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GIS-based slope-stability zonation for soil-slide hazard assessment in Kottayam, Kerala, India

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ABSTRACT

Soil slides, induced mainly by slope instability, imply a critical localised hazard in terrains characterised by high monsoonal rainfall, undulating relief, and intensified human activity. Despite their localised extent, they could cause a significant socio-economic impact in Kottayam taluk, one of Kerala's densely populated taluks. Thematic layers derived from the ASTER GDEM indicate that the taluk exhibits undulating topography with slope values ranging from 0° to 35°, and an increasing relief ratio towards the east, making it more vulnerable to slope failures. Although the drainage network, which forms part of the Meenachil River system, predominantly shows a dendritic drainage pattern, a perfect trellis pattern is developed towards the eastern part of the taluk due to the presence of lineaments trending NW–SE. In the study, a GIS-based heuristic ranking and weighting method is effectively integrated to prepare a stability zonation map of the Kottayam taluk, using various geo-environmental factors such as slope, relative relief, drainage, lithology, rainfall, land use, and lineaments. The stability zonation map demarcates four zones: very stable, stable, moderately stable, and unstable. The moderately stable and unstable zones are concentrated at various localities of the east and central parts of the taluk. Adopting appropriate mitigative measures, developing community awareness of various geo-environmental factors that influence slope stability, and following scientific land-use practices are important to ensure long-term slope stability and reduce hazard risk and adverse socio-economic impacts of slope failures.

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1. Introduction

Slope stability analysis is significant in hazard assessment because it relates to many types of large- and small-scale slope failure events, which can be disastrous in regions with complex topography, steep slopes, intense precipitation patterns, erosion, and substantial anthropogenic activities. The resistance of inclined surfaces to failure by sliding or collapsing constitutes the fundamental definition of slope stability and is influenced by geological, vegetational, hydrological, and geomorphological factors (Duncan et al., 2014; Manohar and Vasudevan, 2021; Cruden and Varnes, 1996; Kumar, 2025; Ehsan et al., 2025; Quevedo et al., 2023). Rainfall-induced sliding is a common natural hazard in many tropical regions (Rahardjo et al., 2007). Different processes contribute to the reduction in the shear strength of rock masses, including increased pore pressure, cracking, swelling, decomposition of clayey rock fills, creep under sustained loads, leaching, strain softening, weathering, and cyclic loading (Brahimaj and Dambov, 2018). The shear stress in rocks increases due to additional loads at the slope's top, increased water pressure within cracks, higher soil weight resulting from increased water content, excavation at the bottom of the slope, and seismic effects (Brahimaj and Dambov, 2018; Mekonnen, 2021). Though slope stability problems are frequently encountered in the

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construction of roads, buildings, canals, dikes, and dams, some of them are naturally unstable (Bouajaj et al., 2016). Slope failure can significantly impact the environment and livelihoods, and it can be catastrophic. Slope stability analysis and zonation are therefore essential for identifying and categorising regions based on their failure susceptibility, aiding risk reduction and the development of land-use strategies to mitigate related hazards. Stability zonation mapping differentiates the land surface into various stability zones by accounting for the known impacts of contributory factors that trigger instability. It is useful for planners to identify hazard-prone areas, determine suitable methods for development and construction, and outline hazardous areas of instability to adopt appropriate mitigative measures.

Studies conducted by several researchers in many landslide-prone or slope-failure areas around the world have focused on mapping slope failures, identifying the factors that cause them, forecasting future occurrences, analysing susceptible zones, and studying the role of contributing factors. The landslides and slope failure events are being studied both quantitatively and qualitatively using Remote Sensing (RS) and the Geographic Information System (GIS), as well as through the application of various statistical and computational models. The earliest documented landslide susceptibility mapping in India was conducted in the Nilgiri area of the Western Ghats by Seshagiri et al. (1982) and in the Kathgodam–Nainital region of the Himalayan belt by Anbalagan (1992). In 1998, the Bureau of Indian Standards (BIS) developed macro-scale (1:50,000) landslide susceptibility zonation guidelines for the entire country (BIS, 1998). These guidelines propose mapping landslide susceptibility indirectly, focusing on a generalised heuristic approach that involves direct or indirect fixed weighting or ranking of geo-factors, without relying on a landslide inventory database. Since then, several studies have been published nationwide, including site-specific investigations to identify the primary contributing factors, GIS based landslide hazard zonation using subjective and objective rating technique, Quantitative Method, BIS Multi- Criteria Analysis (MCA), Frequency Ratio (FR), and Rank & Weightage method (Paul et al., 2000; Sah and Mazari, 1998; Sarkar and Gupta, 2005; Pareta et al., 2012; Kannan et al., 2015; BIS, 1998; Rajamohan et al., 2014; George et al., 2025; Sreekumar, 2009; Vijith and Madhu, 2008).

The Indian monsoon significantly influences the frequency and distribution of landslides and slope failures (Kuriakose, 2006). Large volumes and high-intensity rainfall (Soja and Starkel, 2007) and the resulting development of pore water pressure are considered as the primary triggers of landslides in the Western Ghats (Jaiswal and Van Westen, 2009; Sreekumar, 2009; Kuriakose et al., 2009; Sajinkumar et al., 2011; Sajinkumar et al., 2014; Sajinkumar et al., 2017) and in the Himalayas (Joshi and Kumar, 2006; Vinod Kumar et al., 2008). In the Himalayas, landslides are also triggered by earthquakes (Saraf, 2000; Ray et al., 2009), but are not known to have occurred in the Western Ghats (Kusala and Rajendran, 1995). During monsoon season, the Western Ghats in Kerala experience several types of slope failures. This involves slides, creeps, debris flows, rock falls, rock slips, and, in some cases, rotational slides (Thampi et al., 1998). Basak and Narasimhaprasad (1989) emphasised the role of soil saturation, pore-water pressure, and the resulting loss of shear strength during severe rainfall events in triggering landslides in Kerala. According to Sankar (1991), slope failures in the state were more likely to occur on terraced slopes without adequate drainage systems. The first regional-scale landslide susceptibility mapping using the heuristic districts method was conducted by Thampi et al. (1998) in the Kottayam and Idukki districts, and it was reported that most mass movements occur on hill slopes with angles greater than 20 degrees along the Western Ghats of Kerala. Sreekumar (2009) critically analysed the stability of a typical hard rock profile. He concluded that the geotechnical failure threshold increases due to rising piezometric head and pore pressure during rainstorms. Jishnu (2015) employed a similar approach to identify potential landslide-vulnerable zones in Wayanad district, Kerala, using remote sensing and GIS. Ajin et al. (2014) generated landslide-susceptible zone mapping using RS and GIS techniques in the Meenachil and Kanjirapally taluks of Kottayam district.

Although various studies have explored landslides and debris flows in Kerala's Western Ghats, limited attention has been given to small-scale slope failures, such as soil slides, despite their increasing frequency and socio-economic impact. Ajith et al. (2024) mentioned that soil slumps/slides commonly initiate at the upslope part and advance downslope. It is often observed that during the monsoon season, soil slides occur more frequently on sloping terrain in Kerala.

