International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS)
Volume XI, Issue VI, June 2022|ISSN 2278-2540

Preparation of Earth Slip Hazard Zonation Map in Upcountry Railway Line Using GIS & Remote Sensing

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***Abstract*: The area extends from the Edalgashinna to Bandarawela has become more vulnerable to earth slip disasters than other areas in Sri Lanka's upcountry railway line. Due to the high-intensity rainfall, soil erosion, soil structure, slopes, geological structure, deforestation, and other anthropological activities directly influenced the increasing earth slips along the upcountry railway line, and this earth slip risk also affected to day to day activities. The objective of the study is the preparation of an earth slip zonation map and identifies the earth slip high-risk areas from Idalgashinna to Bandarawela along the railway line. This study is based on secondary data. Mainly used the elevation, rainfall, river network, soil, and land use data. All the data were analyzed with the Analytic Hierarchy Process (AHP) to calculate three risk levels, such as High, Moderate, and law. After that, all vector data were converted into raster formats. The final risk map was cratered using weighted overlay techniques. According to findings, the risk map can be classified into high risk (40%), moderate risk (34%), and low risk (26%). Most of the earth slips occurred in the high-risk and moderate-risk areas representing the reactivation of historical earth slips. Therefore, it is proved that validation of the hazard zonation map with real incidences. In the study area, most of the high and very high hazard class areas were found occupying the areas of the railroad.**

***Keywords*: earth slip, upcountry railway line, hazard zonation map, remote sensing.**

I. INTRODUCTION

During the past few decades, the hill country areas become more urbanization and it has been criticized influenced to removing of natural vegetation cover [1,2,3]. The rapid development had been directly influenced to occurring natural disasters, especially in the mountain areas [4,5,6]. Earth slip is one of the geologic hazards that occur in Sri Lanka. The increasing trend of population growth in Sri Lanka has adversely affected the stability of the central highland due to various human activities. Among them, the establishment of human settlements and changes in land-use patterns have become a serious issue in triggering land instabilities in the central highland of the country.

Earth slip is one of the phenomena among the natural hazards in Sri Lanka. At present increasing earth slip in upcountry areas and also an increasing number of people who are affected by the earth slip. When we consider the history of the earth slip in Sri Lanka, it is reported that the first earth slip occurred on the upcountry railway line in Sri Lanka in 1869. Heavy rains and geological changes in the hill country, accentuated by the indiscriminate clearance of steep slopes in the mountainous areas, have increased the occurrences of frequent earth slips, especially during the last two decades in the mountain slopes of the Central and South Western regions of the island.

Geographic Information Systems (GIS) have become a promising tool for an effective analysis associated with the study of geologic hazards. GIS is an ideal tool for earth slip modeling owing to its versatility in handling a large set of data, providing an efficient environment for analysis and display of results with its powerful set of tools for collecting, storing, retrieving, transforming, and displaying spatial data from the real world [7]. Using these functions of GIS, spatial analysis of areas that are vulnerable to earth slip can be performed. Remote Sensing and Geographical Information systems (GIS) are powerful tools to assess earth slip hazards and are being used extensively in earth slip research for the last decade [8]. This technology is ideally appropriate for unapproachable mountainous regions where the common old earth slips were identified. Previses researchers involved to use GIS and remote sensing for the earth slips studies in mountain areas [9,10].

With this background, this study aimed to identify earth slip hazard zonation areas in the upcountry railway. The specific objectives of this study are as follows (i) Identify the history of the earth slip in the upcountry railway line, (ii) Identify the factors for the earth slip in the upcountry railway line, and (iii) Preparation of the earth slip zonation map in upcountry railway.

II. RESEARCH METHODOLOGY

The methodology section outlines the plan and method that how the study is conducted. This includes the universe of the study, a sample of the study, Data and Sources of Data, the study's variables, and analytical framework. The details are as follows;

The study area

This research study is to identify earth slip zonation areas in the upcountry railway line from Polgahawella to Badulla railway station. The Upcountry railway line is going from Polgahawella to Badulla. However, in this study, the research area is going from Ohiya railway station to Bandarawelarailway station. Because this area can be identified as a high risk of earth slip in the upcountry railway way line. During colonial times, the picture area was once hailed as possessing one of the healthiest climates in the world, & nothing much has happened here to change that. There this was the most favorable climate on the island. Geographically, the upcountry area is hilly and surrounded by a large number of mountains in Central Province. Four climatic seasons can be identified according to rainfall patterns in upcountry areas.

