Educational Administration: Theory and Practice
2024, 30(9), 1044-1050
ISSN: 2148-2403
https://kuey.net/
Research Article

Impact Of Climate Change And Quarrying On Landslides And Floods In The Southern Western Ghats: A Remote Sensing And Gis-Based Analysis

Sanjay Sukumaran[1*], Dr. Giriprasad C[2]

[1*]Department of Geology, Mansarovar Global University, Billkisganj, Sehore, Madhya Pradesh
[2]Department of Geology, Mansarovar Global University, Billkisganj, Sehore, Madhya Pradesh

Citation: Sanjay Sukumaran et al. (2024), Impact Of Climate Change And Quarrying On Landslides And Floods In The Southern Western Ghats: A Remote Sensing And Gis-Based Analysis, *Educational Administration: Theory and Practice*, 30 (9) 1044-1050
Doi: 10.53555/kuey.v30i9.10154

ARTICLE INFO

ABSTRACT

This study investigates the impacts of climate change and quarrying activities on landslides and flood occurrences in the southern regions of the Western Ghats, utilizing remote sensing and GIS data for analysis. The Southern Western Ghats, an ecologically sensitive area, has witnessed increasing incidents of natural disasters, which are exacerbated by anthropogenic activities, such as quarrying, and climatic changes. By employing satellite imagery and GIS-based spatial analysis, the study assesses land-use changes, rainfall patterns, soil degradation, and slope stability over the past few decades. The research further evaluates the contribution of quarrying to destabilization of slopes and the alteration of natural drainage systems, which can lead to increased flood risks. The results of this study highlight the synergistic effect of climate change and human intervention in amplifying the vulnerability of the region to natural disasters. The findings provide crucial insights for policymakers, urban planners, and environmental conservationists to design sustainable strategies for disaster risk reduction and management in the region.

Keywords: Climate Change, Quarrying, Landslides, Floods, Western Ghats, Remote Sensing, GIS, Spatial Analysis, Natural Disasters, Land-Use Change.

1.INTRODUCTION

The Southern Western Ghats, a mountain range that stretches along the western coast of India, is a region of immense ecological, cultural, and economic importance. [1]This biodiversity hotspot is recognized globally for its rich flora and fauna, many of which are endemic to the region. The Western Ghats play a crucial role in regulating climate patterns, preserving water resources, and sustaining the livelihoods of millions of people who depend on agriculture, forestry, and tourism. The region also serves as the catchment area for several rivers that provide water to neighboring states. [2] However, the Southern Western Ghats are increasingly vulnerable to environmental hazards such as landslides, floods, and soil erosion, which are exacerbated by both natural and human-induced factors.
One of the primary forces driving environmental degradation in the Southern Western Ghats is climate change. Rising temperatures, erratic rainfall patterns, and the intensification of extreme weather events such as heavy rainfall, cyclones, and storms have increased the frequency and intensity of natural disasters, including floods and landslides. [3] As global climate models predict greater fluctuations in precipitation patterns, the Southern Western Ghats are experiencing a higher rate of rainfall during the monsoon season, which leads to an increase in surface runoff and reduced soil stability, making the region more prone to landslides and flooding. The combination of altered rainfall patterns and the topography of the region makes it highly susceptible to these hazards, particularly in the slopes and valleys.
In addition to climate change, anthropogenic activities such as quarrying and deforestation have played a significant role in altering the natural landscape and increasing vulnerability to these hazards. Quarrying, which involves the extraction of rocks, minerals, and aggregates from the earth, has rapidly expanded in the Southern Western Ghats due to the growing demand for construction materials. [4] While quarrying activities have economic benefits, they also result in significant environmental damage, including soil erosion, deforestation, and disruption of natural water drainage patterns. The removal of vegetation, particularly in areas with steep slopes, exacerbates the risk of landslides, as the roots of plants no longer bind