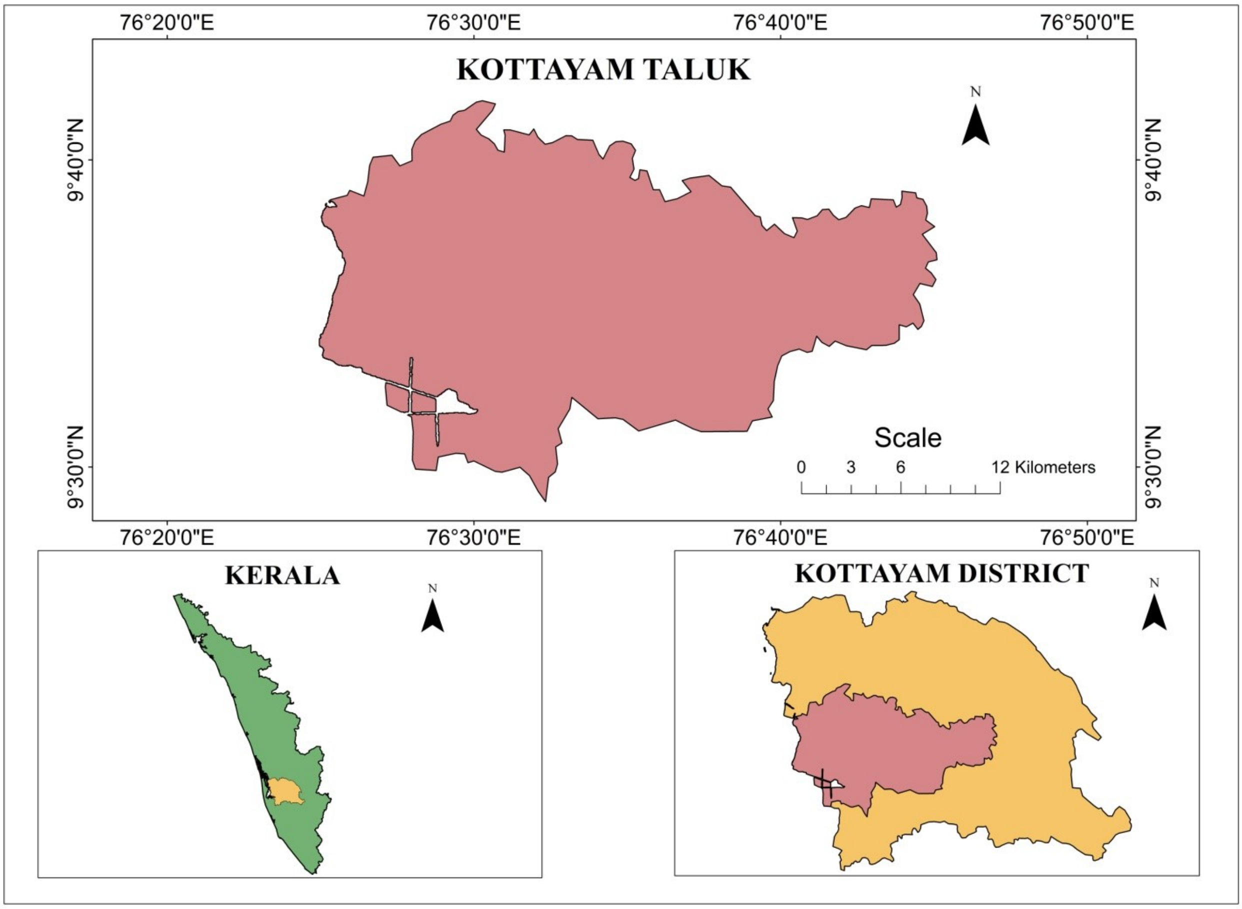

Fig. 1. Location and boundary of the study area.

Even though soil slides are often considered minor compared to large landslide incidents, they pose a significant localised threat to property, land productivity, and livelihoods, especially in the midland terrains of Kerala, which contribute significantly to the state's agricultural and rural economy. Hence, a detailed study of soil slides, focusing on their occurrence, triggering factors, and socio-economic impacts, is necessary to inform suitable prevention and mitigation measures.

2. Study area

The study area, Kottayam taluk, is located between 76°24'56.881" and 76°45'3.516" East longitudes & 9°28'55.512" and 9° 41' 59.307" North latitudes (Fig. 1). The taluk, which forms part of the Kottayam district, has a total area of 499.89 sq. km (Census of India, 2011) and is bordered by Vaikom, Changanassery, Meenachil, and Kanjirapally taluks in the north, south, northeast, and southeast respectively, and Alappuzha district in the west. The area is characterised by its undulating topography and spans across the midland and lowland physiographic divisions of Kerala. The Meenachil River, one of the three major rivers that flow through the Kottayam district along with the Muvattupuzha and Manimala rivers, constitutes the drainage system. Vembanad Lake, the largest backwater in Kerala, forms the western part of the taluk. According to the Kerala Water Resource Information System (n.d.), Kottayam district receives an average annual rainfall of 3,112.8 mm. The villages in the taluk are Akalakunnam, Anicadu, Arpookara, Athirampuzha, Ayarkunnam, Aymanam, Chengalam, Ettumanoor, Kaipuzha, Kooroppada, Kottayam, Kumarakom, Manarcadu, Meenadom, Muttambalam, Nattakom, Onamthuruthu, Pampady, Panachicadu, Peroor, Perumpaicadu, Puthuppally, Thiruvarppu,

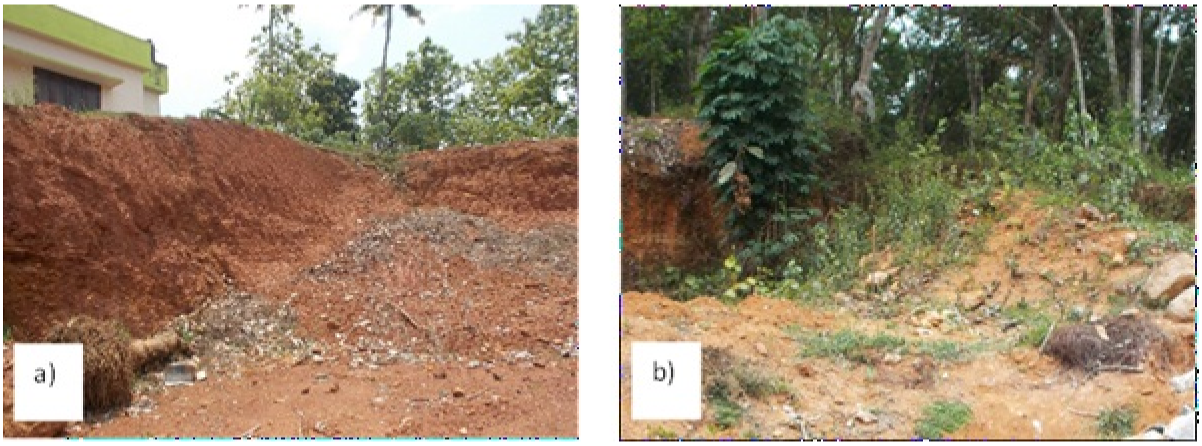

Fig. 2. (a), (b). Soil slides down a slope with a gradient of more than 20°.