The annual rainfall ranges from 1524 to 1905 mm, with an annual average of 1397 mm. The temperature varies with the elevation, respectively. At a height of 200m, the temperatures of Namunukula, Diyathalawe, and Badulla indicate values of 20.6 °C, 23.4 °C, and 25.2 °C, respectively. The upcountry area consists mainly of red-yellow Pdzolic soils with a dark B horizon and red-yellow Podzolic soils with a prominent A1 horizon; rolling terrain, red-yellow Podzolic soils, and mountain regosols; mountainous terrain, steep rockland, and lithosols. The Upcountry railway line from Polgahawella to Badulla railway station was selected for the study (Fig.1).

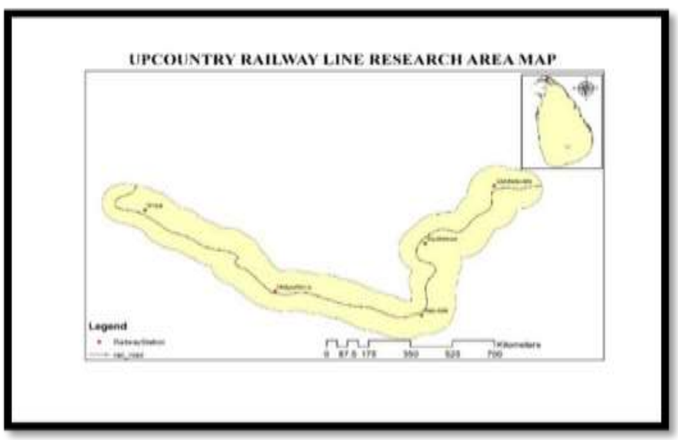


Fig. 1 Research Area

I. Data and Sources of Data

For the study, both secondary and primary data have been collected. In order to improve the quality of the research, provide explanations, as well as supplement the primary data, secondary data was sourced from both published and unpublished sources, including journals, articles, books, etc.

Mainly used the elevation, rainfall, river network, soil, and land use data. All the data were analyzed with the Analytic Hierarchy Process (AHP) to calculate three risk levels, such as High, Moderate, and law. After that, all vector data were converted into raster formats. The final risk map was cratered using weighted overlay techniques. The analytical method can be explained in detail as follows.

III. RESULTS AND DISCUSSION

I. Preparation of earth slip hazard zonation map

The aim of this study is to prepare earth slip hazard zonation maps for the upcountry railway line using GIS. The preparation of earth slip hazard zonation maps can be identified in three ways.

- Mapping the data for the preparation of the earth slip hazard zonation map
- Classification of the data for analysis
- Preparation of an earth slip hazard zonation map

Mapping the data for preparation of earth slip hazard zonation map

For the preparation of the earth slip hazard zonation map, five sources are used as follows.

- Land use maps
- Soil map
- Slope map
- Rainfall map
- Stream map

Following the creation of the five maps, it is clear that all of the data were of different types. All the data can be prepared as one type and reclassified.

This study reclassifies based on the three factors, namely the high-risk areas, moderate-risk areas, and low-risk areas. According to these three sectors, all the maps, as mentioned earlier, should be created. For the analysis, these three sectors should be numbered as follows.

Table 1: Hazard Zonation Area

Hazard zonation area	Value
Low risk	1
Moderate risk	2
High risk	3

Finally, in this study, it should be possible to create a hazard zonation map. That is because it needs all the above criteria as one scale. But it is available on different scales. To escape that situation, all the above maps should be valued on one scale. This is the use of this valuation. According to these criteria, all the above maps should be categorized as follows.

II. Reclassify the slope map

The slope area map can be reclassified using the following table:

Table 2: Reclassified Slope Area

Slope area	Hazard zonation area	Value
0-15	Low risk	1
15-25	Moderate risk	2
>25	High risk	3

According to the above values, the slope map can be created as follows.

