Thus, the slope is divided into four categories and suitable weights are assigned for each category. (Figure - 4)

3.2 Soil: The occurrence of landslide is mainly due to the presence of huge thickness of loose soils. When mixed with rainwater, it triggers the landslide. In the study area, based on the soil's erodable nature, it is divided into four categories as follows:

- Very highly erodable
- Highly erodable
- Moderately erodable
- Poorly erodable.

Thus, the Soil map has got four categories and suitable weights were assigned. (Fig– 5)

3.3 Geology: In the Nilgiri district, the lithology is the charnockite group of bedrocks, covered by the ubiquitous red laterite or lateritic soil. This is taken as a common factor for the whole district. Because of its uniform nature, it is not taken into account for our study.

3.4 Landuse: Based on the aerial photo interpretation, the general landuse of the study area is divided into six categories, i.e. tea, tree plantation, agriculture, grassland, settlement and forest. Suitable weights are assigned. (Fig - 6)

4. Results

4.1 Land slide susceptibility zonation: Management of the landslides disasters can be successful only when detailed knowledge is obtained about the expected frequency, character and magnitude of the mass movement in an area. The zonation of landslide hazard must be the basis for any landslide mitigation strategy and should supply planners and decision-makers with adequate and understandable information.

Table 1: Assignment of Weights and Triggering Criterion

THEME	RANK1 (4 * weight)	RANK2 (3*weight)	RANK3 (2*weight)	RANK4 (1*weight)
Landuse	Grass land, Agriculture	Tea, Tree plantation	Forest	Settlement
Soil	KG4, KG5	KG3, KG6	KG2, KG7, KG8	KG1, KG9
Slope	36-54 deg	18-36 deg	> 54 deg	0-18 deg

CONTOUR MAP - KOTHAGIRI

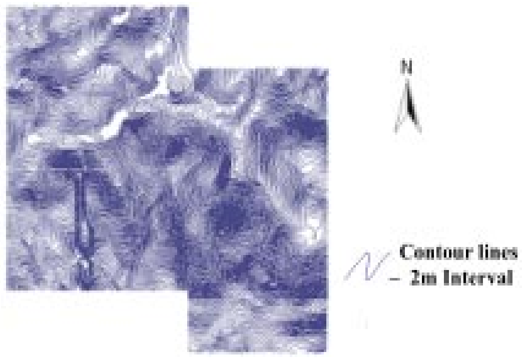

Figure 2 – Contour map of Kothagiri

3D VIEW - KOTHAGIRI

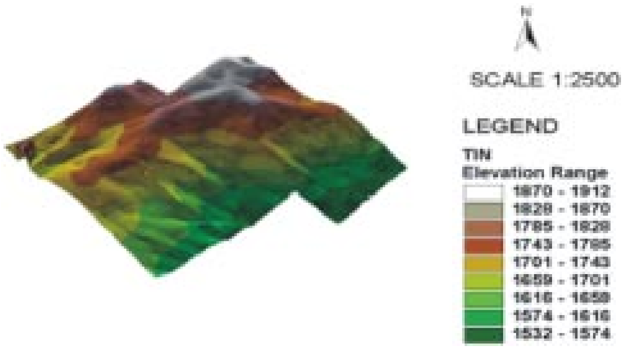

Figure 3

SLOPE MAP - KOTHAGIRI

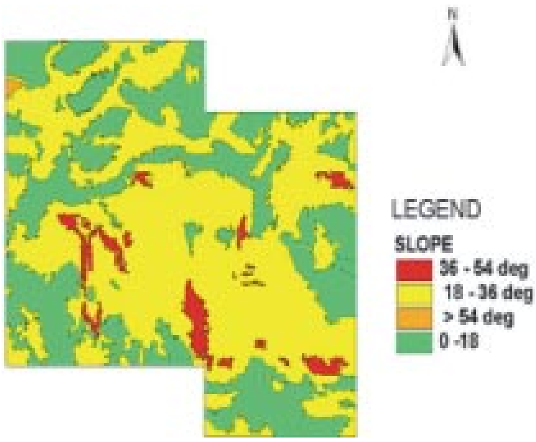

Figure 4

KG3	-	sandy clay
KG4	-	sandy loam – sandy clay loam
KG5	-	sandy loam – sandy clay loam
KG6	-	sandy clay loam
KG7	-	sandy clay – sandy clay loam.
KG8	-	sandy clay loam – sandy loam
KG9	-	sandy loam