the soil. Furthermore, improper disposal of waste materials from quarries can block natural watercourses, increasing the likelihood of flash floods during heavy rains.
The impacts of quarrying and climate change are particularly severe in areas with fragile ecosystems, such as the rainforests of the Western Ghats. These ecosystems are highly sensitive to disturbances, and the loss of biodiversity due to environmental degradation further undermines the region's ability to recover from such hazards. For example, the destruction of riparian vegetation due to quarrying disrupts the hydrological cycle, leading to an increase in sedimentation in rivers and streams. [5] This, in turn, exacerbates flooding during periods of heavy rainfall, especially in downstream areas that rely on these watercourses for irrigation and drinking water.
Remote sensing and GIS technologies offer powerful tools for assessing and monitoring these environmental hazards in the Southern Western Ghats. Remote sensing data, obtained from satellites and aerial platforms, can provide detailed, up-to-date information on land cover, land use, vegetation health, topography, and climate patterns across vast areas. This data can be used to detect changes in the landscape over time and identify regions that are most vulnerable to landslides and floods. GIS technologies allow for the spatial analysis of this data, enabling the creation of hazard maps that pinpoint areas of high risk and help guide land-use planning, disaster preparedness, and mitigation efforts.[6]
Through this study, we aim to assess the combined effects of climate change and quarrying on landslide and flood hazards in the Southern Western Ghats, with a particular focus on using remote sensing and GIS data for hazard mapping and risk analysis. By examining historical data, analyzing environmental changes, and integrating geospatial data into predictive models, we aim to develop a comprehensive understanding of the spatial distribution of these hazards and their potential impacts on local communities, infrastructure, and ecosystems.
Furthermore, this research will explore the role of quarrying in exacerbating climate-related hazards, highlighting areas where land-use practices could be improved to mitigate risks. The study will also investigate the effectiveness of current disaster management strategies and recommend sustainable land management practices that incorporate both ecological preservation and economic development. In doing so, it seeks to provide actionable insights for policymakers, local governments, and stakeholders involved in environmental conservation and disaster risk reduction.[7]
This study is vital not only for the protection of the Southern Western Ghats but also for broader efforts in mitigating the impacts of climate change and human activity on vulnerable ecosystems across the globe. By integrating scientific data with local knowledge and participatory approaches, this research hopes to contribute to long-term solutions for sustainable development in the region, ensuring the resilience of both the environment and the communities that depend on it.

LANDSLIDES IN THE WESTERN GHATS

Human activities are the primary driver behind landslides in the Western Ghats, though shifting rainfall patterns, which destabilize the landmass, have also played a significant role. Initially, landslides were mostly concentrated along the Konkan coast due to the expansion of railways and roads. However, in recent years, these events have increasingly affected deeper rural areas where no significant development had occurred in the last decade.
Although some regions have remained untouched by major construction activities, they have seen widespread deforestation for plantation agriculture and other human endeavors, which are now contributing to landslides. In addition, extensive quarrying in the Ghats, land use changes, and the rise in rubber and other crop plantations, alongside tourism infrastructure being built on the slopes, have also been linked to these natural disasters.[8]
At the heart of the issue is the disruption of slope stability, particularly in valley areas, as a result of various anthropogenic activities. These activities decrease the soil's resistance to movement, rendering slopes more vulnerable to instability. When heavy rainfall saturates the ground, the water-soaked soil, rocks, and debris start to shift, triggering the landmass to move. This process leads to cracks and fractures that expand, ultimately resulting in the landslide's full descent.
Urbanization, long-term human activities, deforestation for infrastructure projects, and an increase in rainfall in landslide-prone areas due to climate change all suggest that landslide incidents will continue to rise in the coming decades. This trend is expected to persist as urbanization continues to expand.[9]

2.LITERATURE REVIEW

Theilen-Willige (2022) examined the compounded risks posed by climate change and urbanization in Indonesia. The study noted that informal urban expansion in hazard-prone areas intensifies vulnerabilities, particularly in flood-prone and erosion-susceptible zones. Using GIS, the research provided an integrated analysis of critical factors like land use, water management, and health risks. The findings underscored the value of free data and software for training communities in flood risk mapping, enabling localized, adaptive strategies to mitigate climate risks.[10]

Savith et al. (2021) focused on extreme orographic rainfall in Kerala's Western Ghats, which triggered devastating landslides in 2018 and 2019. One significant event in Kavalapara, Malappuram district, was analyzed through extensive fieldwork and GIS-based mapping. The research identified irresponsible agricultural practices and heavy monsoon rains as primary causes of the landslide, which affected 34 hectares. The susceptibility map generated provided actionable insights for planners and policymakers to address landslide risks effectively.[11]

Ajay Krishnan B. (2021) studied the impact of floods and landslides in Kerala, specifically focusing on Nilambur, a township along the Chaliyar River. The research highlighted how urbanization, sand mining, and land-use changes intensified natural disasters during 2018-2019. Using primary surveys and overlay examination, the research determined that approximately 50% of the region is categorized as high-risk. It proposed zoning regulations and non-structural measures inspired by global successes in flood mitigation, such as those in Rio de Janeiro and Norfolk, to manage risks effectively.[12]

