



Assessment of Landslide Susceptibility Mapping in Churachandpur District, Manipur, using Geospatial Techniques

OPEN ACCESS

Received: 25-02-2025

Accepted: 10-10-2025

Published: 16-10-2025

Citation: Haokip TL, Naik SRS, Prasad TK, Jayapal G. (2025). Assessment of Landslide Susceptibility Mapping in Churachandpur District, Manipur, using Geospatial Techniques. *Geo-Eye*. 14(1): 10-20. <https://doi.org/10.53989/bu.ge.v14.i1.25.3>

* **Corresponding author.**
shree.rathod72@gmail.com

Funding: None

Copyright: © 2025 Haokip et al. This is an open access article distributed under the terms of the [Creative Commons Attribution License](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Published By Bangalore University, Bengaluru, Karnataka

ISSN

Print: 2347-4246

Electronic: XXXX-XXXX

T L Haokip¹, S R Sreerama Naik^{2*}, T K Prasad³, G Jayapal⁴

¹ Research Scholar, Department of Geography, Kannur University, Edat, Payyanur, Kannur, 670327, Kerala, India

² Assistant Professor, Department of Geography, Kannur University, Edat, Payyanur, Kannur, 670327, Kerala, India

³ Associate Professor, Department of Geography, Kannur University, Edat, Payyanur, Kannur, 670327, Kerala, India

⁴ Associate Professor and Head, Department of Geography, Kannur University, Edat, Payyanur, Kannur, 670327, Kerala, India

Abstract

Landslides are a significant hazard in Churachandpur district, Manipur, frequently triggered by heavy rainfall, earthquakes and human activities such as deforestation, shifting cultivation and construction. The landslides are more prominent along National Highway 150 and 102B due to high topography, ranging up to 2,100 metres above sea level. The research used weighted parameter analysis, remote sensing (RS) and geographical information system (GIS) methodologies to create a landslide susceptibility map for the study area. High-resolution thematic layers were generated from various data sources, including terrain-corrected data from *earthexplorer.usgs.gov* (SRTM 30 m resolution), Sentinel-2A multi-spectral satellite imagery (10 m resolution) and LANDSAT 8 satellite data, alongside other relevant factors such as rainfall distribution, slope and structural features (faults, drainage density, roads). These thematic layers were integrated within a GIS platform (ArcGIS 10.8) to identify zones vulnerable to landslides. A standard weighted overlay technique assigned values ranging from 0 to 10 to different causative factors influencing landslide occurrence. The resulting landslide susceptibility map categorizes the study area into three levels: high, medium and low susceptibility. The landslide displacement in high-susceptibility zones highlights significant terrain movement, ranging from minor soil shifts to large-scale debris flow, disrupting transportation, damaging infrastructure and threatening livelihoods, requiring urgent mitigation measures for regional safety. This research provides valuable insights for regional infrastructure planning, landslide hazard mitigation and geo-environmental development, ultimately contributing to enhanced safety and sustainable development in the Churachandpur district.

Keywords: Human Activities; Satellite Data; Thematic Maps; Landslide Susceptibility; Landslide

1 Introduction

Landslides are geological phenomena characterized by the downward movement of soil, rock and debris on sloped terrains, often triggered by factors like heavy rainfall, earthquakes or human activity⁽¹⁾. These events pose significant risks to life, property and infrastructure, particularly in mountainous regions⁽²⁾. The complex interplay of geological, hydrological and environmental factors contributes to their occurrence and severity^(3,4). Understanding landslide mechanisms is crucial for effective risk assessment and management, especially in vulnerable areas where development and natural hazards intersect, necessitating comprehensive monitoring and zonation strategies to mitigate impacts⁽⁵⁾. In the eastern Himalaya range, landslides are frequently triggered by seismic activity due to the region's tectonic instability⁽⁶⁾. Earthquakes can destabilize slopes, leading to the rapid movement of soil and rock⁽⁷⁾. The steep topography and diverse geological formations of the Himalayas further intensify this risk, particularly in areas with loose or saturated soil. Regions like Manipur, Nagaland, Mizoram, Sikkim and Arunachal Pradesh often experience landslides following significant seismic events, impacting local communities and infrastructure. Additionally, the heavy monsoon rains common in this area can saturate the soil, making it more susceptible to landslides⁽⁸⁾, especially in regions already weakened by seismic activity. Implementing early warning systems and conducting thorough geological assessments are vital for minimizing the impact of landslides in these earthquake-prone zones, ensuring community safety and resilience⁽⁹⁾. Landslide displacement refers to the movement of soil, rock and debris caused by unstable terrain. In high-susceptibility zones, displacement ranges from minor shifts to large-scale flows,⁽¹⁰⁾ disrupting infrastructure, transportation and livelihoods. Addressing this requires mitigation measures like monitoring, proper drainage and sustainable land-use practices.

2 Study Area

Churachandpur district is located in the southwestern part of Manipur, India, situated at coordinates 24.3335° N latitude and 93.6815° E longitude. Its location underscores its importance as a gateway between Manipur and Mizoram, with its highways serving as lifelines for the communities residing in this hilly terrain. This region boasts a wealth of cultural and natural diversity.

Churachandpur district in Manipur spans 2,392 km², bordering Mizoram, Nagaland, Assam and Myanmar. Its headquarters, Lamka, is a vital connectivity hub. The district's terrain is predominantly mountainous (94.75%), with smaller valleys (5.25%), making it highly susceptible to landslides. Key transit routes, including National Highways 150 and 102B, which link Manipur to Myanmar, face frequent disruptions due to landslides triggered by rainfall, steep slopes,

unstable soil and tectonic activity. Located in UTM North 46, landslide-prone areas endanger infrastructure and safety, emphasizing the need for zonation mapping. Using GIS, remote sensing and field data, factors like slope, soil and vegetation are assessed to identify high-risk zones. This approach aids in safeguarding infrastructure, ensuring high-way connectivity and guiding sustainable planning and disaster resilience in northeast India.

