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Applications of GIS and Remote Sensing for Landslide Vulnerability Assessment in Madikeri Taluk, Kodagu District, Karnataka

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Abstract

This study aims to identify and mark the landslide prone zones in Kodagu district using GIS and Remote Sensing. Kodagu received the highest rainfall ever in the year 2018 breaking the 87-year-old record set in 1931. One of the worst-affected areas was Madikeri taluk due to the heavy intensity of rainfall on the high slopes leading to slope failure and consequent landslides. In this study, Maps of Landslide Prone Zones are prepared; quantitative information on slope/ground stability conditions in the study area currently unaffected (or thought to be unaffected) by landslides, but where the terrain geomorphology and geology may indicate potential future landslides is provided and this study also attempts to enumerate the consequences of landslides in Kodagu based on the analysis of statistical data.

Weighted Overlay Analysis method in ArcGIS used in this study aids to identify and localize the landslides susceptible areas. High intensity rainfall, high slopes (greater than 35°), weak soils, geology, geomorphology, drainage density, land use & land cover of the study area – were found to be the prime etiological factors for landslides. The Thematic Maps of these parameters are generated using the ArcGIS software to depict landslide susceptibility zones in different Zones Classified as - very low, low, moderate, high and very high vulnerability zones.

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The study concludes that Monitoring Rainfall from the beginning to understand the pattens; Undertaking Scientific Slope modifications to ensure stability of the soil; Monitoring ground water levels and its changes to reduce the hazards of landslides; Developing Soil Retention walls in the low stability soil formation zones and Soil Pinning technique are need of the hour. The natural drainage systems should remain undisturbed and creation of new ponds, wells etc. should be avoided. The human activities of industrialization, quarrying, irregular human encroachment of forests, etc. need to be regulated carefully to maintain the balance.

Keywords: *Remote Sensing, GIS, Landslide Susceptibility, Kodagu District, Rainfall.*

Introduction

The main objective in the study is to analyze and locate the landslide susceptible zones and to suggest mitigation practices with the integrated use of remote sensing and GIS by the Weighted Overlay Analysis. The purpose of using Remote sensing data is because it is ideal in gathering and assessing the wide range of range data on the environmental impact at affordable cost and rapid pace for a large area. GIS technology helps in integration of the operations like collection and statistical analysis and projecting the results in the form of maps. These processes help in differentiating GIS from other systems and makes it available for usage to the public and private in order to predict and plan strategies. The study has been majorly concentrated on the Madikeri taluk in Kodagu district as it was one of the most affected areas by the landslides that occurred during August 2018. The study area, Madikeri, is a part of Kodagu district in Karnataka is bounded with the latitudes 12°00’00” N and 12°30’00” N and with the longitudes 75°15’00” E and 75°45’00” E. The study area is referred under the toposheets 48P/10, 48P/7, 48P/11, 48P/15 and 48P/12 and the scale used is 1:50000. The study area has an elevation of 1750m. The climate and rainfall that Madikeri experiences, is a typical climate due to the close proximity of the study area to coast. Madikeri has a tropical climate. During most of the months of a year, there is significant rainfall. The average annual temperature is 20.5ºC and average precipitation is 2783 mm.

