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# An Open-Source Geo-spatial Landslide High Risk Area Demarcation for Advancing Sustainable Development in Sri Lanka's Rathnapura Divisional Secretariat Division

Kokawalage I.T.H. <sup>1\*</sup>, Jayasinghe K.D.D.P.<sup>2</sup>

<sup>1</sup>Department of Geography, Faculty of Humanities and Social Sciences, University of Sri Jayewardenepura, Sri Lanka.

<sup>2</sup>Department of Geography, Faculty of Humanities and Social Sciences & International Center for Multidisciplinary Studies (ICMS), Faculty of Humanities and Social Sciences, University of Sri Jayewardenepura, Sri Lanka.

\*Corresponding author: [isinitisara@sjp.ac.lk](mailto:isinitisara@sjp.ac.lk)

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**Abstract:** Natural hazards are environmental processes or phenomena that pose potential threats to human societies and ecosystems. In Sri Lanka, landslides constitute one of the most significant natural hazards, with approximately 20,000 km<sup>2</sup> across ten districts identified as landslide-prone. Among these, the Rathnapura District has recorded a notably high frequency of landslide occurrences. Notably, the 2017 landslide event in this district resulted in substantial impacts, affecting 92,757 individuals and causing extensive damage to property. Therefore, effective identification of high-risk zones is essential for disaster mitigation, yet local and national institutions often face challenges due to the lack of cost-effective assessment tools. This study introduces an open-source geospatial methodology, utilizing freely available satellite data, open datasets, and Quantum Geographic Information System (QGIS) software as a sustainable alternative to commercial GIS solutions. Determinant parameters for landslide susceptibility slope, elevation, topographic wetness, vegetation cover, annual average rainfall, drainage density, and drainage network were derived from literature and integrated through weighted overlay analysis. The analysis revealed that 70.37 km<sup>2</sup> of the Rathnapura District is classified as highly susceptible to landslides, with the Rathnapura Divisional Secretariat Division (DSD) exhibiting the greatest susceptibility, encompassing 18.41 km<sup>2</sup> across 46 Grama Niladhari Division (GND) boundaries. Landslide vulnerability was evaluated using physical features (road networks, building footprints from OpenStreetMap) and population census data. High and very high socio-economic vulnerability areas were concentrated within 10 Grama Niladhari Divisions (GNDs). Combined susceptibility and vulnerability analysis revealed 10 GNDs as high-risk areas. This open-source geospatial approach directly contributes to Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 15 (Life on Land), by enabling cost-effective hazard mapping, strengthening local adaptive capacity, and supporting evidence-based land use planning. By promoting equitable access to spatial data and analytical tools, it empowers local authorities, planners, and communities to implement proactive disaster risk reduction strategies, optimize resource allocation, and ensure environmentally responsible development. The methodology promotes economic sustainability through reduced dependency on costly software, social sustainability by prioritizing at-risk populations, and environmental sustainability by guiding development away from ecologically sensitive areas. Findings provide a scientific basis for proactive, non-structural mitigation measures, fostering resilient, safe, and sustainable communities in landslide-prone regions as the initial step of disaster management cycle, which are prevention,

preparedness and response activities in order to achieve an advancing sustainable development in Sri Lanka's Rathnapura DSD.

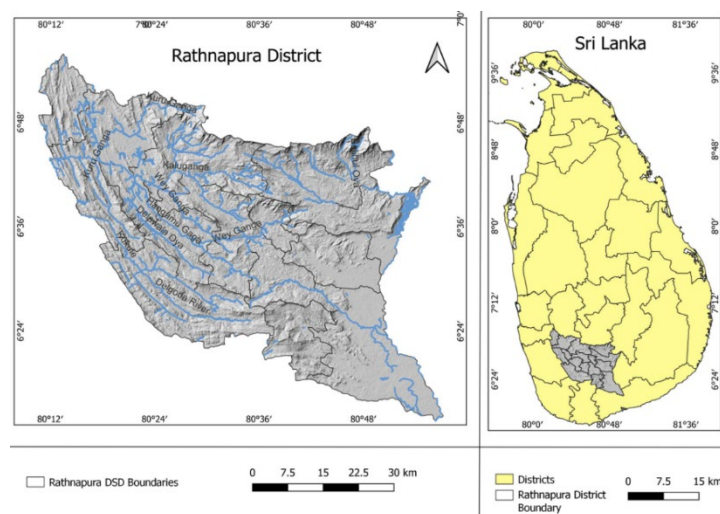
**Keywords:** GIS, Landslides, Open Source, Sustainability, Risk