2.1 Climatic Condition

Churachandpur experiences a subtropical highland climate with distinct wet and dry seasons. The monsoon season, from May to October, brings heavy rainfall, ranging from 1,500 to 2,500 mm annually, often causing floods and landslides in the hilly areas. The winter months, from November to February, are dry and cool, with temperatures dropping to around 5°C in the colder regions. Summers, from March to April, can reach temperatures up to 30°C.

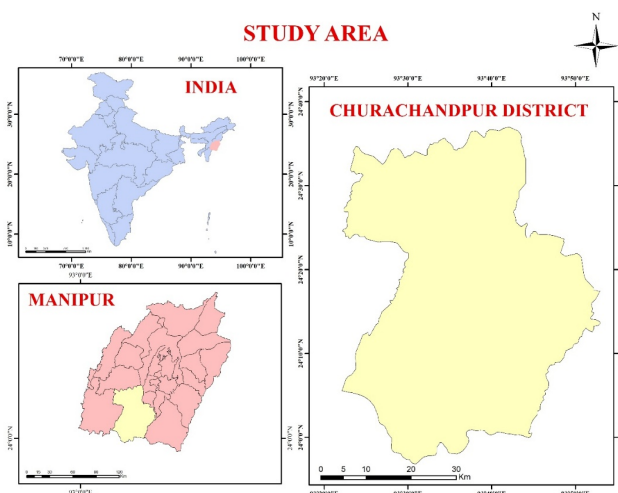


Fig. 1. Location Map of Study Area (Churachandpur District). Source: ArcGIS

Humidity is high during the monsoon season but decreases in winter. Rainfall can vary significantly across the district, sometimes reaching 2,000 mm during the peak monsoon months from June to September.

2.2 Topography

Churachandpur district, in southwestern Manipur, spans a rugged terrain with 94.75% hilly areas and 5.25% plains. It lies within the Indo-Burma range, with elevations from 300 m to over 2,100 m above sea level. High hills and ridges dominate the north and east, gradually descending to flatter, cultivable lands in the south and west. Rivers like the Khuga, locally known as Tuitha, shape the valleys and provide vital water resources. This diverse landscape, marked

by steep slopes and deforested areas is prone to natural hazards like landslides. The district's topography significantly impacts land use, agriculture and environmental challenges, highlighting the need for sustainable development and hazard management.

2.3 Historical Background

Churachandpur district, in southwestern Manipur, features a diverse and rugged topography critical to its environmental and developmental dynamics. About 5.25% comprises plains or valleys, while 94.75% is hilly terrain. It lies within the Indo-Burma range, with elevations from 300 m to over 2,100 m above sea level. The northern and eastern regions are dominated by high hills and ridges gradually descending southward and westward into flatter, cultivable lands. Rivers like the Khuga (locally Tuitha) carve through the landscape, forming valleys and supplying vital water resources. This distinct terrain, marked by steep gradients and deforested slopes makes the region highly susceptible to natural hazards like landslides. The district's topography significantly shapes its land use, agriculture and vulnerability presenting both challenges and opportunities for sustainable regional development.

3 Materials & Methods

A systematic approach was undertaken to collect a wide range of data for this study, primarily from primary sources, with rainfall data obtained as a secondary source. Essential geographical attributes such as geology, elevation, slope, aspect and curvature were gathered from the USGS Earth Explorer portal, while rainfall data was sourced from the CHRS data portal. Additionally, geomorphology, lineament and lithology information were acquired through Bhukosh GSI, soil data from NBSSLUP, drainage details from Hydrosheds and the road network from the PMGSY portal. Integrating these diverse data sources establishes a robust base for analysing land features and assessing terrain risks.

3.1 Thematic Layers

3.1.1 Slope

A slope map is a critical thematic layer in landslide studies, representing the steepness or incline of the terrain. Slope angles are directly correlated with landslide susceptibility, as steeper slopes are generally more prone to failure. This map is generated using a SRTM DEM. The slope is classified into 5 (five) classes, ranging from 0° to 70°. The slope map helps identify areas where the angle of incline exceeds the threshold for stability, making them more likely to experience landslides. It also aids in planning mitigation measures such as slope reinforcement or terracing, in these high-risk zones.

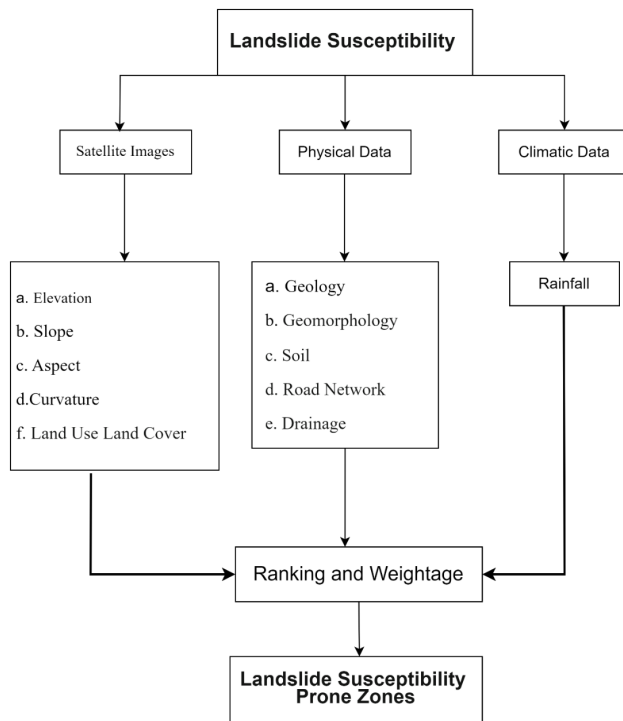


Fig. 2. Flow chart

Table 1. Slope Data

Sl. No	Count	Weightage	Ranking	Total
1	416237	9	1	9
2	731558	9	2	18
3	821443	9	3	27
4	551553	9	4	36
5	173604	9	5	45

3.1.2 Elevation

The elevation of Churachandpur, Manipur, ranges from 100 m to 2,000 m. Lower elevations (100 m-400 m) are flat plains supporting agriculture and settlements. Between 400 m and 800 m, the terrain features gentle slopes, while 800 m to 1,200 m showcases rolling hills. From 1,200 m to 1,600 m, the land becomes steeper with dense forests. The highest regions, 1,600 m to 2,000 m, consist of rugged mountainous areas. This elevation classification informs land use, environmental diversity, and vulnerability to hazards like landslides.