Methodology

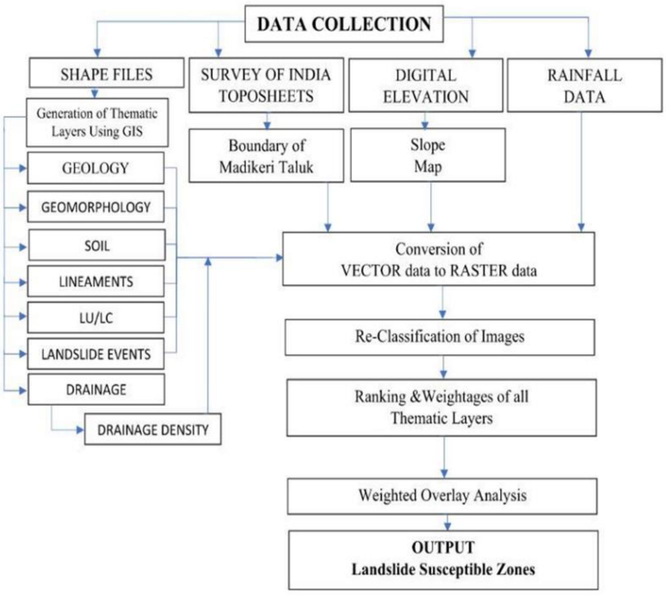

Figure 1: The process of mapping

The first step is the data collection, the Survey of India topo sheets which gives the boundary of the study area, the digital elevation model rainfall data and the thematic maps. Digital elevation model is a three-dimensional representation on the earth surface, it helps in analyzing the slope and thus generation of a slope map. For the study we have preferred the themes geology, geomorphology, soil,

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lineaments, land use and land cover, formerly occurred landslide events and drainage based on their influence on the landslide, all the thematic layers are generated using GIS. Using the drainage map, the drainage density is extracted and it helps in identifying the runoff potential, infiltration capacity of the land. Once all the maps are generated, they are converted from vector to raster format before the analysis as the GIS spatial analysis uses a mathematical elaboration of numerical data and the result can be easily represented in raster format. The next step is reclassification, a process of assigning value for new raster output and for excluding the unnecessary data. This helps in simplifying the output and easy interpretation.

Weighted overlay analysis is a type a type of suitability analysis that helps in the analysis of the site conditions based on a number of factors

The tool allows to combine, weigh and rank several types of information and visualize them so that we can evaluate the multiple factors all at once.

The evaluation scale is the representation of the range of suitability or the criteria where values at one end represent one extreme condition and other represents another condition. The default evaluation scale is from 1 through 9 with the increments of 1. The least suitable is 1 and most suitable is represented by 9. The input raster files are already reclassified with the help of the reclassification tool which helps in choosing an evaluation value suitable to the reclassification value. The cell values given helps in analysis of the assigned values from the evaluation scale. We can change if required the default values based on the suitability.

Each input raster is weighed and assigned a percentage depending on its importance. The summation of the influence given should be equal to 100 percentages.

Finally, the study area is then classified into different landslide susceptible zones depending on the vulnerability of the area to landslide. They are majorly classified into five zones: very low, low, moderate, high and very high.