### Introduction

Natural hazards occur when environmental processes or phenomena interact with human society and ecosystems in ways that produce adverse impacts. Among these, landslides are a serious geomorphic hazard in steep, humid landscapes, particularly in tropical and subtropical regions, due to the combined influence of rainfall, terrain, geology, and land use dynamics. In Sri Lanka, landslides rank among the most frequent and damaging natural hazards to people, infrastructure, and ecosystems. [1] Among Sri Lanka's districts, Rathnapura has long been identified as a hotspot for landslides. Located in the Sabaragamuwa region, the district experiences intense rainfall during the southwest monsoon, which exacerbates slope instability Thennakoon et al., [2]. For instance, the 2017 landslide event in Rathnapura caused extensive damage to houses, infrastructure, and agricultural lands, while displacing tens of thousands of people, underscoring the region's high vulnerability. Identifying zones of heightened landslide risk through the integration of susceptibility, exposure, and vulnerability is therefore a foundational task in disaster risk reduction and land-use planning. However, many local and regional institutions face obstacles such as limited geospatial expertise, the high costs of commercial GIS software, and inadequate access to updated spatial datasets. Open-source geospatial tools and freely available remote sensing data offer a promising and sustainable alternative. Recent research has demonstrated how satellite imagery, digital elevation models (DEMs), and thematic datasets integrated with open-source GIS platforms QGIS can support landslide susceptibility and risk mapping in data-constrained contexts [2]. Nevertheless, the application of fully open-source workflows for landslide risk assessment in Sri Lanka remains relatively limited. By integrating terrain, hydrological, vegetation, and climatic parameters through weighted overlay analysis, and combining susceptibility with socio-economic vulnerability, the study seeks to generate actionable risk maps for planners, communities, and disaster management authorities. In doing so, it provides both a methodological framework and localized insights for proactive risk reduction in one of Sri Lanka's most landslide-prone areas.

### Methodology

Rathnapura District is one of the areas in Sri Lanka most affected by landslides, highlighting the urgent need for effective prevention and mitigation measures. This study seeks to identify zones that are prone to landslides, understand their vulnerability, and evaluate the risks communities face. Using open-source geospatial tools, primarily QGIS, and freely available data such as OpenStreetMap and satellite imagery, the research provides an accessible and cost-effective approach to disaster management. This approach is especially valuable for developing countries, where resources for large-scale interventions may be limited. The following sections outline the datasets, methods, and spatial framework employed to map risk of landslides.



**Figure 1: Study Area Map of Rathnapura**

Source - author's development

Rathnapura District is located in Sabaragamuwa Province, Sri Lanka. The district lies between approximately 6°15' N and 6°55' N latitude and 80°10' E and 80°57' E longitude. Its central region is deeply dissected by tributaries of the Kalu Ganga and Walawe Ganga. Climatically, the district is classified under the “A” climate group denoting a rainy tropical climate, where the average temperature of the coldest month remains above 18 °C and there is no distinct cold season [3]. The predominant soil type in the area is Red-Yellow Podzolic soil, which is characteristic of wet tropical and hilly terrains and commonly found in Sri Lanka’s wet zone [4, 5, 6]. Vegetation in the district is dominated by tropical rainforest in the lowland and mid-altitude zones, transitioning to mountain forest in higher elevations [3]. Based on data from City Population, the district had a population density of about 332.2 persons per km<sup>2</sup> as of the 2012 census [7].