3.1.3 Curvature

Churachandpur district in Manipur features a diverse elevation range, classified into five classes from -24 m to 24.88 m, according to data from Earth Explorer (USGS). The elevation variation especially the lower and upper limits, influences the district's landslide susceptibility, with low-lying areas facing erosion and the higher slopes vulnerable to instability. The



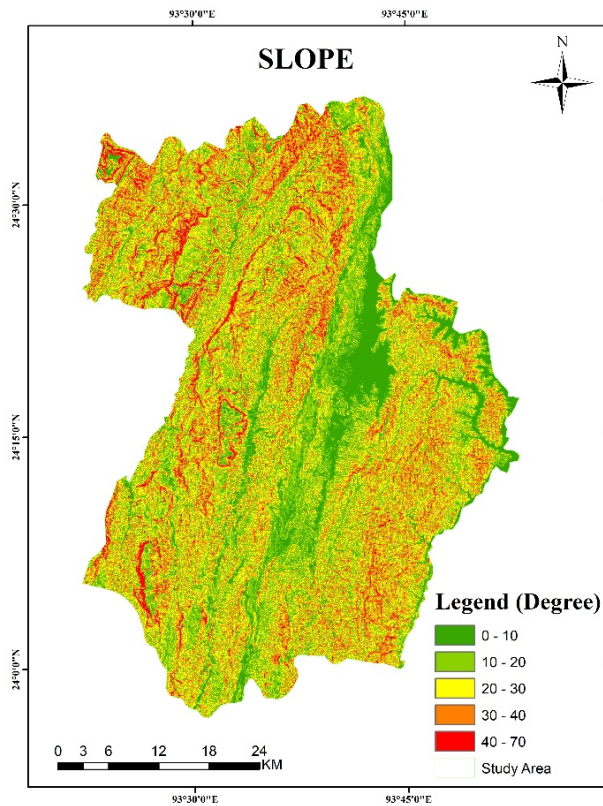


Fig. 3. Slope Profile

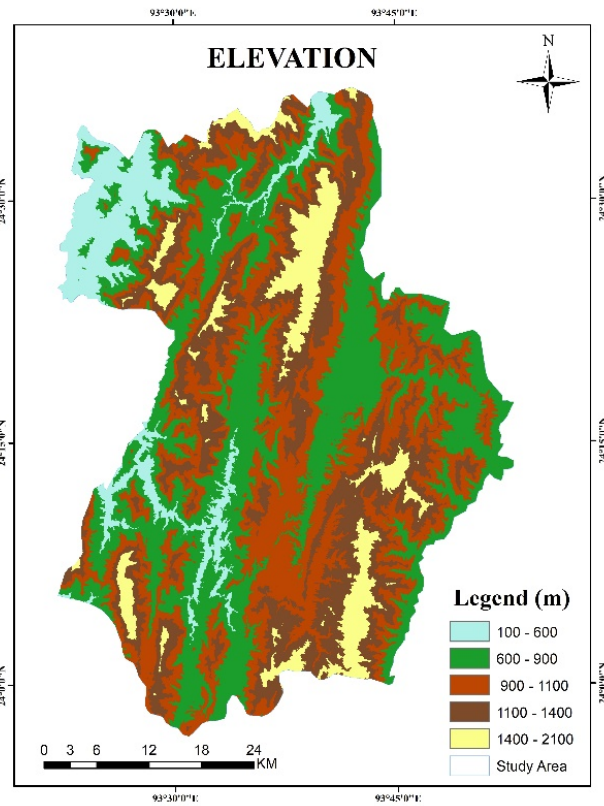


Fig. 4. Elevation Profile

Table 2. Elevation Data

Sl. No	Count	Weightage	Ranking	Total
1	205610	9	1	9
2	475624	9	2	18
3	621587	9	3	27
4	744623	9	4	36
5	643646	9	5	45

district's hilly terrain and soil types, influenced by clay and sandy deposits, also play a significant role in landslide occurrence. Effective mapping of elevation variations is essential to understanding high-risk zones and implementing proper landslide management strategies.

Table 3. Curvature Data

Sl. No	Count	Weightage	Ranking	Total
1	87349	9	1	9
2	615560	9	2	18
3	1104173	9	3	27
4	729425	9	4	36
5	166432	9	5	45

3.1.4 Aspect

An aspect map shows the direction a slope faces, influencing environmental factors like sunlight, moisture, and wind patterns. The slope's orientation affects erosion and vegetation, both crucial to landslide risk. Southern-facing slopes (in the Northern Hemisphere) are drier and more erosion-prone, while north-facing slopes retain more moisture, impacting soil stability. Aspect can be classified into five classes, ranging from 70° to 360°. An aspect map provides vital information for understanding how slope orientation contributes to landslide risk.

Table 4. Aspect Data

Sl. No	Count	Weightage	Ranking	Total
1	505539	9	1	9
2	608310	9	2	18
3	503068	9	3	27
4	577966	9	4	36
5	499512	9	5	45