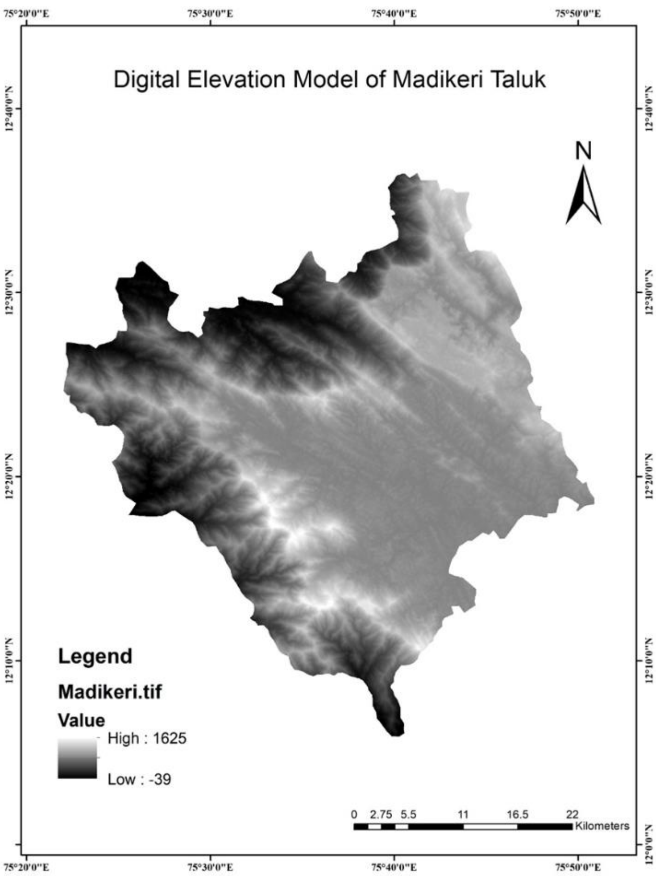

Figure 2: Digital Elevation Model of Madikeri

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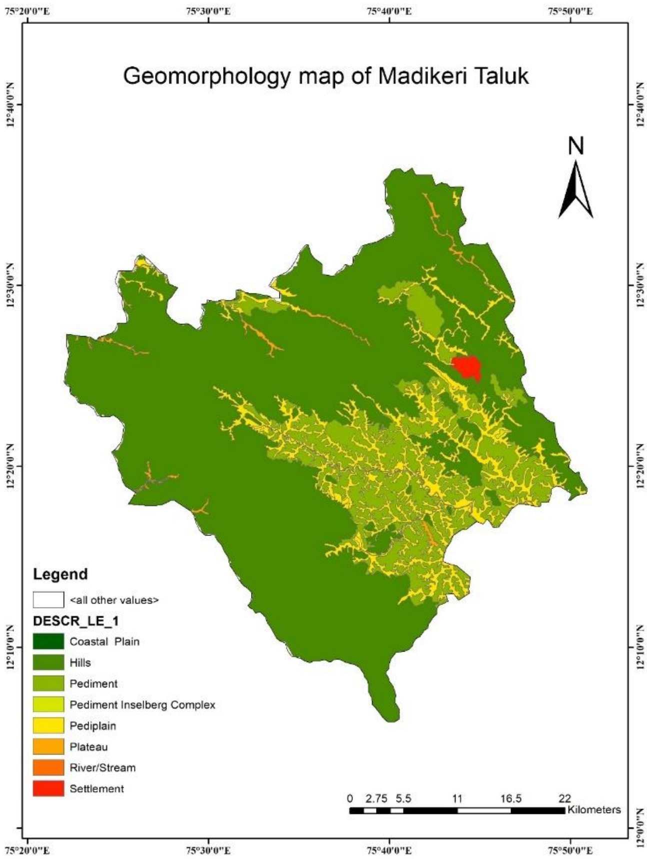