SOIL MAP - KOTHAGIRI

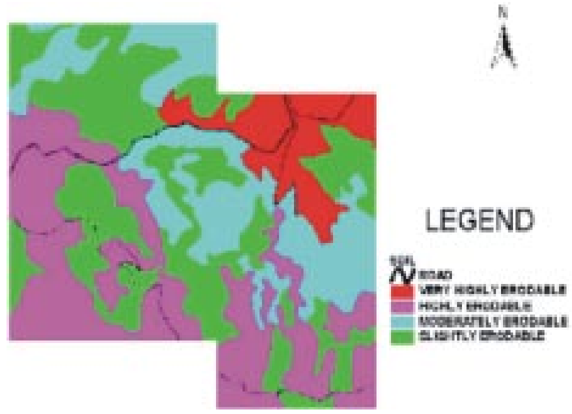

Figure 5

LANDUSE MAP - KOTHAGIRI

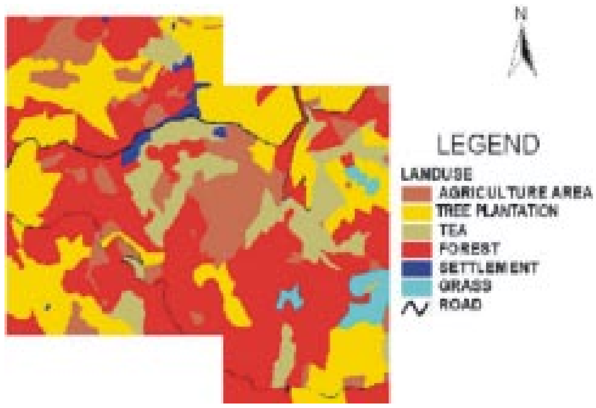

Figure 6

While dealing with landslide-hazard mitigation, the hazard planner is concerned mainly about the final outcome i.e., the zonation map. In preparing the landslide zonation map, synthesized and weighed the data pertaining to geology, slope morphometry, distribution of soils and land use pattern have been analyzed,. The role of geology and structure is limited in the formation of landslides. The geology of the region has a bearing on the origin and types of soils and has little to do with landslides.

4.2 Landslide Susceptibility Values (LSV): To achieve the landslide zonation, the different factors were grouped according to their relative importance and land susceptibility values (LSV). Landslides are being essentially gravity-type hence; the degree of slope was accorded the prime importance. Taking all the factors into consideration and with an intimate knowledge of the Nilgiri landslides, an LSV of 40 was assigned to slope. The thickness of the soil was considered next in importance, as all the slides were soil slides of varying thickness. An LSV of 35 was assigned to this factor. Under similar topographic conditions with similar thickness of soil and type of drainage, the susceptibility to landslides is accelerated by human environment. Hence the land use practices adopted was also considered and an LSV of 25 was assigned to this.

4.3 Landslide Hazard Zonation Mapping: Landslide hazard zonation (Figure-7) map was prepared by integrating the effect of various triggering factors. The Zonation map was divided into four zones of landslide vulnerability viz., low susceptibility to landslides, moderate susceptibility to landslides, high susceptibility to landslides and very high susceptibility to landslides. Thus, the landslide prone areas having four zones were obtained and superimposed on DEM as shown in Figure-8. The percentage of the different risk zones of the study area is given below.

Different Categories	Percentage of Area
Zone of low susceptibility to landslides	- 21%
Zone of moderate susceptibility to landslides	- 28%
Zone of high susceptibility to landslides	- 34%
Zone of very high susceptibility to landslides	- 17%

The risk zones of high and very high are incident mainly on forest, agriculture and tree plantation areas. These landslide zones occur in most of the study area due to changes in landuse/ landcover and indiscriminate deforestation in the forest area.

LANDSLIDE ZONAL MAP - KOTHAGIRI

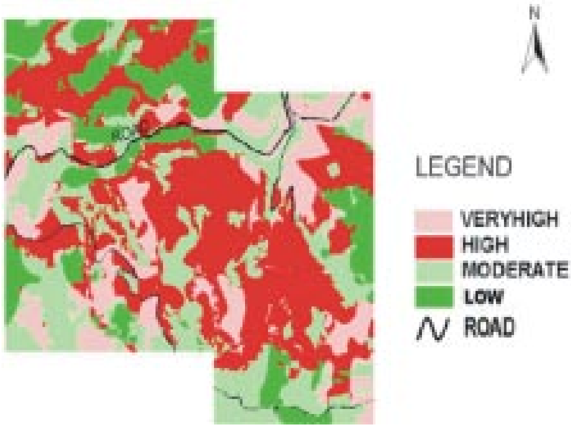

Figure 7

LANDSLIDE HAZARD ZONATION MAP ON PERSPECTIVE VIEW

Figure 8: Landslide

5. Conclusion

This present study brings out a definite relationship between the Photogrammetry and GIS techniques, which play a significant role in landslide zonation mapping. Landslide identification, which is a crucial parameter for any regional landslide hazard assessment, can be very well done particularly with aerial photographs. Coupled with aerial photos, GIS is an excellent tool to display the spatial distribution of landslides along with their attributes. However, the landslide map so prepared should be validated with ground checks.

6. Acknowledgements

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