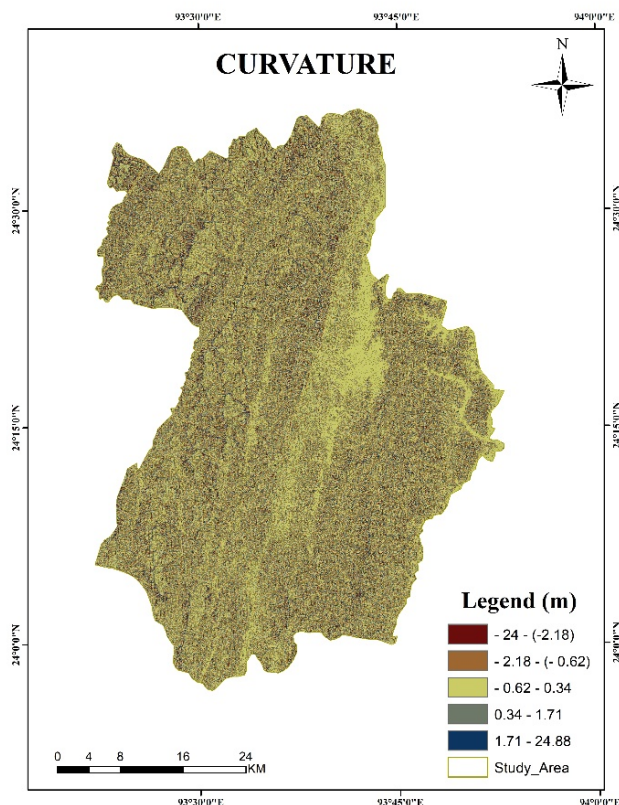


Fig. 5. Curvature Profile

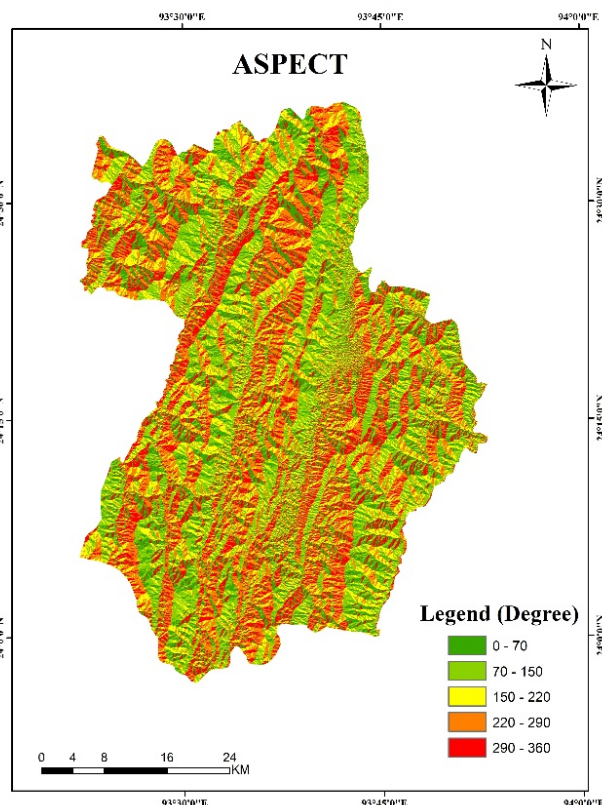


Fig. 6. Aspect Profile

3.1.5 Geology

A geological map is indispensable in landslide studies as it shows the distribution of different rock types, fault lines and soil compositions within the study area. The nature of the bedrock and surface materials plays a crucial role in determining slope stability. Fault lines also indicate zones of weakness where landslides are more likely to occur. Understanding the geological context through this map helps in predicting potential landslide zones and in designing appropriate engineering solutions to mitigate risks.

Table 5. Geological Data

Sl. No	Categories	Weigh-tage	Rank-ing	Total
1	Disang Fm.	10	1	10
2	Barail Gp.	10	3	30
3	Undiff. Fluvial & Sediments	10	4	40
4	Surma Gp.	10	5	50

3.1.6 Geomorphology

The geomorphology of Churachandpur district, analysed from Bhukosh.GSI.gov.in data, is categorized into seven

classes, reflecting terrain characteristics that influence landslide susceptibility. Moderately dissected hills and valleys, covering about half of the area, feature rugged slopes prone to significant soil erosion. Highly dissected hills and valleys, with steep gradients, are especially vulnerable to landslides during heavy rainfall. Other geomorphic units, like low dissected hills and isolated hillocks, contribute to the region’s complex topography, necessitating detailed landslide susceptibility zonation and monitoring.

3.1.7 Soil

A soil map provides detailed information on the types and properties of soils present in the study area, including factors like soil texture, composition, permeability and cohesion. These properties are critical in determining the stability of a slope. For instance, soils with high clay content may expand and contract significantly with moisture changes, leading to slope instability. Sandy soils, on the other hand, may have low cohesion, making them prone to erosion and landslides. Understanding the soil characteristics through this map helps in assessing landslide susceptibility and in designing appropriate mitigation measures such as soil stabilization techniques.