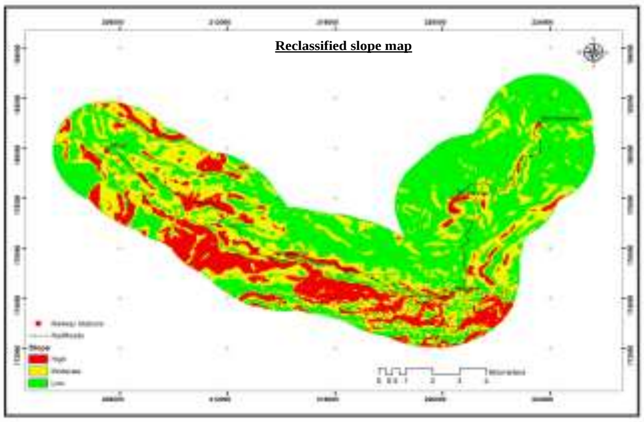


Fig: 2 Reclassified slope map

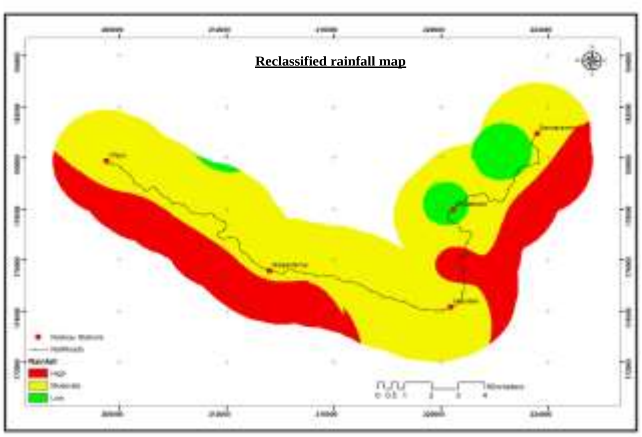
III. Reclassify the rainfall map

In the study, rainfall areas can be identified as follows: It can be reclassified using the following table.

Table 3: Reclassified Rainfall Area

Rainfall range	Hazard zonation area	Value
< 1800	Low risk	1
1800-2200	Moderate risk	2
>2200	High risk	3

Fig: 3 Reclassified rainfall map



IV. Reclassify the land use map

According to the study, the following land use types can be identified in the study area:

Table 4: Reclassified Land-Use Area

Land-use type	Hazard zonation area	Value
Chena	High	3
Other cultivation	High	3
Tea	High	3
Grassland	High	3
Homesteads	Moderate	2
Homesteads	Moderate	2
Stream	Moderate	2
Tank	Moderate	2
Water holes	Moderate	2
Forest	Low	1
Paddy	Low	1
Rock	Low	1
Scrubland	Low	1

According to the above values, the land use map can be created as follows.

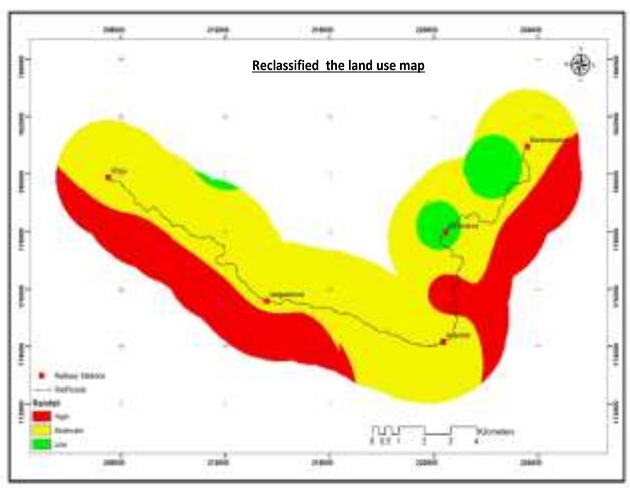


Fig: 4 Reclassified land use map

V. Reclassify the soil map

Can be identified as four types of soil types in the study area. According to the above values, they created the soil map as follows.