Figure 3: Geomorphology map of Madikeri

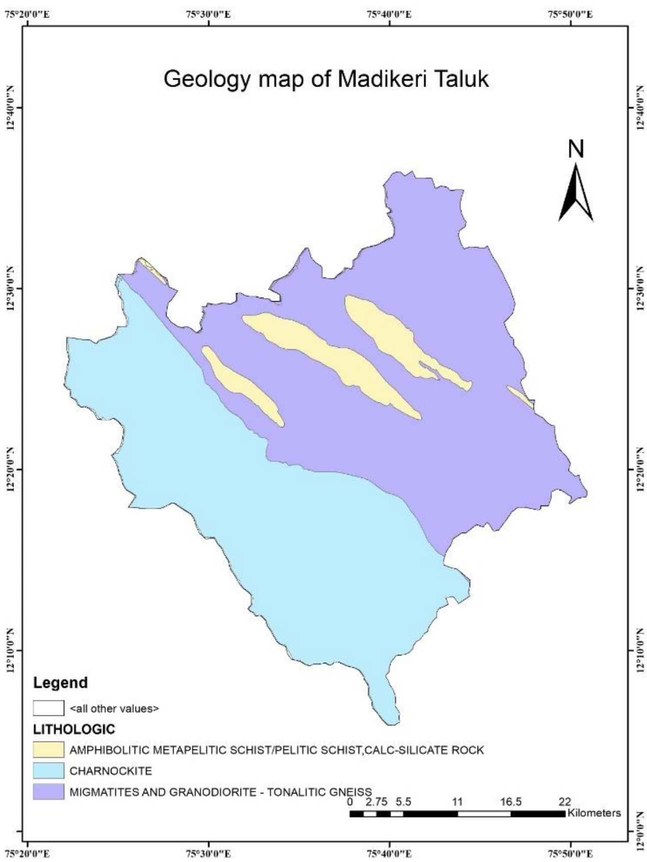

Figure 4: Geology map of Madikeri

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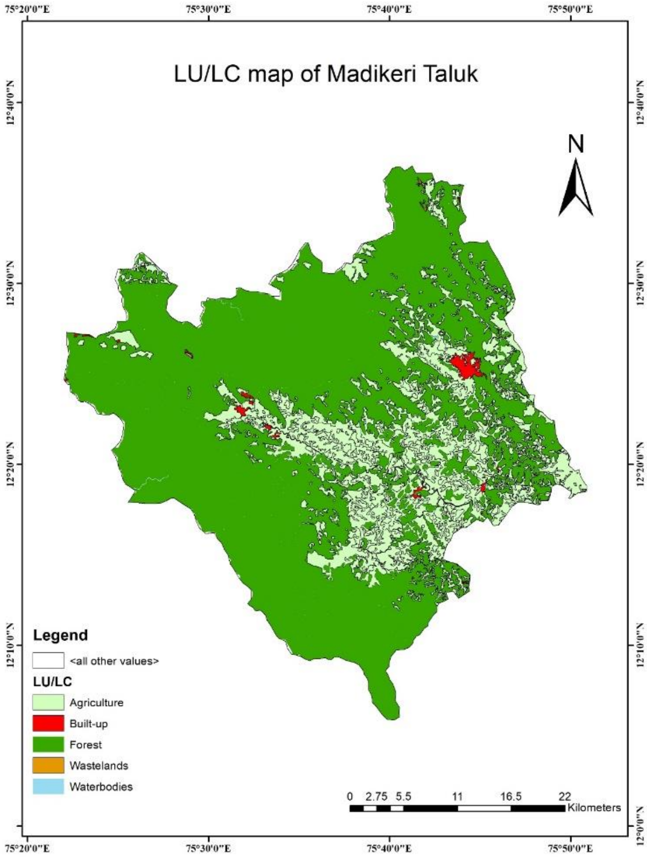