**Data and Methods**

**Table 1: Indicators and Measures of Variables**

Assessment	Variables	Indicator	Measures
Landslide Susceptibility	Slope	Angle of the slope	Ranking variables based on researches and recognized Sri Lankan classifications and weighted overlay variables to find landslide susceptibility.
	Elevation	Distance above the Mean Sea Level (DEM)	
	Rainfall	Average of 12 years annual rainfall of 2010 - 2021	
	Vegetation	Area of the different vegetation canopy coverage (NDVI) of 2022	
	Topographic Wetness	Topographic Wetness Index	
	Drainage Density	Streams density	
	Drainage Network	Streams distance	
Socio Economic Vulnerability	Population	Population density 2022	Find the nature of vulnerability to landslides for all high susceptible areas of landslides.
	Built-up areas	Building density	
	Transport Network	Road Density Calculation	
	High susceptible and high vulnerable areas of landslide	High susceptible and high vulnerable locations	
Risk of Landslide			Find the highest and lowest risk areas of landslides based on landslide high susceptibility and vulnerability analysis

Source: author's development [8, 9, 10, 11, 12]

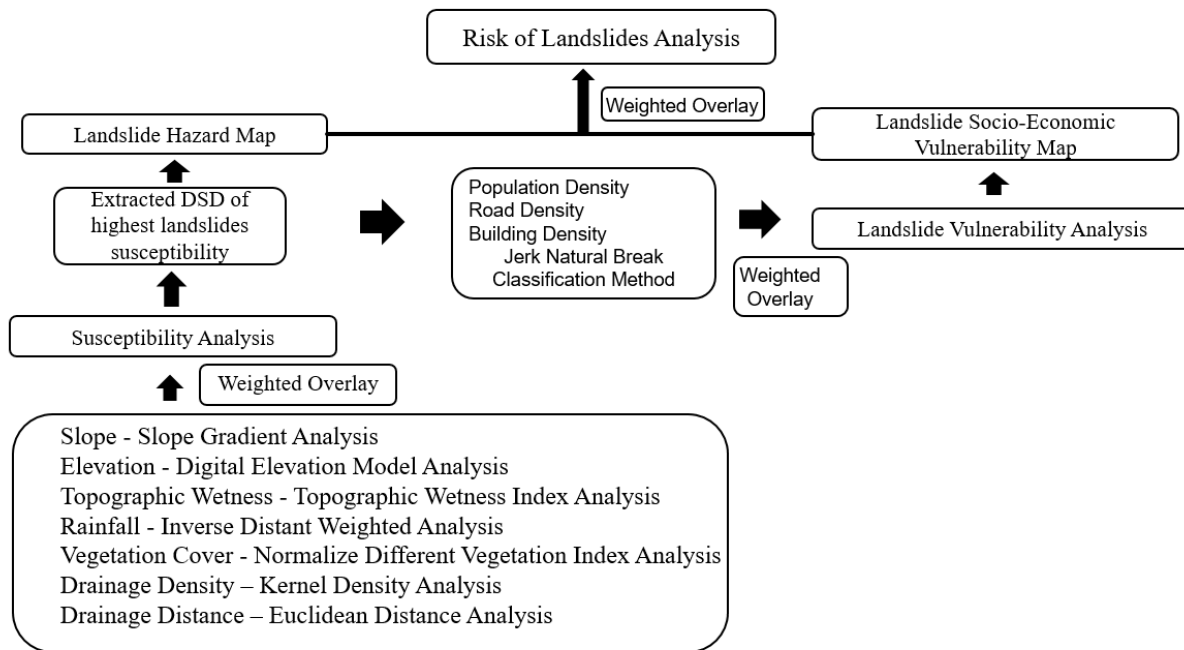
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**Table 2: Data Type Used in the Study**

Data	Year	Data Source
Slope		30m Shuttle Radar Topography Mission (SRTM) data downloader – Digital Elevation Model
Elevation		30m Shuttle Radar Topography Mission (SRTM) data downloader – Digital Elevation Model
Rainfall	2010 - 2021	NASA Power open data portal
Vegetation	2022	United States Geological Survey (USGS) Earth Explorer data downloader
Topographic Wetness Index		30m Shuttle Radar Topography Mission (SRTM) data downloader – Digital Elevation Model
Drainage Density	River Network	OpenStreatMap
Drainage Distance	River Network	OpenStreatMap
Population	2022 estimated population density	2011 population censuses data
Built-up Areas		OpenStreatMap
Road Network		OpenStreatMap