Table 5: Reclassified Soil Types

Soil type	Hazard zonation area	Value
Red-Yellow Podzolic soils with dark B horizon &RedYellowPodzolic soils with prominent A1 horizom; rolling terrain	High	3
Red-Yellow Podzolic soils & Mountain Regosols; mountainous terrain	Moderate	2
Red-Yellow Podzolic soils; steeply dissected, hilly and rolling terrain	Low	1
Steep rock land & Lithosols	Low	1

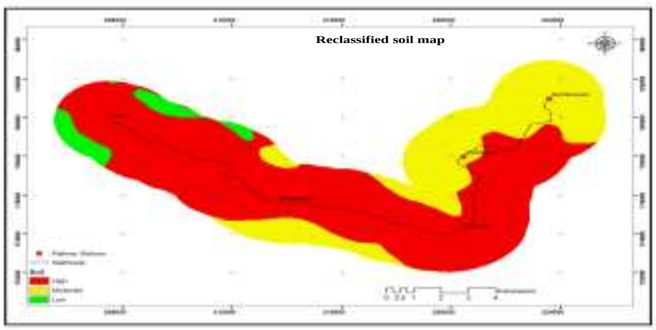


Fig: 5 Reclassified soil map

VI. *Reclassify the stream map*

According to the map, a classification stream map should be created by using the buffer zone. For the preparation of the earth slip hazard zonation map, a stream map should also be created using the following values:

Table 6: Reclassified Stream

River stream	Hazard zonation area	Value
<100	High	3
100-200	Moderate	2
>200	Low	1

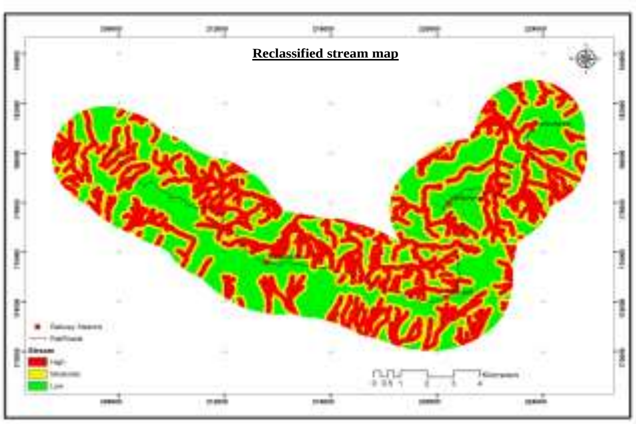


Fig: 6 Reclassified stream map

VII. CONVERT TO RASTER

Slope maps and rainfall maps are in raster format. However, land use, stream, and soil maps are not in a raster format. Therefore, it should be converted to raster format by using the Arc GIS "feature to raster" tool. After that, it can create a hazard zonation map. because all maps are in a raster format. After the creation of all maps in the raster format, the next step is the preparation of the hazard zonation map. When we create a hazard zonation map, it can be done with the following steps and tools:

Multi-Criteria Decision Making (MCDM) Techniques, Pairwise Comparison Matrix

By using Multi-Criteria Decision Making (MCDM) Techniques, it can be calculated how far it contributes to the earth's slip by these factors. For this study, it can be used as the Analytical Hierarchical Process (AHP).

Analytical Hierarchical Process (AHP), construction of a pairwise comparison matrix

The AHP considers a set of evaluation criteria and a set of alternative options among which the best decision is to be made. It is important to note that, since some of the criteria could be contrasting, it is not true in general that the best option is the one that optimizes every single criterion, rather the one which achieves the most suitable trade-off among the different criteria. The AHP generates a weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria. The higher the weight, the more important the corresponding criterion. The AHP incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision-making process.

According to this concept, a pairwise comparison matrix can be used for the identification of earth slip vulnerability areas. It can be identified very clearly as follows.

Table 7: Pair Wise Comparison Matrix

	Land use	Slope	Water bodies	Soils	Rainfall	Sum	Weight
Land use	0.11	0.12	0.06	0.20	0.12	0.60	0.12
Slope	0.32	0.35	0.34	0.20	0.46	1.67	0.33
Water bodies	0.32	0.18	0.17	0.20	0.12	0.98	0.20
Soil	0.05	0.18	0.09	0.10	0.08	0.49	0.10
Rainfall	0.21	0.18	0.34	0.30	0.23	1.26	0.25
							1.00

Table 8: Standardize Pairwise Comparison Matrix

	Land use	Slope	Water bodies	Soils	Rainfall	Sum	Weight
Land use	0.11	0.12	0.06	0.20	0.12	0.60	0.12
Slope	0.32	0.35	0.34	0.20	0.46	1.67	0.33

The AHP can be implemented in three simple consecutive steps:

1) Computing the vector of criteria weights.
2) Computing the matrix of option scores.
3) Ranking the options.