Veloor, and Vijayapuram. The study area is primarily composed of metamorphic rocks with a thick lateritic cover. The eastern part of the taluk is covered by lateritic soil, whereas the western part is covered by river alluvial and clayey soil. The major structural lineaments are concentrated in the eastern part of the taluk, trending NW–SE. The land-use pattern of Kottayam taluk includes agricultural fields, built-up areas, wastelands, and water bodies. Rubber plantations are the predominant vegetation type in the area, accounting for 17.4% of the total rubber plantations in Kottayam district (Meti et al., 2008). Based on the data published by the Census of India (2011), Kottayam taluk has one of the highest population densities in Kerala, with 1264 persons per sq. km. In such a densely populated taluk, even a small-scale slope failure can result in disproportionately serious damage or loss to properties, agricultural assets, built structures, land and life (Fig. 2a & b). Thus, these small localised failures will have a greater potential impact on human life than the larger landslides that occur in sparsely populated high-altitude areas of the Western Ghats. This necessitates a scientific slope stability assessment to identify fragile zones, particularly within settlement areas, agricultural fields, and transportation corridors, thereby aiding the local governing body in developing appropriate preventive and mitigation measures to minimise socioeconomic losses and environmental degradation in the populated area.

3. Methodology

In the present study, the heuristic rank-and-weight method using GIS, proposed by Varnes (1984) and subsequently enhanced by Anbalagan (1992), has been applied to develop a stability zonation map. Thematic layers reflecting the primary contributing factors to slope instability were ranked and weighted according to their significance in influencing slope failure, in accordance with the Bureau of Indian Standards (BIS, 1998) guidelines. Eight geo-environmental factors, slope, rainfall, relative relief, drainage density, slope aspect, geology, land use, and lineaments, are considered for the study. A comprehensive field investigation was also undertaken to identify and assign appropriate weightages to these factors. Primary data sets used for preparing the thematic layers include Aster Global DEM (USGS Earth Explorer), geological map, and LU/LC map of the Kerala State Land Use Board, average yearly rainfall data from the Kerala Water Resource Information System (n.d.), SOI Toposheet (58C/C;1:50:000; surveyed in 1973), and administrative boundaries from DIVA-GIS. Lithology and lineaments of the Kottayam taluk have been digitised from the District Resource Map of the Kottayam district, prepared by the Geological Survey of India (GSI). All the spatial data are processed, georeferenced, and analysed using ArcGIS 10.4 software to create thematic layers and a slope stability zonation map. The thematic maps of various geoenvironmental factors, such as slope, slope aspect, relative relief, land use, lithology, drainage network, drainage density and lineament, are prepared using ArcGIS.

A numerical weight, called the Slope Failure Susceptibility Value (SFSV), is assigned to each geoenvironmental factor based on its relative importance, depending on terrain conditions. The selected zonation factors, along with their respective SFSVs, are tabulated in Table 1. Since the majority of mass move-

Table 1. Different factors with their SFSV and CSFSV values.

	SFSV*	**Factors used for Raster calculation**	**CSFSV****	
Slope	30	Slope	50	0.5
Slope aspect	10			
Rainfall	10			
Relative Relief	20	Relative Relief	25	0.25
Geology	5			
Drainage Density	10	Drainage Density	15	0.15
Lineament Density	5			
Agriculture & Fallow land	5	Land use	10	0.1
Built-up	4			
Water bodies	1			
Total	**100**		**100**	**1**

SFSV: Slope Failure Susceptibility Value, CSFSV**: Combined Slope Failure Susceptibility Value.*

ments have occurred on hill slopes with angles greater than 20° along the Western Ghats scarps (Kuriakose et al., 2009; Thampi et al., 1998), slope was assigned greater weightage, as the study area exhibits an undulating topography with slopes varying between 0° and 35°. After assigning SFSV to each factor, related factors are combined to calculate the Combined Slope Failure Susceptibility Values (CSFSV), which is used for raster calculation (Table 1). For that, the thematic layers were reclassified into four classes to be used for raster calculation; subsequently, the ranks 1 to 4 are assigned to the classes based on the susceptibility of occurrence of slope failures, as an increase or decrease in the values of each factor. Rank 1 indicates a poor factor in causing slope failure, and the rank increases with the factor's favourability in causing slope failure. The calculations were performed using raster calculations in map algebra within the spatial analyst tool of the GIS, applying the equation (R * C), where R = the reclassified thematic layer and C = CSFSV calculated for 1. Further, all the weighed maps are integrated, and a stability zonation map is generated (Fig. 3).

4. Results and discussion

The DEM and the slope distribution map (Fig. 4 a, b) generated for the Kottayam taluk indicate undulating topography with an increase in slope towards the eastern part of the taluk, and hence is classified into four classes based on Young's (1972) quantitative classification, viz., $<10^\circ$, $10–18^\circ$, $18–30^\circ$, and $30–45^\circ$. Since slopes above 20° are prone to slope instability, the slope aspect map of the area shows 10 divisions (Fig. 5a), with the majority of slopes facing the S–SW and N–NW directions. The S–SW facing slopes have more chances for slope failures due to the greater intensity of mechanical weathering as the slopes form a major storm front, whereas failures along the N–NW slope faces are due to their steeper slopes. The relative relief of the taluk, which is also a manifestation of lithological variations, is grouped into four classes: 6.8–42, 42–78, 78–114, and 114–150 m/sq.km (Fig. 5b). The relative relief increases toward the eastern part of the taluk; hence, slope failures are more likely to occur in the eastern part with higher relative relief, compared to the western part, characterised by gentle slopes and thick residual soil cover. Evidence from the Western Ghats consistently shows a strong positive correlation between relative relief and landslide occurrence. Both the Wayanad and Amboori landslide studies suggest that the frequency of landslide occurrences increases markedly within relative-relief classes of 150–300 m/sq.km and 200–400 m/sq.km (Achu et al., 2020; Vineetha et al., 2019). Therefore, slope failure is expected to be higher where relative relief exceeds 100 m/sq.km. The landuse pattern of Kottayam taluk mainly includes agricultural fields, water bodies, and built-up areas, which constitute 92%, 4%, and 3% of the total area, respectively (Fig. 6). Although dominant vegetation types in the Kottayam taluk include pepper, paddy, pineapple, coconut, teak, and mixed homestead vegetation, rubber plantations are the predominant vegetation type in the taluk.

Agricultural practices associated with rubber plantations, such as contour bunding, often block the free passage of water and accelerate water infiltration, thereby contributing to slope failure events (Sajinkumar et al., 2014; Fig. 7a). Quarrying for construction materials and site development activities (Fig. 7b) without considering terrain conditions can also induce instability. Many quarries are located in Pampady, Akalakunnam, Chengalam East, Ayarkunnam, and Kooroppada areas of Kottayam taluk. Tremors produced by large-scale explosions & blasting oper-