Figure 5: LU/LC Map of Madikeri Taluk

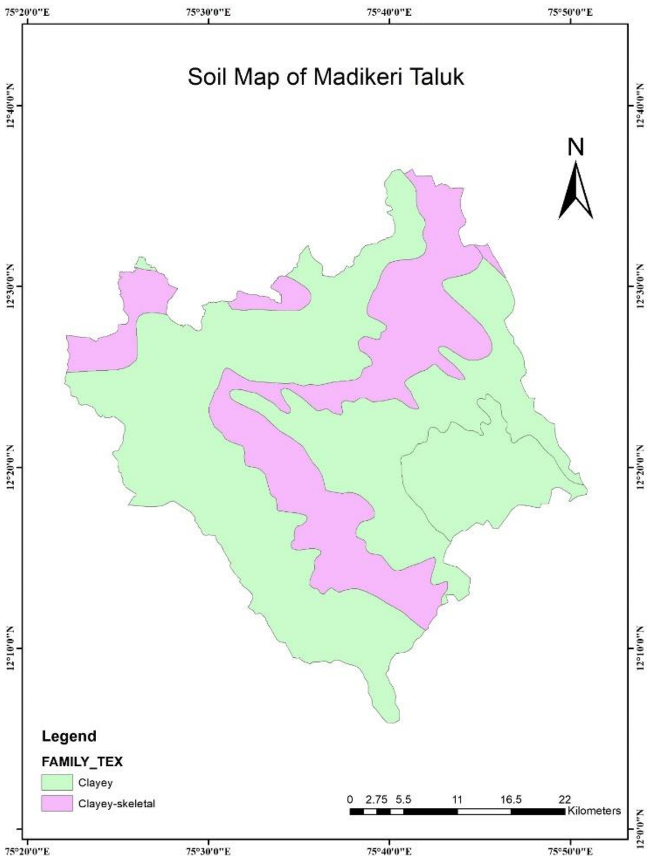

Figure 6: Soil map of Madikeri Taluk

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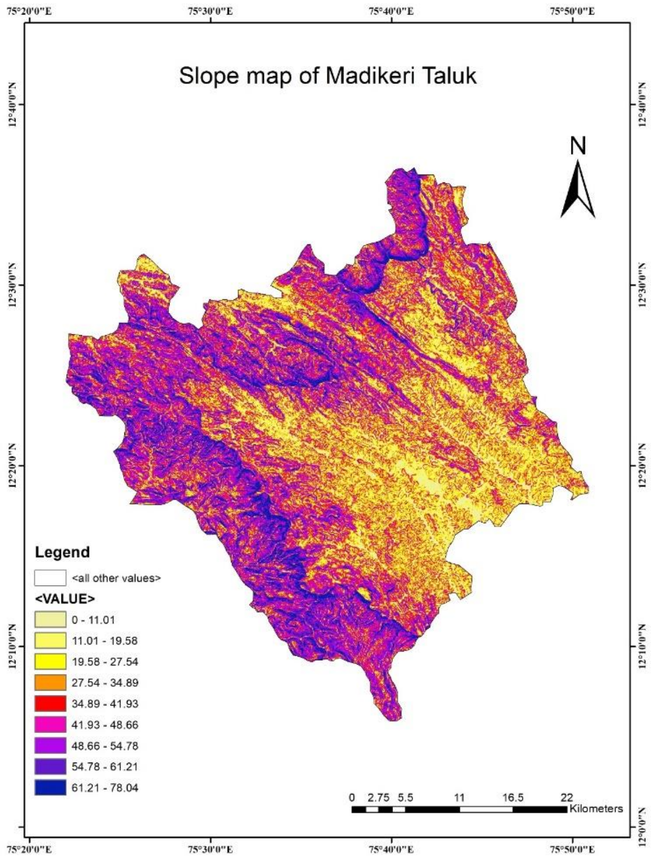