Source: author's development

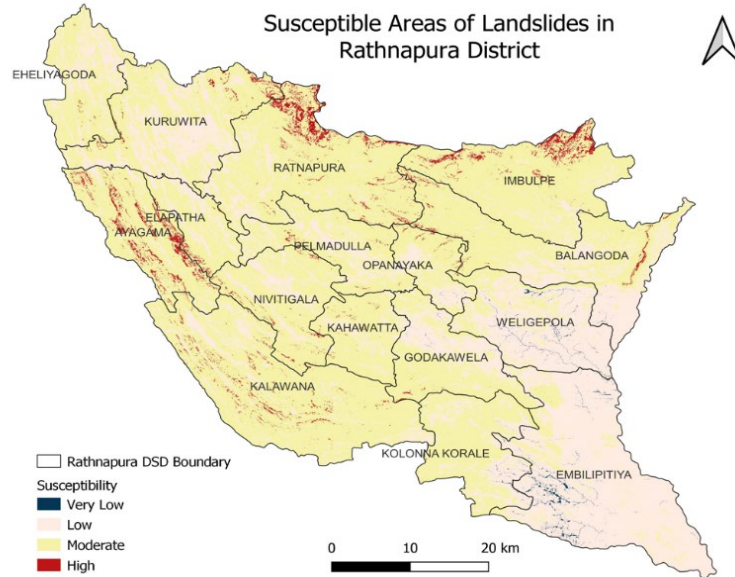
**Methods of Data Analysis**



Source: author's development

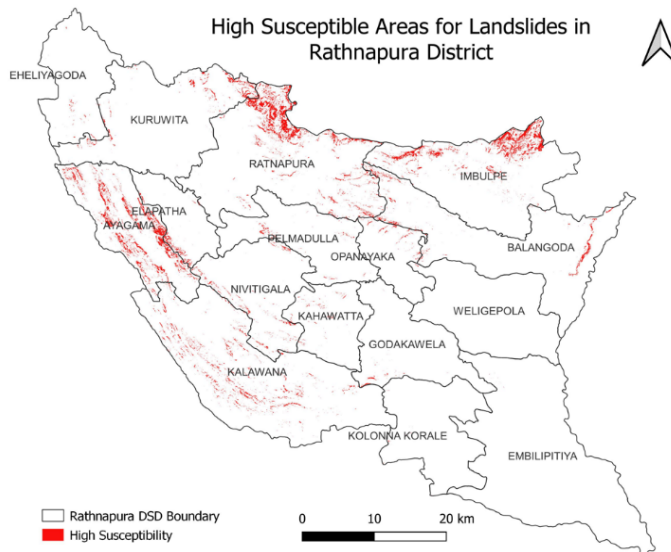
Results and Discussion - Steep slopes, particularly at higher elevations with sparse vegetation, are highly susceptible to landslides during periods of heavy or prolonged rainfall. Water infiltration and surface runoff on these slopes gradually weaken the soil, reducing slope stability. Areas with dense drainage networks and short drainage paths are especially prone to severe erosion under intense rainfall, further increasing the risk of slope failure. The Topographic

Wetness Index (TWI) also plays a crucial role, as locations with high TWI values tend to accumulate water, leading to prolonged soil saturation and reduced shear strength. When these factors steep gradients, high rainfall, and water-retentive terrain occur simultaneously, the likelihood of landslide events rises substantially. Vegetation can mitigate these risks by enhancing soil cohesion and slowing runoff, whereas deforestation or vegetation clearance significantly heightens vulnerability. Considering these key triggering factors, the landslide-prone areas of Rathnapura District have been delineated and are presented in the following map.