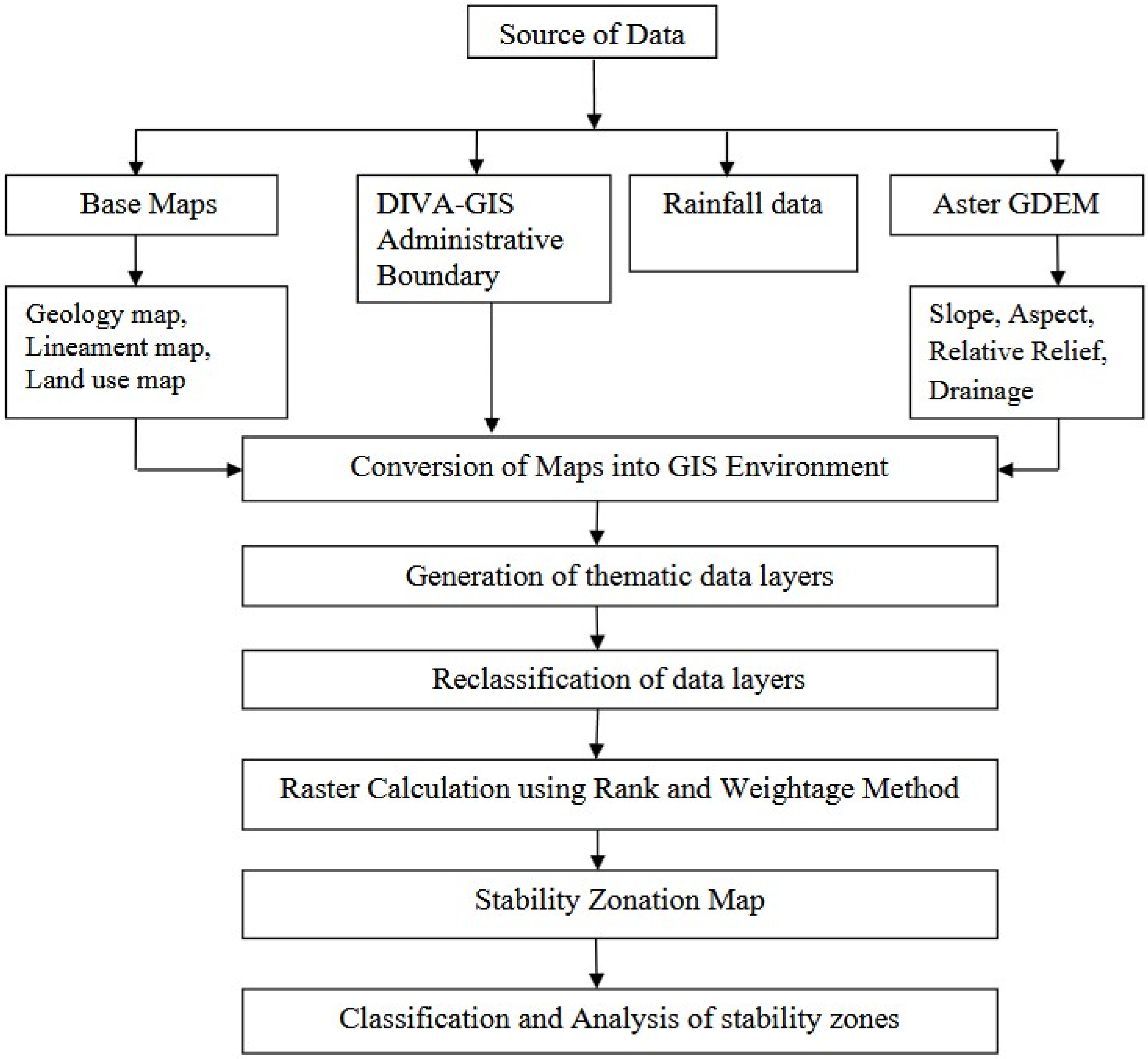

Fig. 3. Flow diagram of the methodology followed.

ations for quarrying, and machine vibration can adversely affect the equilibrium of slopes, and eventually lead to slope failures. The cracks & fractures that would form in the basement rocks and weathered column, and the loosening of soil by various quarry operations, could trigger soil slides even years later due to the continuous action of natural and/or anthropogenic agents along these weak zones. Therefore, built-up and agricultural areas are more vulnerable to slope failures.

The main rock type in the Kottayam taluk belongs to the charnockite group of the Precambrian metamorphics, concentrated in the central and eastern parts of the taluk, with patches of other crystalline rocks of the khondalite group and basic rocks (Fig. 8). The migmatite complex is located in the central part, and acidic rocks in the Southwestern part. From east to west, the area exhibits a gradual transition from hard crystalline basement rocks to Quaternary sedimentary units of sand, silt, sandstone, and clay. The natural strength of rocks is governed by several factors, such as their types, the presence of various discontinuities like faults, joints or fractures, and the degree of weathering (Ajin et al., 2016).

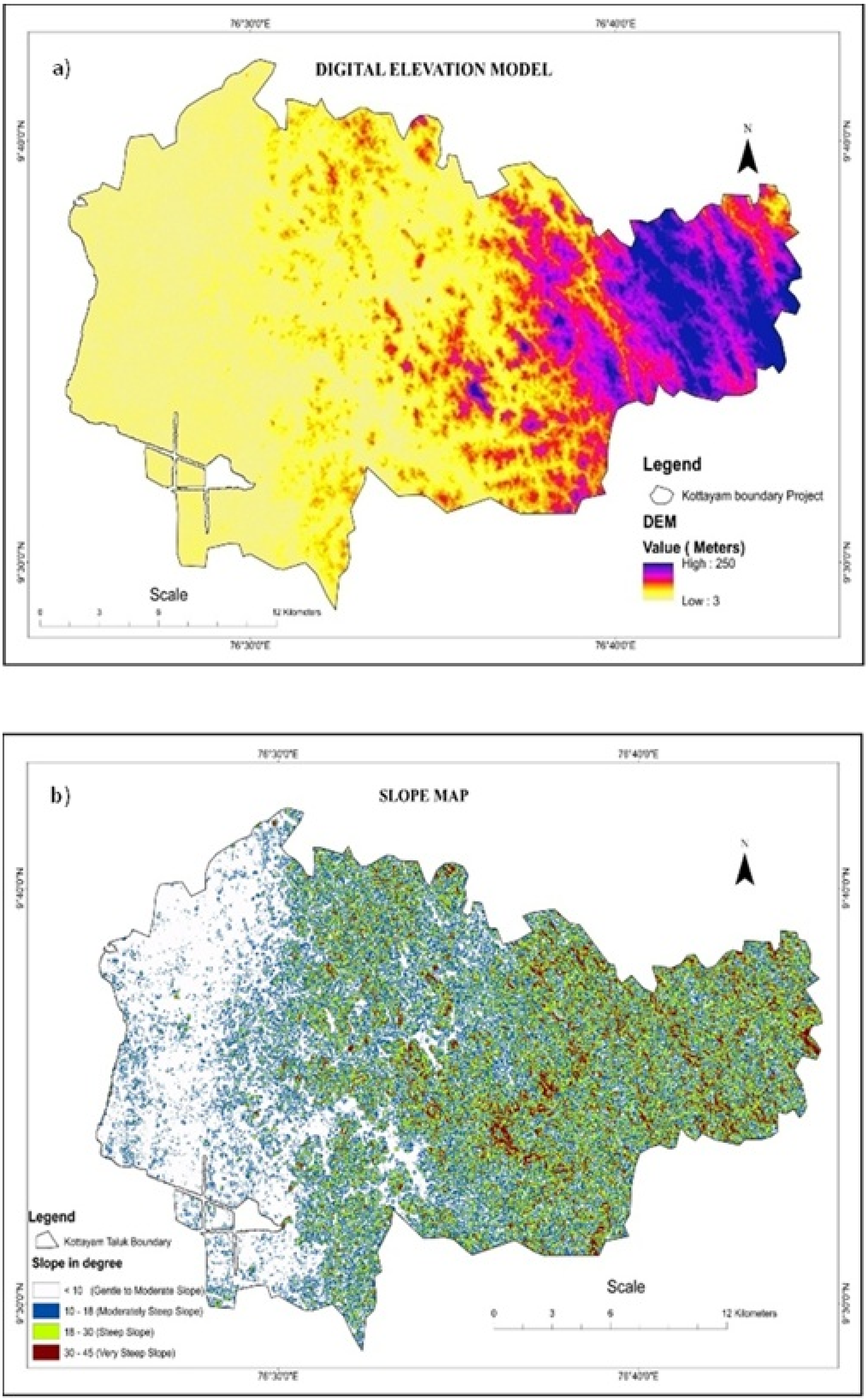

Fig. 4. (a) Digital Elevation Model, and (b) Slope distribution map of the Kottayam taluk.