Figure 7: Slope map of Madikeri Taluk

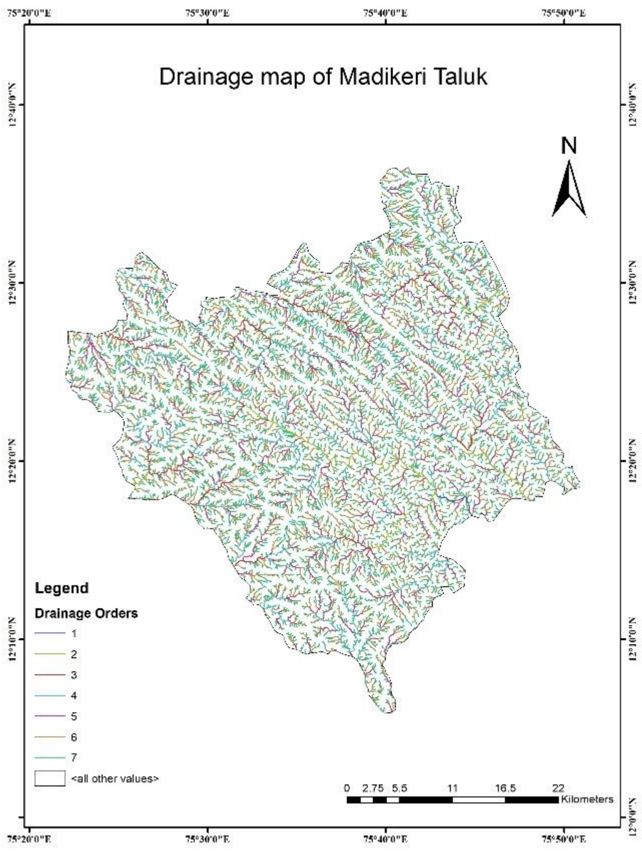

Figure 8: Drainage Map of Madikeri Taluk

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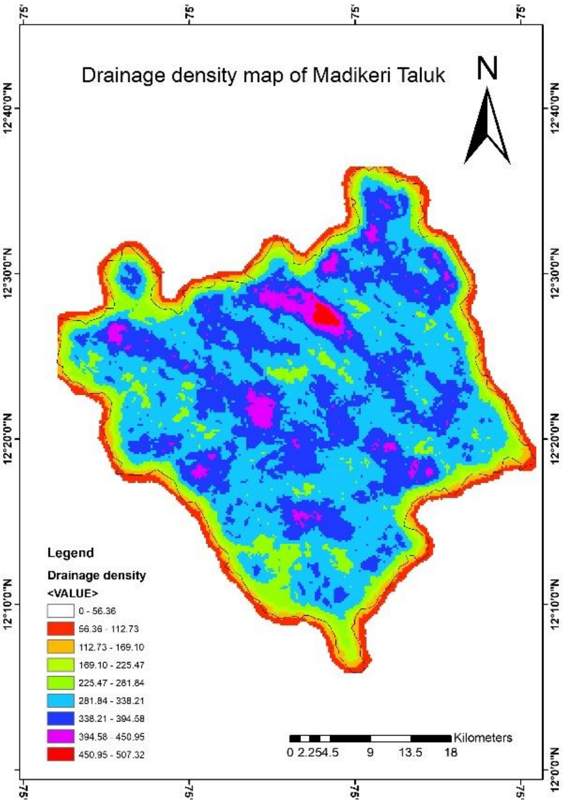

Figure 9: Drainage Density Map of Madikeri

SL.NO	LAYERS	TYPE	RANKING	WEIGHTAGES
1	GEOMORPHOLOGY	Hills	9	10
		Plains	1	
		Rivers	3	
		Pediment	4	
		Settlement	6	
2	GEOLOGY	Amphibolitic	2	10
		Charnokite	1	
		Granadorite	5	
3	LU& LC	Forest	1	10
		Agriculture	2	
		Built-up	6	
		Wastelands	2	
		Water bodies	3	
4	SOIL	Clayey	5	15
		Clayey-skeletal	4	
5	SLOPE	0-1	1	20
		1 to 3	2	
		3 to 5	3	
		5 to 10	4	
		10 to 15	6	
		15 to 35	8	
		>35	9	
6	DRAINAGE DENSITY	1	1	15
		2	2	
		3	3	
		4	4	
		5	5	
		6	6	
		7	7	
		8	8	
		9	9	
7	RAINFALL	3000 mm	5	20
		4000 mm	6	
		5000 mm	7	

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Table 1: Weightages & Rankings Assigned