**Figure 2: Susceptible areas of landslides in Rathnapura District**

Source: author's development



**Figure 3: High Susceptibility Areas for Landslides in each DSDs of Rathnapura District**

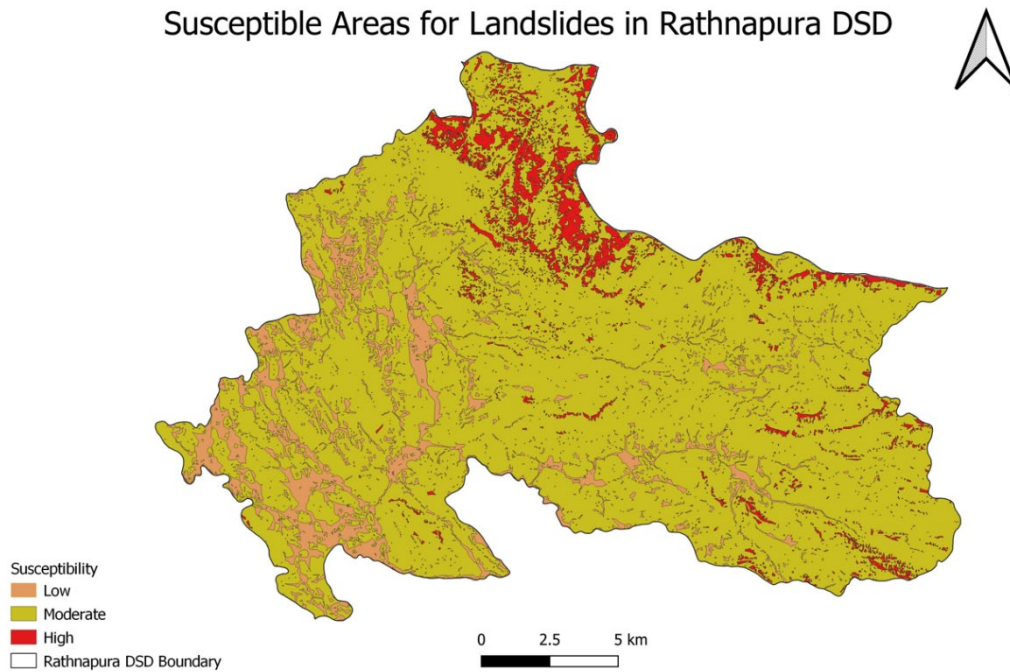
Source: author's development

**Table 3: High Susceptibility Areas for Landslides in each DSDs of Rathnapura District**

Divisional Divisions	Secretariat	Area of DSD SqKm	Area of Susceptibility SqKm
Rathnapura		326.93	18.41
Ayagama		165.66	15.40
Imbulpe		255.33	14.15
Kalawana		381.57	7.65
Kuruwita		260.20	3.76
Balangoda		277.53	3.72
Nivithigala		157.55	2.12
Elapatha		80.44	1.63
Pelmadulla		145.95	0.90
Opanayake		74.86	0.89
Kahawatta		101.43	0.67
Godakawela		156.53	0.46
Ehaliyagoda		136.52	0.42
Kolonna Koral		171.37	0.06
Weligepola		201.38	0.042
Embilipitiya		396.86	0.016

Source: author's development

According to above grid, Rathnapura DSD has very high susceptibility areas of landslides than the other DSDs of Rathnapura District and it covers 18.41 km<sup>2</sup> area out of 326.93 km<sup>2</sup> of Rathnapura DSD boundary. Following map shows very high susceptibility of landslides in Rathnapura District.