Additionally, the overburden thickness plays a crucial role in controlling slope stability, as the shear strength of the soil column is primarily governed by gravitational forces (Rudra et al., 2024). Generally,

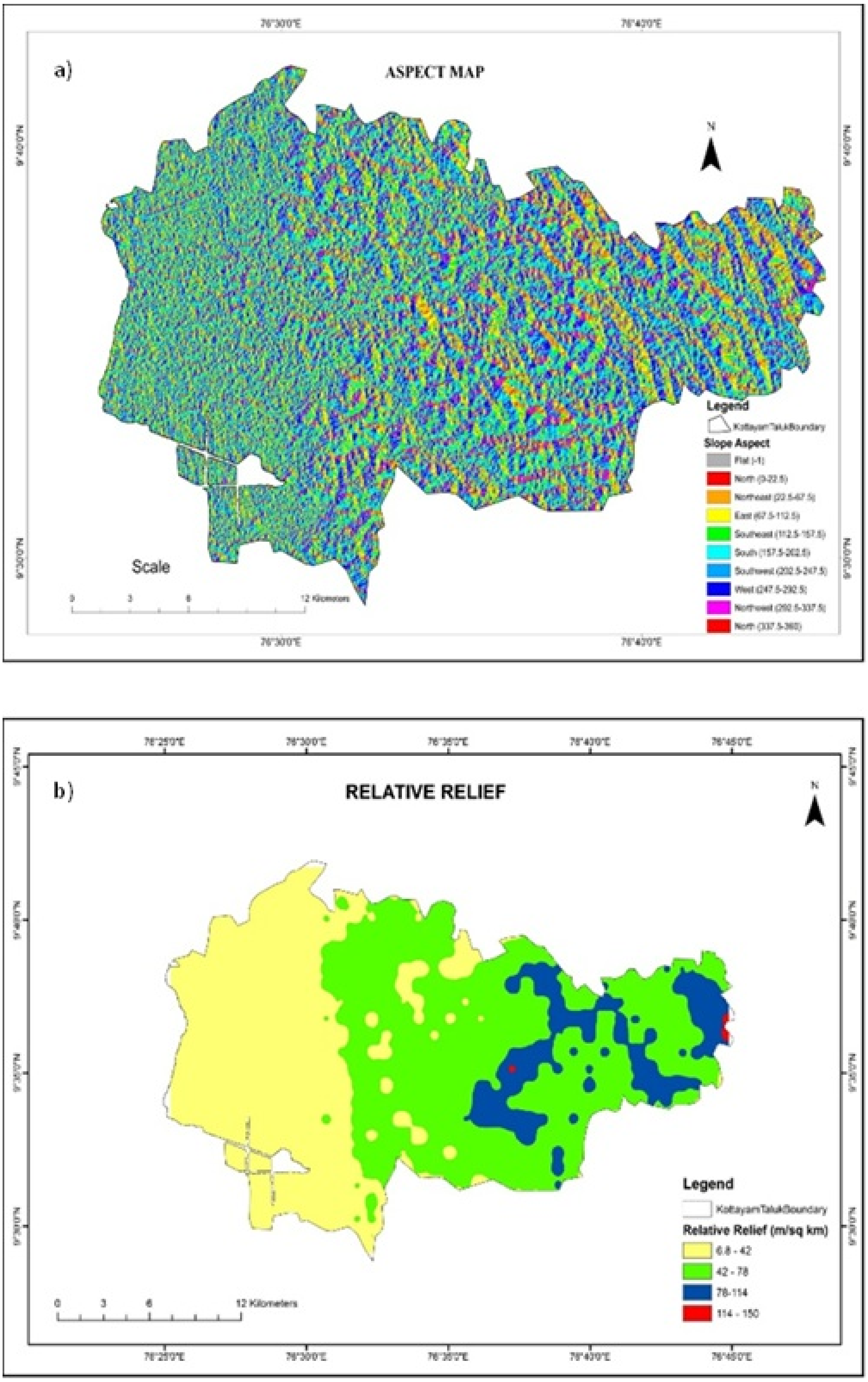

Fig. 5. (a) Slope aspect map and (b) Relative relief distribution map of the Kottayam taluk.

the slopes with thin to moderately thick soil cover are more prone to failure. However, during the rainy season, gravity-driven slippage of materials can occur along slopes due to the combined effects of an increase in the weight of thick soil cover, pore-water pressure, and plasticity of clay minerals in the soil.

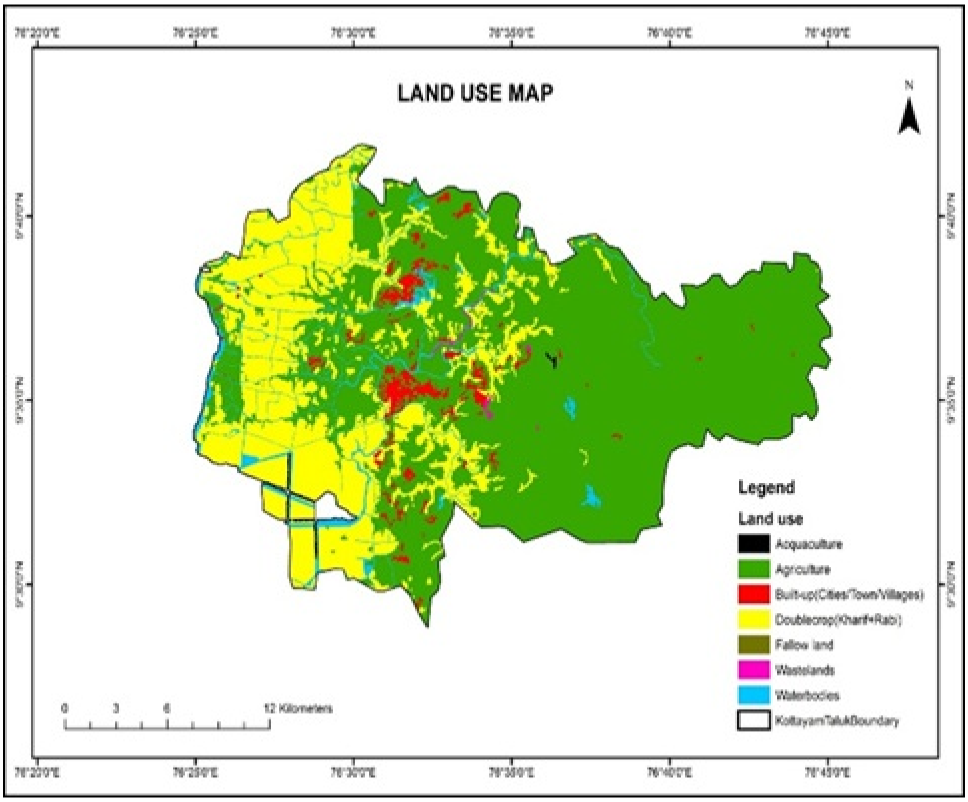

Fig. 6. Land-use pattern of the Kottayam taluk *(Produced from the LU/LC Map of Kerala State Land Use Board).*

Fig. 7. (a) Contour terracing without a proper drainage system, and (b) development activities that could destabilise the slopes.