Results & Discussion

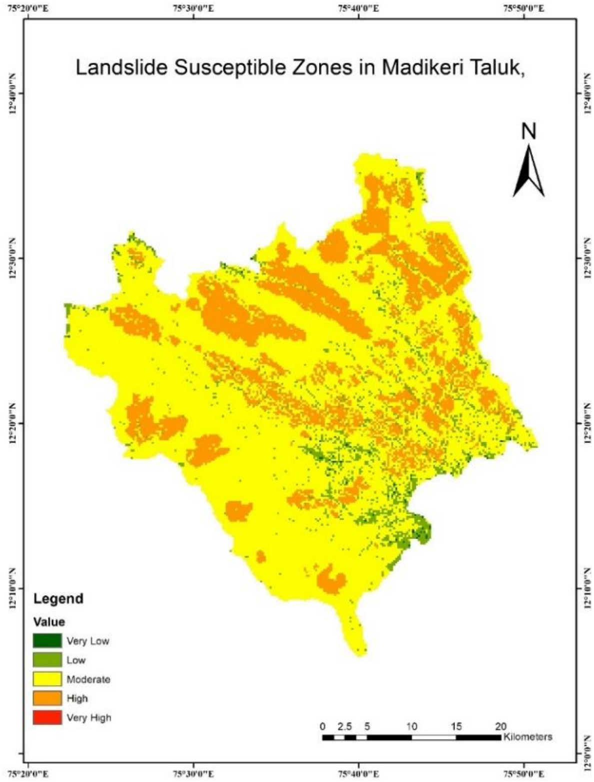

Figure 10: Output 1- Landslide Vulnerable Zones at 3000mm cumulative rainfall

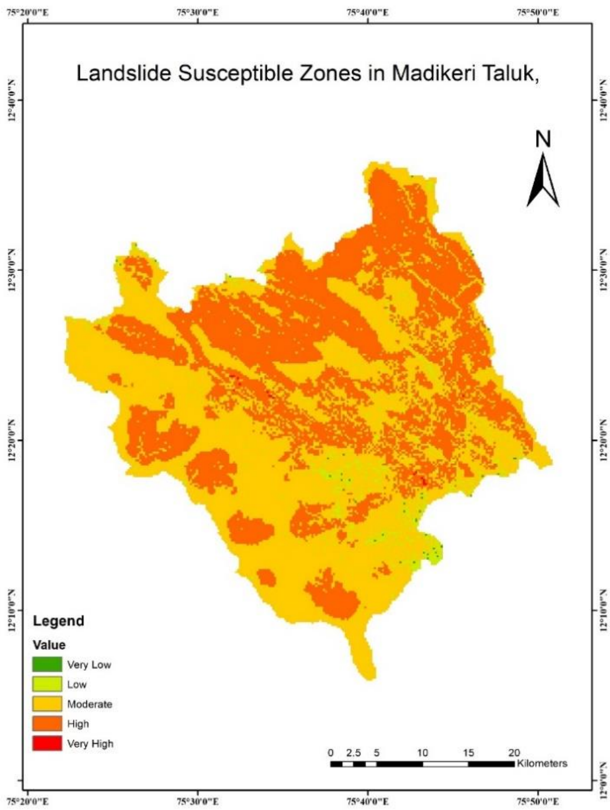

Figure 11: Output 2- Landslide Vulnerable Zones at 4000mm cumulative rainfall

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- The resulting map for Output 1 shows that most parts of Northern Madikeri are highly susceptible to landslide and majority of the part in Madikeri taluk comes under moderate susceptible zone.
- Output 2 shows higher number of landslide vulnerable zones because the cumulative average rainfall occurrence over the study area is assumed to be 4000mm. Rankings and Weightages given to all the other factors are kept constant except rainfall. The ranking of rainfall is increased as the assumption of average amount of rainfall if increased. It can be observed the zones which are very highly Susceptible to landslides have increased and spread from northern parts to western parts of the study area.
- 60.46% of the study area encompasses >35º slopes. Higher percentage of slope indicates higher vulnerability towards landslides. As per the above data, north western and south western parts of Madikeri taluk has higher percentage of slope hence much vulnerable.
- Clay is a weathering product of rock mass. Soil clayey and clayey skeletal soil covers an area of 1017.54 sq.km and 409.19 sq. km respectively in the study area. The intense rainfall in Madikeri not only contributes to the weathering of the rock mass, but also increases the water content in the clays that leads to reduction in the stability of natural slopes.
- Spatial distribution of geomorphology shows 5 types of classification namely hills and plateaus, pediment, plains, river/stream and settlement. It covers an area of 1050.03, 214.14, 154.41, 2.6, 5.5 sq.km respectively. 73.60% of the area out of the total being hills and plateaus.
- Built up, agriculture, forest, wastelands and water bodies are the 5 classifications of Land use and Land cover with having an area of 8.47,347.53,1066.91,0.49,3.33 sq.km respectively in Madikeri taluk.74.78% of the area being forest. Land Use Land Cover features helps in the mitigation processes of landslides.
- Three classifications of rocks are found in Madikeri taluk namely Amphibolite metapelitic, calcium silicate, Charnockite, Megmatites and granodiorite having an area of 93.322,619.48,709.48 sq.km respectively. Megmatites, Granodiorites and Charnockite covers majority space. The type of rocks in the study area can also cause landmass movement.
- Drainage network shows that dendritic type of formation and more drainage density is accumulated in north, northwest, northeast and central part of the study area.
- Spatial distribution of lineaments shows that minor lineaments are running in northern part of the study area.
- Annual percentage departure in 2018 is more compared to the normal rainfall as it records +53.44 %.
- Cumulative monthly rainfall compared with normal monthly rainfall shows increase in the trend.
- Cumulative 15 days rainfall and 3 months (June, July and August) cumulative rainfall shows high intensity rainfall pattern.
- Groundwater study indicates that there is significant increase of groundwater level in the month of June and July where as drastic decrease of groundwater levels in the month of august and September.
- The sudden fall in groundwater level even in heavy rainfall season indicates that pore water pressure is high and this directly influences high runoff.
- Landslide susceptible maps are generated by assigning rankings and weightages for different thematic layers.
- Rainfall being the triggering factor for 2018 landslide events. Rainfall is assigned as higher ranking for different landslide susceptible maps; 2 different landslide susceptible maps are obtained from the above study. Landslide susceptible maps show that more vulnerable zones in Madikeri taluk are in the hilly regions having higher slopes.