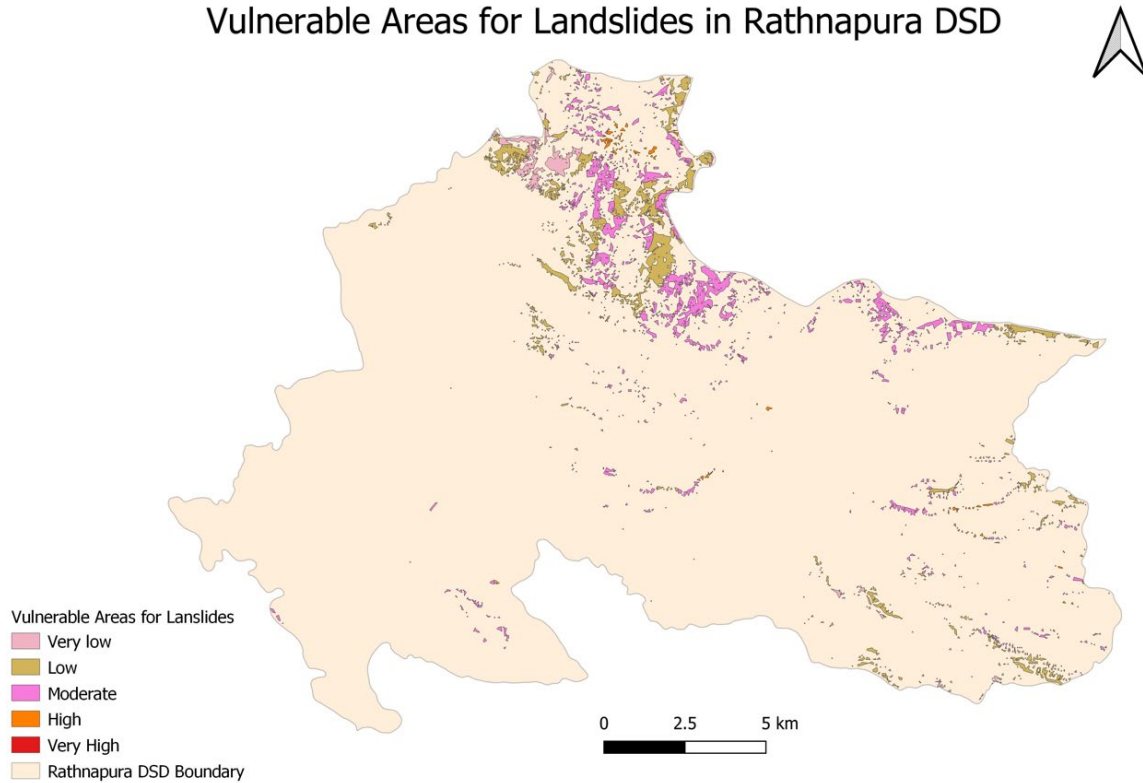


**Figure 4: Susceptible Areas for Landslides in Rathnapura DSD**

This map illustrates the distribution of the 18.41 km<sup>2</sup> landslide-prone area among the Rathnapura DSD boundary in terms of low, moderate, and high susceptibility. The majority of the places are classified as moderately susceptibility to landslides. High susceptible areas to landslides spread among 46 GND boundaries.

Population density of year 2022, Road density and building density utilized for the vulnerability Analysis of landslides. Below maps, demonstrate how socio and economic vulnerability influences for susceptible landslides areas of Rathnapura DSD.