The drainage network, characterised by stream orders 1–4, is part of the drainage system of the Meenachil River (Fig. 9a). Most of the streams flow towards W–SW in the area. Even though the dendritic drainage pattern predominates the study area, its eastern part is characterised by the trellis pattern due to the presence of lineaments trending in the NW–SE. Dendritic drainage patterns form where tributaries join the main stream at acute angles, producing irregular branching networks, and underlying rock structures do not control the position of stream channels. Such patterns typically develop in terrains where rocks have uniform resistance to weathering and erosion, and are not intensely joined. In contrast, a trellis drainage pattern consists of long, parallel or sub-parallel streams linked by short, right-angled segments. Trellis drainage pattern is typically indicative of faults and folding in the underlying rocks, where parallel outcrops of erodible rocks form valleys between more resistant ridges. The drainage density of the Kottayam taluk is grouped into four different classes, viz., 0–1 km/sq.km, 1–2 km/sq.km,

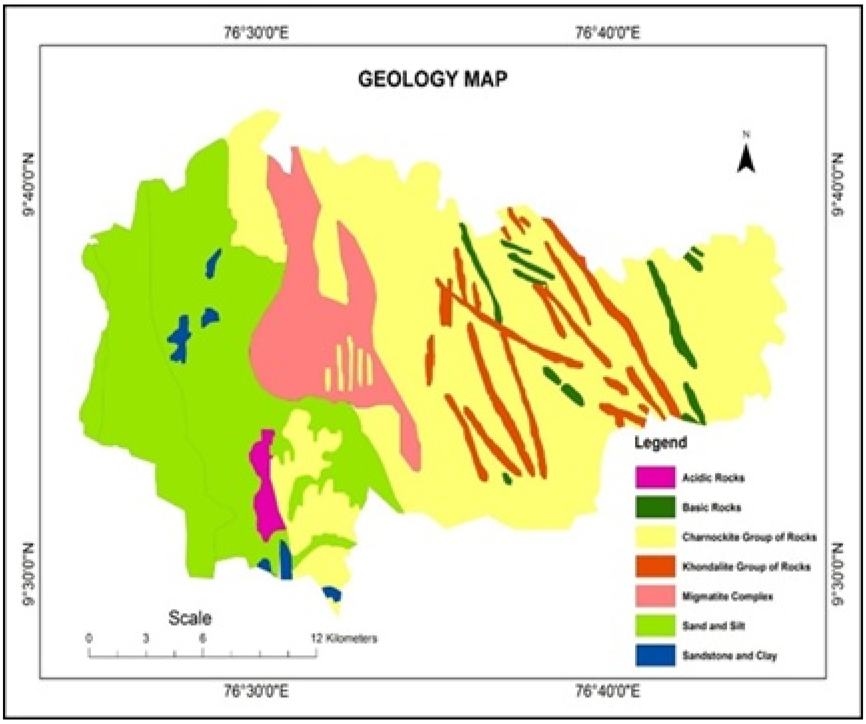

Fig. 8. Geological map of the Kottayam taluk *(After Geological Survey of India).*

Table 2. Classes, ranks, and CSFSV values for factors used in raster calculation.

SL No	Factors used for raster calculation	Classes	Rank	CSFSV	
1	Slope (Degree)	<10	1	50	0.5
		10–18	2		
		18–30	3		
		30–45	4		
2	Relative relief (m/sq.km)	0–62	1	25	0.25
		62–124	2		
		124–186	3		
		186–248	4		
3	Drainage density (km/sq.km)	0–1	4	15	0.15
		1–2	3		
		2–3	2		
		3–4	1		
4	Landuse	Double crop/water bodies	1	10	0.1
		Aquaculture/ Fallow land/Wasteland	2		
		Agriculture	3		
		Built-up	4		

2–3 km/sq.km, and 3–4 km/sq.km (Fig. 9b). The lowland-midland areas with high drainage densities will restrict infiltration of water during heavy rainfall, promoting considerable surface runoff, and will have less erosion and steepening of valleys compared to those in the highland areas, where the drainage causes steepening of valleys by deep cut erosion. If proper drainage facilities are not provided, infiltration of water during heavy rainfall increases the pore pressure of soil and rock masses, which ultimately results in slope failures. In the Kottayam taluk, drainage density is higher in the localities of Kumarakam, Chengalam South, Perumbaikad, and lower in Anikkad, Chengalam East, Pampady, and Meenadam.

Lineaments are geologically weaker narrow zones associated with faults, fractures, or shear movements. Many NW–SE trending lineaments are present in the eastern part of the taluk (Fig. 10). Their presence affects the natural strength & weathering of rock masses, and the drainage network of an area, increasing the likelihood of slope failure in the area. All these thematic layers described above were subsequently reclassified based on their corresponding contribution to slope instability. Each class within these layers