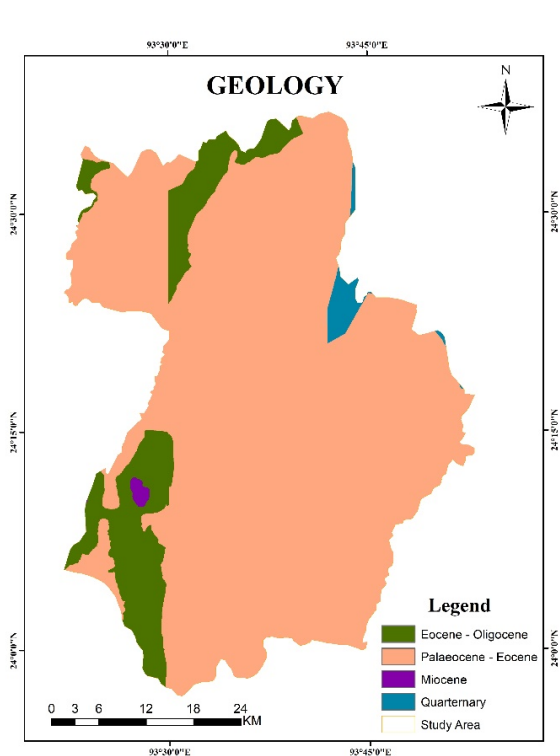


Fig. 7. Geological Profile

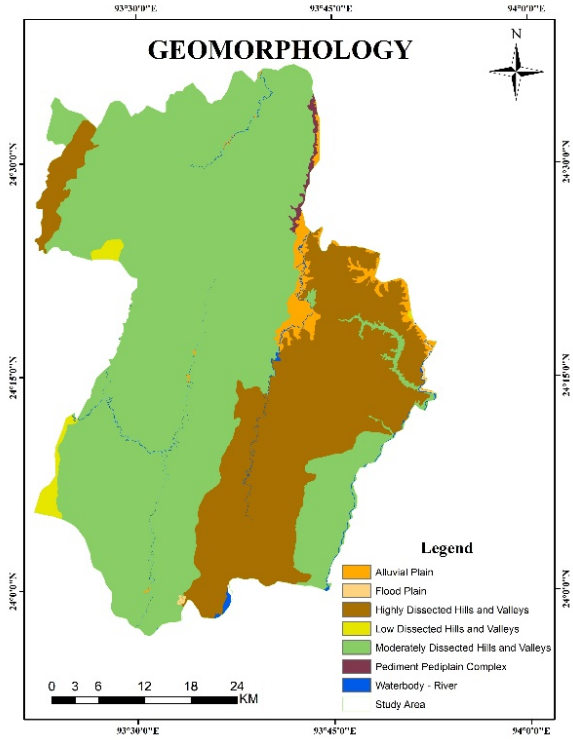


Fig. 8. Geomorphological Profile

Table 6. Geomorphological Data

Sl. No	Categories	Weightage	Ranking	Total
1	Alluvial Plain	5	1	5
2	Flood Plain	5	2	10
3	Highly Dissected Hills and Valleys	5	5	25
4	Low Dissected Hills and Valleys	5	3	15
5	Mod. Dissected Hills and Valleys	5	4	20
6	Pediment Pedit plain Complex	5	1	5
7	Waterbody - River	5	3	15

Table 7. Soil Data

Sl. No	Count	Weightage	Ranking	Total
1	1227467	7	5	35
2	1366269	7	3	21
3	109236	7	1	7

3.1.8 Land Use and Land Cover

Land use and land cover maps provide detailed information on how the land is being utilized, including vegetation cover, agricultural activities, urban development and deforestation. Human activities, such as construction and deforestation can significantly alter the natural stability of slopes, making them more susceptible to landslides. For example, areas that have been deforested or converted for agriculture might lose the root structures that help bind the soil, increasing the likelihood of landslides. This map is crucial for assessing the impact of human interventions on slope stability and for planning land use in a way that minimizes landslide risk. The study area is mostly comprising of hills and mountains where it covers 94.75% of the total area and the plains and valleys covers just about 5.25% of the total area.

3.1.9 Drainage

The drainage system of Churachandpur, classified into classes 1, 2, 3, 4, and 6 based on data from Earth's Hydrosheds.org, significantly influences landslide susceptibility. Higher drainage classes represent larger, more defined water channels. In the hilly topography, streams in classes 1 and 2 are prone to rapid water flow and erosion, creating high-risk zones for landslides due to slope instability. Conversely, class 4 and 6 drainages, with larger networks, accumulate more water, contributing to soil saturation and weakening, partic-



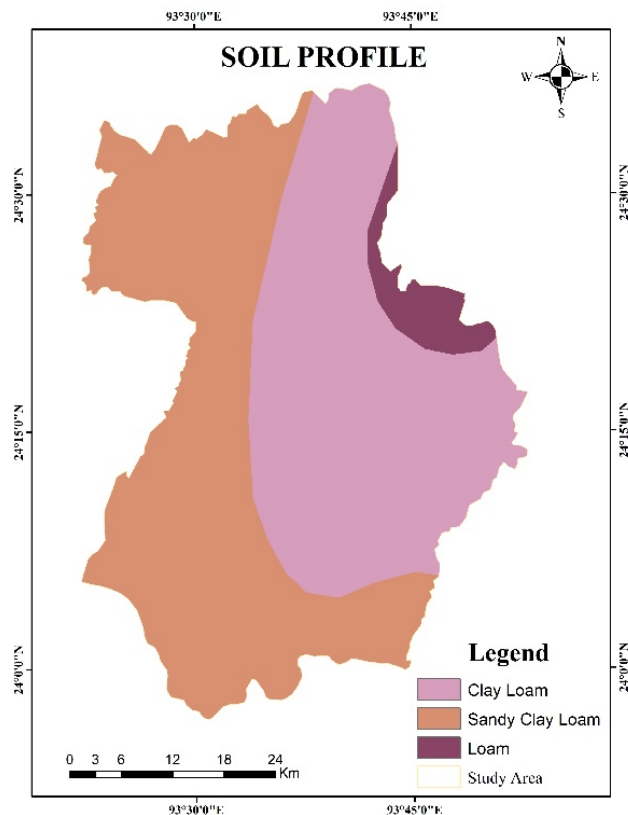


Fig. 9. Soil Profile

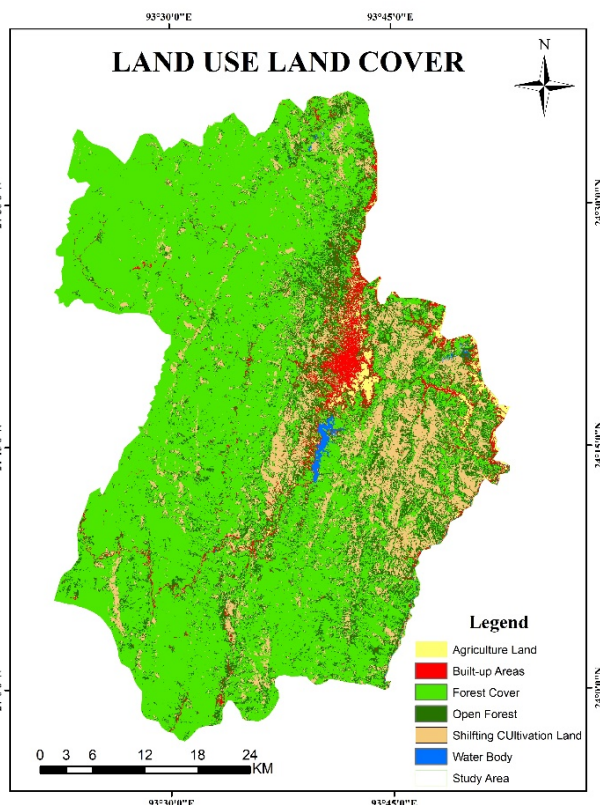


Fig. 10. Land Use Land Cover

Table 8. Land Use Land Cover Data

Sl. No	Categories	Weightage	Ranking	Total
1	Agriculture Land	4	5	20
2	Built-up Areas	4	5	20
3	Forest Cover	4	4	16
4	Open Forest	4	3	12
5	Shifting Cultivation Land	4	2	8
5	Water Body	4	5	20

ularly during heavy rainfall. Understanding these patterns is crucial for identifying landslide-prone areas and implementing erosion control.