Each step will be described in detail in the following. It is assumed that evaluation criteria are considered and that options are to be evaluated. A useful technique for checking the reliability of the results was also introduced.

Table 9: Value For The Weighted Overlay Operation

	Weight
Land use	0.12
Slope	0.33
Water bodies	0.20
Soil	0.10
Rainfall	0.25
	1.0

According to the above values, the equation can be created as follows.

*Hazard zonation map = Land use*0.12 + Slope*0.33 + Water bodies*0.20+Soil*0.10 + Rainfall*0.25*

This research is based mainly on secondary data. Here, the researcher mainly focuses on map preparation. For this map, preparation researchers used maps of land use, soil, rainfall, slope, and stream maps. Next, they reclassified the three factors, namely high-risk areas, moderate-risk areas, and low-risk areas. According to these three sectors, all the above maps should be created. Next, it should be converted to raster format by using Arc GIS "feature to raster" tool. We mainly used the Digital Elevation Model (DEM), rainfall, river network, soil, and land use data. All the data were analyzed with the Analytic Hierarchy Process (AHP) to calculate three weighted classes, such as high, moderate, and law. After that, all vector data was converted into raster formats. The final risk map was cratered using weighted overlay techniques. In order to GIS methods like pairwise comparison, the matrix explains the effective method of the proper distribution of slope movements that took place after the drawing of the map.

By using the following map, the high risk, moderate risk, and low-risk areas of an earth slip in the upcountry railway line can be identified.

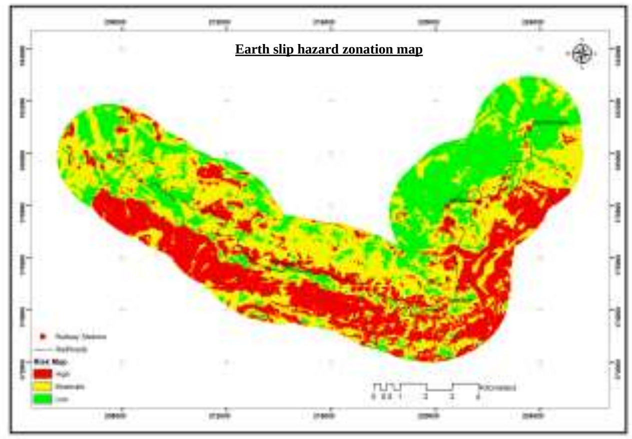


Fig: 7 Earth slip hazard zonation map

VIII. CONCLUSION

Earth slip is a series of geologic hazards that occur in Sri Lanka. Globally, earth slips cause billions of dollars in damage and thousands of deaths and injuries each year. The central part of Sri Lanka, especially the upcountry railway line, has become more vulnerable to the earth slip hazard than the other areas. At present, increasing earth slip in upcountry areas is also increasing the number of people who are affected by the earth slip. Most of the earth slipping along the upcountry railway line is increasing due to the influence of natural and anthropogenic activities.

At present, details show an increasing occurrence of earth slides in the upcountry railway line for various reasons, such as improper cultivation in hilly areas, reservoir projects, and tunnel roads.

Earth slips are common natural hazards on the upcountry railway line. These earth slips can be systematically assessed and mapped. Using a geographical information system (GIS) to create a map is discussed in this section in detail. As a result of the map analysis, it can identify the actual condition of the earth slip risk areas in the upcountry railway line. According to the findings, the risk map can be classified into three categories: high risk (40%), moderate risk (34%), and low risk (26%). Most of the earth slips that occurred in the high-risk and moderate-risk areas represent the reactivation of historical earth slips. Therefore, it is proved that validation of the hazard zonation map with real incidences is possible.

Manage and prevent the earth slip on the upcountry railway line. It can be recommended to do the following things:

I. Drainage Corrections

As such, the first and foremost mitigation measure is drainage correction. This involves the maintenance of natural drainage channels, both micro and macro, on vulnerable slopes.

II. Proper land-use measures

Adopt effective land-use regulations and building codes based on scientific research. Through land-use planning, discourage new construction or development in identified hazard areas without first implementing appropriate remedial measures.

III. Structural measures

Adopt remedial techniques (buttresses, shear keys, sub-drains, soil reinforcement, retaining walls, etc.)

IV. Afforestation

The afforestation program should be properly planned. The selection of suitable plant species should be such that they can withstand the existing stress conditions.

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