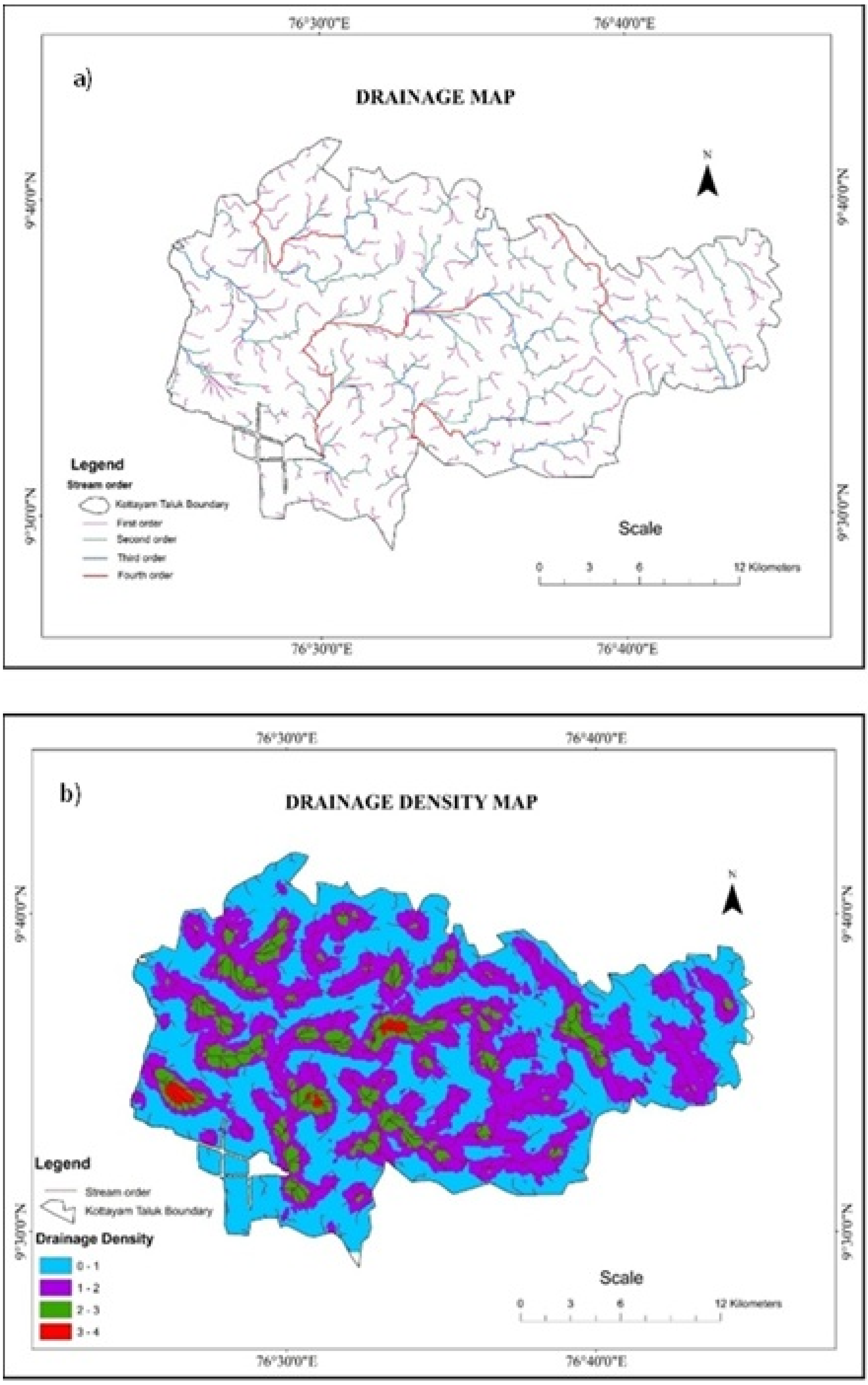

Fig. 9. (a) Drainage network and (b) Drainage density of the Kottayam taluk.

was assigned a rank and a corresponding weightage, and then integrated using GIS raster calculations to derive the Combined Slope Failure Susceptibility Values (CSFSV) for every spatial unit within the study area (Table 2). These resulting CSFSV values were used for creating the stability zonation map, delineating zones of varying slope instability (Fig. 11).

The stability zonation map demarcates the Kottayam taluk into four zones of varying degrees of stability, such as very stable, stable, moderately stable, and unstable. The analysis of the stability zonation map indicates that very stable and stable zones together constitute the majority of the study area, exhibiting minimal slope failure risk. Regular land use and development activities can be accommodated in the area, provided that proper geotechnical and environmental guidelines are followed. The moderately stable zone, which covers approximately 7% of the

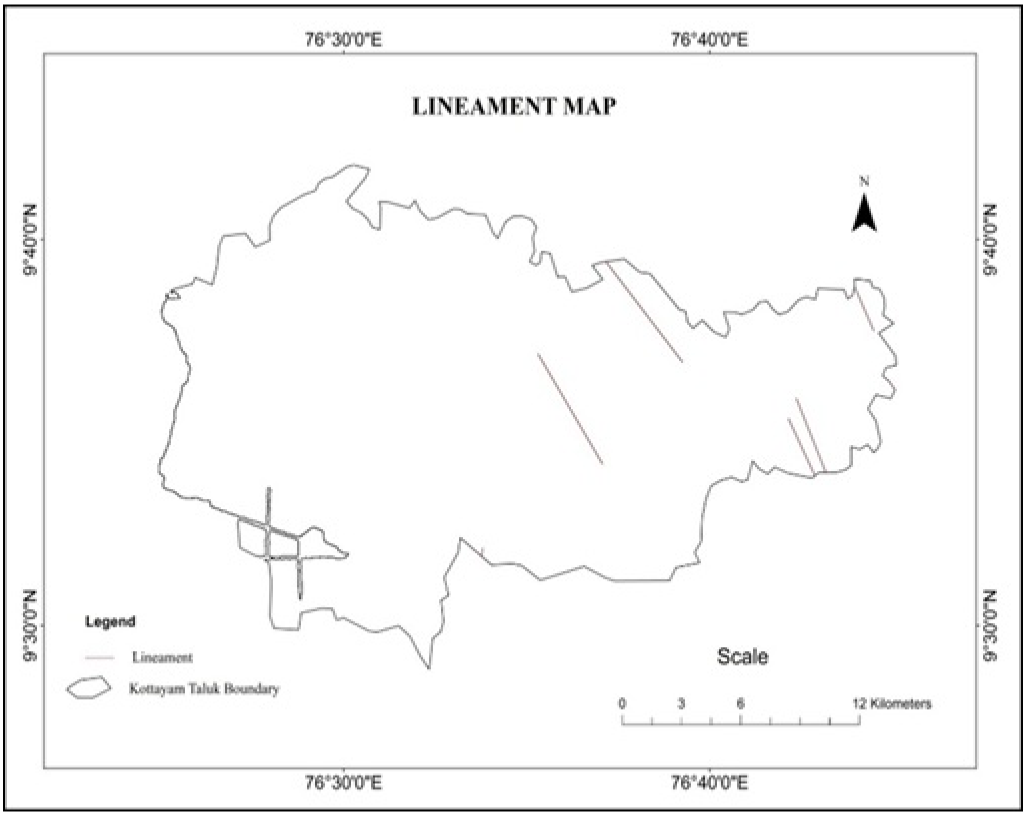

Fig. 10. Lineament distribution in the Kottayam taluk *(Digitised from the District Resource Map, Kottayam district, GSI).*

taluk (37.22 sq. km), is located around Chengalam East, Anikkad, Kooroppada, Pampady, Meenadam, Puthupally, Akalakunnam, Manarcad, Vijayapuram, Ettumanoor, Athirampuzha, and Peroor. Although the zone is considered to have relatively low risk, slope failures can still occur when development and agricultural activities are initiated without proper geotechnical study and without adopting suitable mitigative measures.

However, the unstable zone is limited to 1% (2.21 sq.km) of the taluk; it gains critical importance due to its substantially high risk of slope failure. This zone is distributed in many localities in the east, southeast, northeast, and central parts of the Kottayam taluk, particularlyaround Anikkad, Chengalam East, Kooroppada, Akalakunnam, Meenadam, Pampady, Puthupally, and Ettumanoor. Since any construction or terrain modification could severely accelerate slope failures in these localities, it is always advisable to avoid any kind of development and agricultural activities.