Table 9. Drainage Data

Sl. No	Count	Weightage	Ranking	Total
1	778669	2	1	2
2	598967	2	2	4
3	615545	2	3	6
4	463449	2	4	8
5	246476	2	5	10

3.1.10 Road Network

Churachandpur’s road network, critical for regional connectivity, includes Village Roads, Major District Roads, State Highways and National Highways. Data from the PMGSY portal highlights the vulnerability of these roads, particularly due to frequent landslides from the district’s rugged topography and heavy monsoon rains. National Highways 150 and 102B, essential for trade are especially susceptible to landslides. These disruptions require extensive maintenance, particularly in steep areas with unstable soil types like Barail and Surma-Disang formations. Effective road planning and drainage management are vital for enhancing resilience and safety.

Table 10. Road Network

Sl. No	Count	Weightage	Ranking	Total
1	912566	3	1	3
2	747762	3	2	6
3	606019	3	3	9
4	312043	3	4	12
5	124716	3	5	15



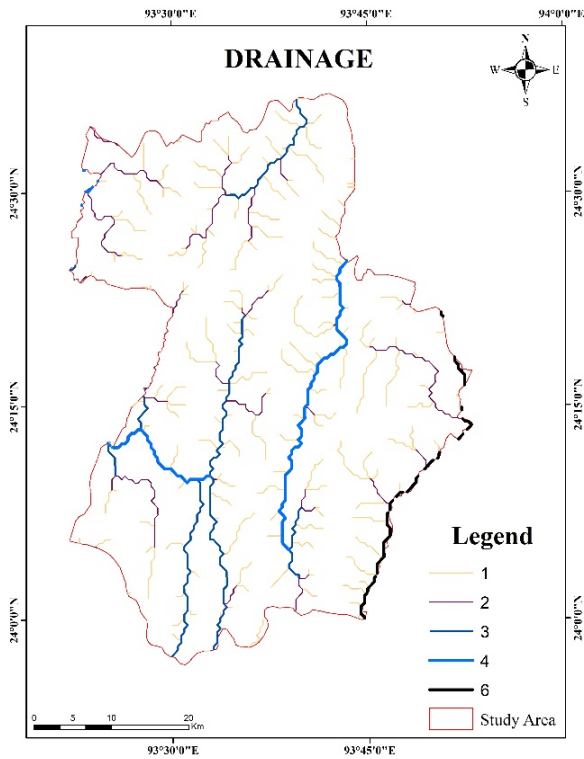


Fig. 11. Drainage System

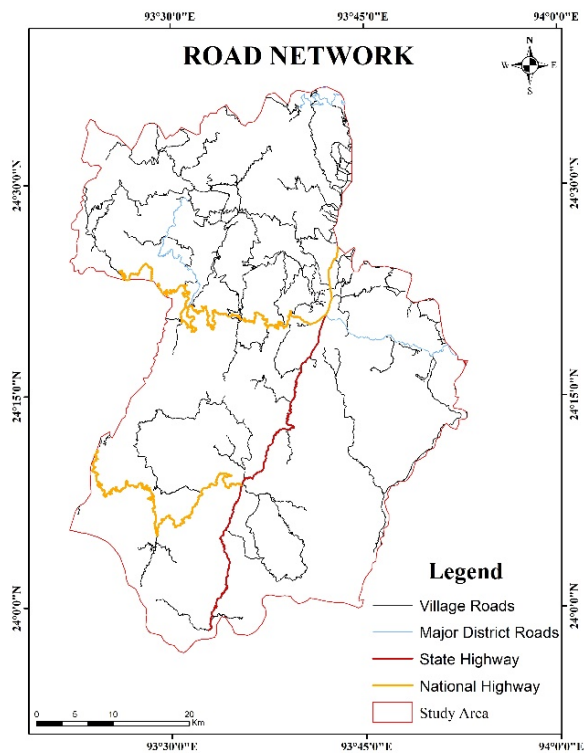


Fig. 12. Road Network

3.1.11 Rainfall

Churachandpur district experiences substantial annual rainfall, generally ranging from 700 mm to 1,200 mm, as indicated by CHRS data portal records, with some years experiencing surges up to 2,000 mm due to climatic variability. The district's rainfall distribution varies geographically, with the southern and southeastern areas, particularly near the Myanmar border, receiving higher rainfall compared to the northern parts. This gradient is shaped by topography and monsoon patterns, bringing more moisture-laden winds to the southern regions. While this supports rich biodiversity, it also contributes to soil erosion and landslide susceptibility, especially on steep slopes. These conditions underscore the district's vulnerability to extreme weather events and the need for effective watershed management to mitigate environmental risks.

Table 11. Rainfall Data

Sl. No	Count	Weightage	Ranking	Total
1	295625	8	1	8
2	731689	8	2	16
3	297087	8	3	24
4	754962	8	4	32
5	628702	8	5	40