### Vulnerable Areas for Landslides in Rathnapura DSD

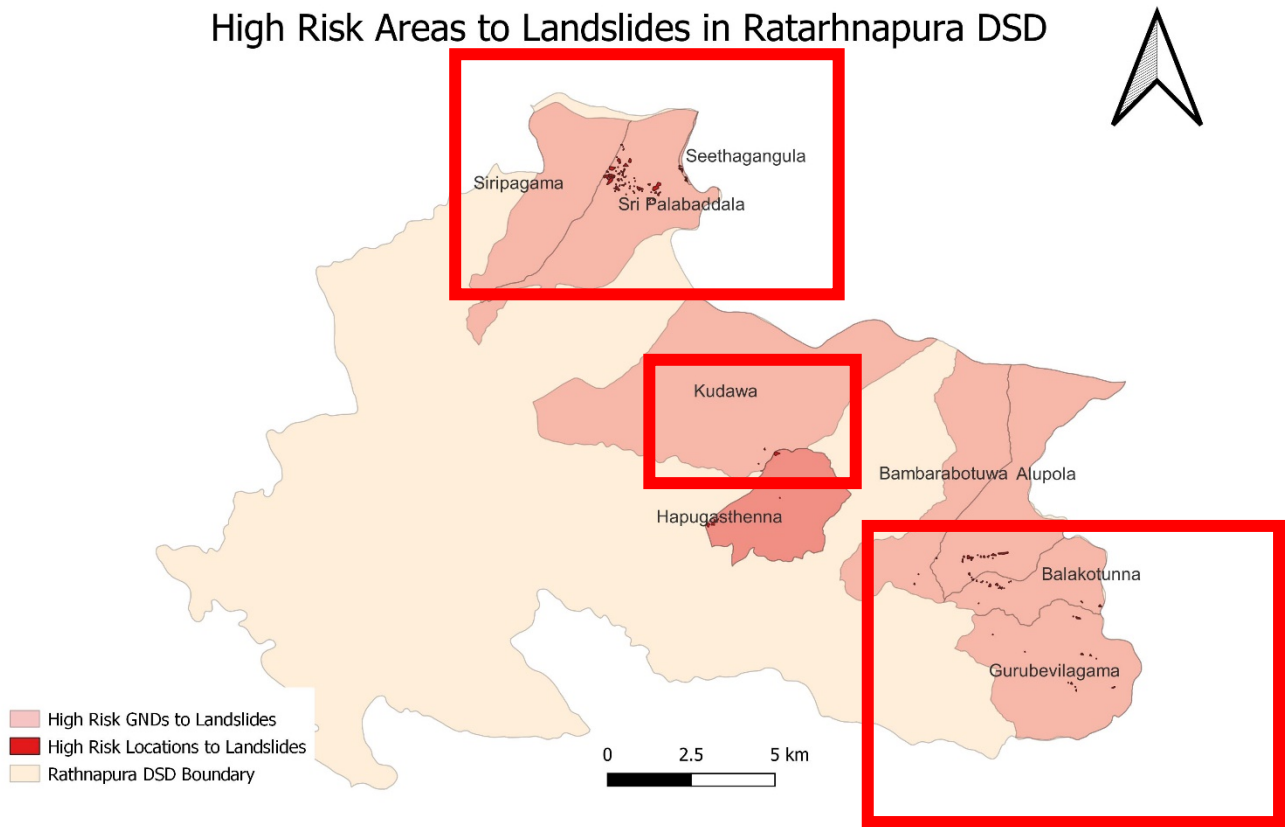


**Figure 5: Vulnerable Areas for Landslides in Rathnapura DSD**

Source: author's development

Areas classified as having very high and high socio-economic vulnerability to landslides are concentrated within 09 GND boundaries. In contrast, both very low and low socio-economic vulnerability areas are distributed across 37 GND boundaries, out of a total of 46 GNDs.

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**Figure 6: Risk Areas to Landslides in Rathnapura DSD**

Source: author's development

High-risk areas are concentrated within 09 GND boundaries of Siripagama, Sri Palabaddala, Seethagangula, Hapugasthenna, Kudawa, Bambarabotuwa, Alupola, Balakotunna and Gurubevilagama suggesting that these regions face a significantly elevated threat of landslides. In contrast, low-risk areas are more widely dispersed, covering 37 GND boundaries.

### Conclusion

Effective landslide mitigation requires a holistic approach that integrates both non-structural and structural measures. Non-structural strategies focus on proactive planning and community preparedness, including land-use planning, zoning regulations, public awareness programs, and the use of open-source geospatial technologies such as QGIS. These tools enable cost-effective identification of hazard zones, vulnerability mapping, and preliminary risk assessments. When combined with field data collection tools like QField and Merging Maps, they enhance the accuracy of risk analysis and support early warning systems, ultimately strengthening community resilience.

Structural strategies, on the other hand, involve engineering interventions designed to reinforce vulnerable slopes and minimize the impacts of landslides. Key measures include constructing retaining walls, soil nailing, and slope reshaping, improving drainage systems, and implementing hydro-shedding techniques. Monitoring early warning signs—such as ground cracks, leaning trees, or sudden water emergence—further facilitates timely interventions. In Sri Lanka, communities in landslide-prone areas have benefited from a range of engineering solutions, including slope stabilization, protective barriers, and geotechnical reinforcement.

By combining these structural and non-structural approaches, it is possible to reduce landslide susceptibility, mitigate risks, and promote sustainable development, providing both safety and long-term resilience for vulnerable communities.

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