5. Mitigative measures

The soil slides could occur in both the moderately stable and unstable zones. Since the taluk is thickly populated with a population density of 1264 persons per sq.km, human life could be significantly impacted by these slope failure events, posing a significant threat to property, land productivity, and livelihoods. Overall, the insight derived from the stability zonation map underscores the need for effective mitigation measures in both unstable and moderately stable zones, where human interference can initiate slope failures. Strengthening these vulnerable zones through appropriate geotechnical planning is crucial for reducing the risk of slope failure and ensuring safe and sustainable land use. Effective mitigation strategies can be developed more easily when slope instability problems are identified early in the planning and site investigation process. The mitigative measures that can be adopted for instability zones of the study area, for various development activities, mainly include drainage correction, scientific land-use practices, regrading or terracing, retaining walls and buttresses, vegetative turfing, and coir/jute net application. The drainage corrections include drainage collection works and drainage channel works. Both these methods avoid an increase in fluid pressure, the possibility of liquefaction, and increased weight due to the addition of water (Highland and Bobrowsky,

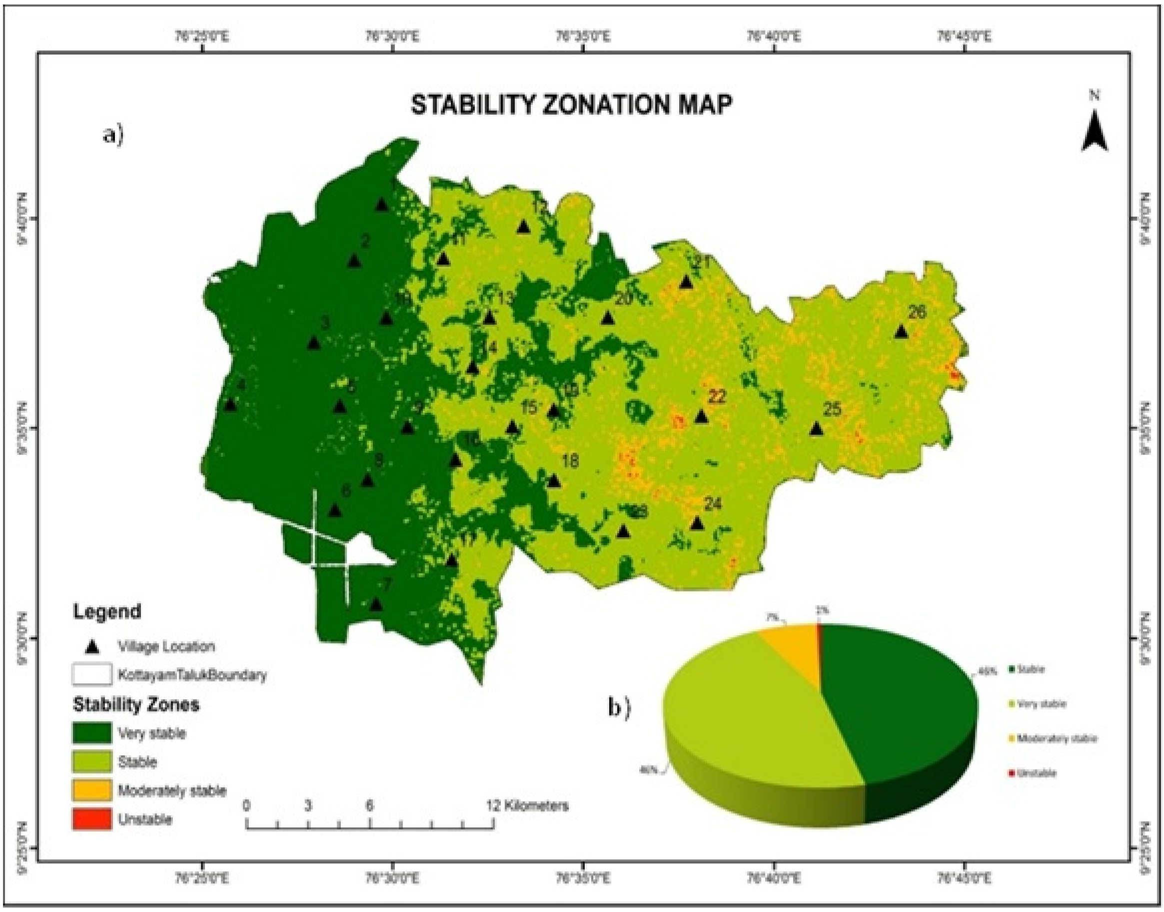

Fig. 11. (a) Map showing the distribution of various stability zones in the Kottayam taluk. Triangles depict each village locations: 1-Onamthuruthu, 2-Kaipuzha, 3-Aimanam, 4-Kumarakam, 5-Chengalam South, 6-Thiruvarpu, 7-Nattakam, 8-Veloor, 9-Kottayam, 10-Arpookara, 11-Athirampuzha, 12-Ettumanoor, 13-Peroor, 14-Perumbaikad, 15-Vijayapuram, 16-Muttampalam, 17-Panachikkad, 18-Puthuppally, 19-Manarcad, 20-Ayarkunnam, 21-Akalakunnam, 22-Kooroppada, 23-Meenadam, 24-Pampady, 25-Anikkad, 26-Chengalam East; and (b) Percentage of each stability zone.

2008; Sari et al., 2023; Ige et al., 2016). Scientific land-use practices such as stubble mulching and systematically designed contour bunding along the slope should be promoted. The contour terraces should be designed in such a way that the excess water collected over them needs to be drained off. It is also preferable to have permanent vegetation over seasonal cultivation to avoid frequent surface soil disturbance during land preparation practices. Another method, known as regrading or terracing can be used to reduce steep slopes in vulnerable zones below the land's natural angle of repose. Retaining walls can be built to stabilise slopes in moderately stable zones, preventing small-scale slope failures. In the unstable zones, buttresses can be used to support overhanging blocks that are too large or too dangerous to remove. Vegetative turfing, which involves vegetation on embankment or hill slopes, is the most economical method of slope stabilisation. This method uses fast-rooting plants to control erosion and can be applied effectively in unstable zones. Jute or coir netting on man-made embankments and natural slopes acts as a check dam, protecting the soil until vegetation takes root and thereby protecting the slope.

6. Conclusion

Soil slides are recognised as the most common slope failure mechanism in many parts of Kottayam taluk, mainly influenced by various geoenvironmental factors such as slope, rainfall, relative relief, drainage density, land use, and others. Since Kottayam taluk is one of the most densely populated regions of Kerala, such soil slide incidents can have a greater impact on human life than the large landslides that occur along the Western Ghats. The combined analysis of thematic maps of slope, slope aspect, relative relief, geology, drainage, and lineament distribution in this study shows that the eastern part of Kottayam taluk is more vulnerable to slope failures than other areas. Moreover, anthropogenic activities for agriculture and construction further worsen slope instability in the region. Stability zonation mapping, using Remote Sensing and Geographic Information Systems, effectively identified and delineated different stability zones. The stability zonation map created using the Heuristic rank and weightage method in GIS identified four zones viz., very stable, stable, moderately stable, and unstable. While the stable zones are evenly spread, the unstable zones are mainly found in specific localities in the central and eastern parts of Kottayam taluk, around Anikkad, Chengalam East, Kooroppada, Akalakunnam, Meenadam, Pampady, Puthupally, and Ettumanoor. This scientific assessment highlights fragile areas, more prone to slope failure, that require close monitoring by local authorities for development and agricultural activities. Several mitigation measures, including drainage improvements, scientific land-use practices, regrading or terracing, retaining walls & buttresses, vegetative turfing, and coir/jute net application, can help stabilise the slopes. Raising community awareness about slope stability, following scientific land-use guidelines, and actively engaging in mitigation efforts are equally vital for long-term stability and hazard reduction.

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Conflict of interest statement

The authors declare that they have no competing financial interests or personal relationships that could influence the outcome of this work.

CRediT statement

K.K.A.-Conceptualization, supervision, resources, formal analysis, data curation, visualization, writing original draft, validation. **J.J.**-Conceptualisation, formal analysis, data curation, investigation, methodology, writing original draft, visualization, validation. **X.T.**-Conceptualisation, data curation, methodology, formal analysis, visualization.

Data availability statement

Data will be made available on request.

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