Mitigation

- Rainfall, being the triggering factor for landslide, needs to be monitored to study the rainfall pattern. If the Rainfall increases the threshold level, then it will lead to landslides.
- To ensure the stability of the soil, slope modifications should be done scientifically.
- Undisturbed forests will make the area less vulnerable to landslides. So Human activities like development of industries, quarry activities, habitation etc. need to be regulated carefully to maintain the balance. Contour cropping can be carried out in hilly regions.
- The sudden changes in ground water level can lead to landslides. In view of this, ground water level has to be monitored closely.
- On low stability soil formation zones, construction of soil retaining walls may be opted.

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- Soil pinning technique may be followed in the landslide vulnerable areas.
- The natural drainage systems should remain undisturbed and creation of new ponds, dug wells etc. should be avoided. Natural drainage systems should remain undisturbed.

Conclusion

Landslide hazard zonation mapping was attempted in and around Madikeri taluk of Kodagu district using Remote sensing and GIS technique. Recurring landslides are major risks faced by the region every subsequent year, especially in monsoon.

Based on the detailed analysis of maps, it's found that north western and south western region of the study area has higher percentage of slope hence most vulnerable to landslides. The study area has an annual rainfall of 2783 mm, this heavy rainfall can become the triggering factor along with the steep slope of the of the region for landslides. Remote sensing and GIS technique can be effectively used in such map preparation in order to mitigate the risk of landslides the region possess.

Heavy rainfall during the monsoon months of June, July and august of 2018 has triggered the landslides all over Kodagu district wherein deaths and damage to infrastructure were caused. High intensity rainfall, high slopes (greater than 350°), weak soils, geology, geomorphology, drainage density, land use and land cover of the study area were found to be the major triggering factors for landslides. The thematic maps of these parameters are generated using the ArcGIS software to depict landslide susceptibility zones in different zones classified as: very low, low, moderate, high and very high vulnerability. The thematic maps were integrated using GIS and the landslide hazard zonation map was created.

Landslide hazard zonation map illustrates that north western and south western parts of Madikeri taluk has higher percentage of slope hence more susceptible for landslides. The prime factor which catalyze the slope failure is when soil gets saturated during heavy rains in monsoon season, the pore water pressure increases and effective cohesion decreases which effectively leads to the slope failure.

This study aims at providing accurate scientific data on landslide risk zones, which will help planners and engineers in landslide mitigation measures.

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