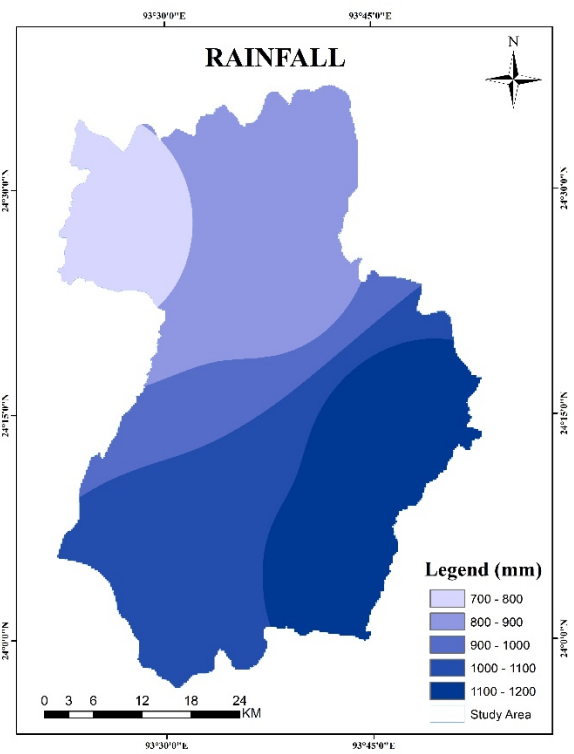


Fig. 13. Rainfall Distribution

4 Results and Discussions

Churachandpur district in Manipur, India, is prone to landslides due to its rugged terrain, frequent rainfall and seismic activity. The area’s steep slopes, combined with deforestation and human activities make it particularly vulnerable to landslide events. Landslides in Churachandpur often disrupt transportation notably along major highways such as NH 150 and NH 102b, impacting connectivity and local economies. Understanding the distribution of landslide-prone zones within the district is essential for infrastructure planning, disaster risk reduction and ensuring the safety of residents and travellers.

Table 12. Landslide Susceptibility Zonation Data

Sl. No	Level of Landslide	Area in Km ² .	Area in %
1	Low Landslide Zones	1,089.47	45.55
2	Medium Landslide Zones	904.52	37.81
3	High Landslide Zones	398.01	16.64
Total Area in Km².		2,392	100

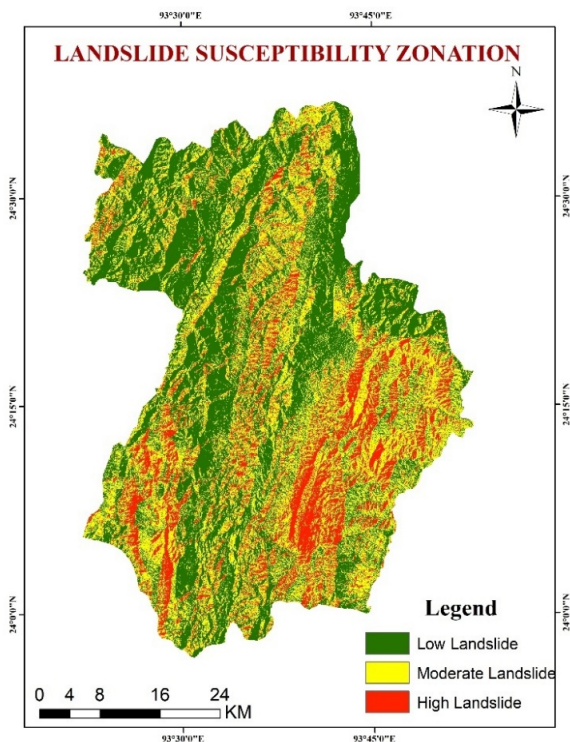


Fig. 14. Landslide Susceptibility Zonation

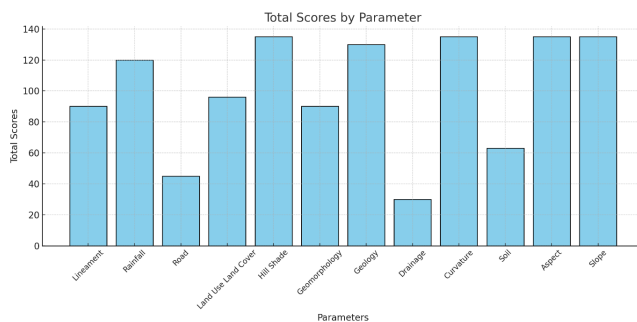


Fig. 15. Parameters and Scores Chart

Analysis

In the analysis, each parameter (e.g., lineament, curvature, soil, aspect, slope) is assigned weightage and ranked by subcategories or counts. The weightage reflects the importance of each parameter, with higher values indicating greater significance. Rankings show the relative position of subcategories within each parameter. Total scores are calculated by multiplying the weightage and ranking for each subcategory, reflecting their contribution to the overall analysis. To visualize the results or test hypotheses, bar charts or line graphs are used to compare total scores across parameters. Hypothesis testing, such as correlation or ANOVA, assesses the relationship between weightage and total scores. For example, the Pearson correlation coefficient is 0.89, with a p-value of 0.00009.

Interpretation

- Correlation (0.89): A strong positive relationship indicates that parameters with higher weightage have higher total scores.
- P-value (0.00009): Statistical significance ($p < 0.05$) confirms the correlation is unlikely due to chance.

This supports the hypothesis that higher weightage parameters significantly influence total scores. Key factors like slope, curvature, hill shade and geology hold critical weight in assessing landslide susceptibility. High-scoring regions demand immediate attention for sustainable planning. Integrating these insights into zonation mapping enables proactive disaster management, safeguarding infrastructure, livelihoods and resilience in vulnerable areas through informed data-driven decisions.

4.2 Landslide Susceptible Zones

4.2.1 Low Landslide Zones

Low Landslide Zones in Churachandpur district cover 1,089.47 sq. km (45.55% of the area), offering stable terrain with minimal landslide risks, making them suitable for development and infrastructure. These zones include



Lamka town, much of the northwestern and northeastern regions, and areas bordering Bishnupur district, primarily valley regions with naturally lower landslide risks. Villages like Kangvai, Tolbung, Zalenphai and Tollen lie within these zones, providing safer environments for expansion. Ongoing monitoring and sustainable practices like controlled land use, vegetation preservation and soil conservation are crucial for maintaining stability and fostering resilient growth.

4.2.2 Medium Landslide Zones

Medium Landslide Zones in Churachandpur district cover 904.52 sq. km (37.81% of the area), facing moderate landslide risks. These regions require careful construction and land use planning, incorporating mitigation strategies like slope stabilization, vegetation reinforcement and improved drainage to minimize incidents, particularly during heavy rains. Located mainly in the southeastern, southwestern and northern areas, these zones include villages such as Suangdoh, Changlei, Lungthul, Behiang, Panglian, Munhoih, Lhangnom, Nabil and Sehken. Critical transit routes, including National Highways NH-150 and NH-102B, also fall within these zones, requiring close monitoring and regular maintenance to ensure stability and prevent disruptions.

4.2.3 High Landslide Zones

High Landslide Zones in Churachandpur district cover 398.01 sq. km (16.64% of the area) and pose severe hazards due to steep slopes and frequent landslides, mainly in the south-eastern, south-western and northern parts. These areas are unsuitable for extensive development without specialized engineering solutions. Critical highways NH-150 and NH-102B pass through high-risk zones, connecting Lamka to Aizawl, Tipaimukh and Behiang at the Mizoram border. NH-150 serves the Pherzawl district along Henglep subdivision, while NH-102B is crucial for transportation of goods and commodities into Lamka town. Six landslides occurred between Maukot village and Suangdoh village recently along NH-102B, 13 landslides occurred between Suangdoh village and Lungthul village and 30-35 landslides between Lungthul village and Tuivai Bridge. Additionally, 2-3 landslides were recorded along Teddim Road which runs towards Behiang. Urgent measures like slope stabilization, erosion control and deforestation restrictions are essential to ensure infrastructure stability.

5 Conclusion

In conclusion, Churachandpur district's landslide-prone areas demand proactive management to safeguard lives and

infrastructure. High Landslide Zones cover 398.01 sq. km (16.64%) and pose the greatest risk due to steep slopes and unstable sandy shales. Areas like Behiang and its vicinity, areas bordering with Mizoram state and critical routes such as NH-150 and NH-102B require urgent stabilization, erosion control and restricted development. Monitoring these areas especially in dissected hills with unstable rocks is essential. Medium Landslide Zones, spanning 904.52 sq. km (37.81%), face moderate risks, necessitating land use planning and reinforced infrastructure. Villages like Suangdoh and Changlei along with NH-150 and NH-102B sections need erosion control, slope reinforcement and improved drainage to prevent water infiltration. Low Landslide Zones, covering 1,089.47 sq. km (45.55%), are relatively stable but require monitoring. Areas like Lamka, Kangvai and Tolbung are safer for development but need sustainable practices to maintain stability. A comprehensive approach combining mitigation, conservation, and planning across all zones is vital for Churachandpur's resilience and sustainable growth.

Conflict of Interest

We declare that we have no conflict of interest. However, it is important to note that this article is based on the authors' personal experiences and opinions and may not reflect the views of all individuals or organizations.

Authors Contribution

- **T. L. Haokip:** Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Data Curation, Writing Original Draft Preparation, Visualization.
- **Sreerama Naik S. R.:** Methodology, Software, Validation, Formal Analysis, Investigation, Data Curation, Writing Review and Editing.
- **Dr. T. K. Prasad:** Supervision, writing review and editing.

Acknowledgement

We wish to express our sincere gratitude to the GIS Lab, Department of Geography, Kannur University, Bhukosh for GSI, Sentinel-2A data from Copernicus and Landsat data from USGS Earth Explorer for providing the essential geospatial data and tools necessary for this research. Their contributions have been invaluable in enabling the analysis and interpretation.



References

- 1) Highland LM, Bobrowsky P. The landslide handbook-A guide to understanding landslides (No. 1325). US Geological Survey. 2008. Available from: https://pubs.usgs.gov/circ/1325/pdf/C1325_508.pdf.
- 2) Beniston M. Climatic Change in Mountain Regions: A Review of Possible Impacts. *Climatic Change*. 2003;59(1-2):5-31. Available from: <https://dx.doi.org/10.1023/a:1024458411589>.
- 3) Gill JC, Malamud BD. Reviewing and visualizing the interactions of natural hazards. *Reviews of Geophysics*. 2014;52(4):680-722. Available from: <https://dx.doi.org/10.1002/2013rg000445>.
- 4) Meusbürger K, Alewell C. Impacts of anthropogenic and environmental factors on the occurrence of shallow landslides in an alpine catchment (Urseren Valley, Switzerland). *Natural Hazards and Earth System Sciences*. 2008;8(3):509-520. Available from: <https://dx.doi.org/10.5194/nhess-8-509-2008>.
- 5) Cascini L, Bonnard C, Corominas J, Jibson R, Montero-Olarte J. Landslide hazard and risk zoning for urban planning and development. In: *Landslide risk management*. CRC Press. 2005;p. 209-246. Available from: <https://www.taylorfrancis.com/chapters/edit/10.1201/9781439833711-10/landslide-hazard-risk-zoning-urban-planning-development-cascini-ch-bonnard-corominas-jibson-montero-olarte>.
- 6) Mishra BK, Bhattacharjee D, Chattopadhyay A, Prusty G. Tectonic and lithologic control over landslide activity within the Larji-Kullu Tectonic Window in the Higher Himalayas of India. *Natural Hazards*. 2018;92(2):673-697. Available from: <https://dx.doi.org/10.1007/s11069-018-3219-x>.
- 7) Jibson RW. Methods for assessing the stability of slopes during earthquakes—A retrospective. *Engineering Geology*. 2011;122(1-2):43-50. Available from: <https://dx.doi.org/10.1016/j.enggeo.2010.09.017>.
- 8) Jeong S, Lee K, Kim J, Kim Y. Analysis of Rainfall-Induced Landslide on Unsaturated Soil Slopes. *Sustainability*. 2017;9(7):1280. Available from: <https://dx.doi.org/10.3390/su9071280>.
- 9) McBride SK, Smith H, Morgoch M, Sumy D, Jenkins M, Peek L, et al. Evidence-based guidelines for protective actions and earthquake early warning systems. *Geophysics*. 2022;87(1):WA77-WA102. Available from: <https://dx.doi.org/10.1190/geo2021-0222.1>.
- 10) Rahman T. Landslide risk reduction of the informal foothill settlements of Chittagong city through strategic design measure. 2012. Available from: https://dspace.bracu.ac.bd/xmlui/bitstream/handle/10361/3405/Tanvia_Rahman_11268012.pdf?sequence=1&isAllowed=y.