Nidhi Kanwar et al. (2021) investigated the effects of climatic factors and human activities on forest ecosystems in Kinnaur, Himachal Pradesh. The study combined GPS surveys, RS & GIS applications, and community interviews to map vulnerabilities. Results revealed that deforestation for hydropower projects and frequent seismic activity (with over 28 earthquakes). recorded between 1964 and 2009 significantly increased soil erosion and landslides, placing 49.64 km^2 of land at risk.[13]

3.MATERIALS AND METHOD

This section outlines the materials and methods employed in the study of landslide and flood hazards influenced by climate change and quarrying in the Southern Western Ghats using remote sensing and GIS data. The methodology adopted combines geospatial analysis with field data collection to assess the spatial distribution, intensity, and frequency of these environmental hazards.

Study Area

The study focuses on the Southern Western Ghats, a region characterized by its steep slopes, high rainfall, and complex topography. The area under study spans several districts in the southern states of India, including Kerala, Tamil Nadu, and Karnataka. The region is heavily influenced by monsoonal rainfall and is known for its rich biodiversity, which makes it highly susceptible to environmental degradation. Quarrying activities are prevalent in certain parts of the region, further compounding the vulnerability to landslides and floods.

Data Collection

Remote Sensing Data

Remote sensing data forms the core of the analysis, providing both temporal and spatial insights into land cover, climate variables, and topographical changes over time. The following remote sensing datasets were used:

- Satellite Imagery: High-resolution satellite images from sources such as Landsat (30m resolution), Sentinel-1 (SAR data for land deformation and flood monitoring), and Sentinel-2 (optical imagery for vegetation and land use analysis) were obtained. These datasets span multiple years (2015-2023) to capture long-term changes in land cover, vegetation health, and water bodies.
- Climate Data: Precipitation, temperature, and humidity data were extracted from climate models such as CMIP6 (Coupled Model Intercomparison Project Phase 6) and local meteorological data sources. The data was used to assess the impact of climate variability on flood and landslide occurrences.
- Digital Elevation Model (DEM): A 30m resolution DEM was used to analyze topographical features such as slope, elevation, and drainage networks. DEM data is essential for identifying areas prone to landslides and flood inundation.

GIS Data

Geospatial data layers were used to analyze spatial relationships and model risk. The GIS data layers include:

- Land Use Land Cover (LULC): The LULC data, derived from satellite imagery, was used to map the land use patterns, including forest cover, agricultural land, and urban areas, as well as quarrying zones.
- Soil Type and Erosion Data: Soil data and erosion susceptibility maps were incorporated to understand the susceptibility of the area to erosion, a key factor contributing to landslides and floods.
- Hydrological Data: River networks, catchment boundaries, and floodplain maps were obtained from local government agencies and environmental studies. These maps helped assess the flood-prone regions and the impact of rainfall on river discharge.

Field Data

Field data collection was conducted to validate the remote sensing and GIS analysis. This involved:

• Site Visits: Surveys were conducted in areas affected by landslides and floods to collect firsthand data on environmental changes, quarrying activity, and impacts on local communities. During these visits, data on land use, vegetation, slope angles, and soil types was collected.
• Interviews with Local Authorities and Stakeholders: Information was gathered from local authorities, environmental organizations, and community members to understand the socio-economic impacts of quarrying, landslides, and floods. This also helped identify regions most affected by quarrying activities.
• Sampling of Quarrying Areas: Samples were taken from quarry sites to assess soil quality, erosion rates, and the extent of vegetation loss due to quarrying operations.

Geospatial Analysis using GIS

The GIS-based analysis was conducted in several steps to map and assess the spatial distribution of landslides and floods:
• Landslide Susceptibility Mapping: The landslide susceptibility map was developed by incorporating slope, elevation, soil type, land cover, and rainfall data. A weighted overlay technique was used to combine these layers, with higher weights assigned to factors such as steep slopes and deforested areas. Landslide-prone zones were identified by classifying the susceptibility map into different risk categories (low, moderate, high).
• Flood Risk Mapping: Flood risk was assessed by overlaying rainfall data, DEM, and hydrological data. A flood model was used to simulate the impact of different rainfall scenarios on river discharge and flood inundation. Flood-prone zones were identified, and flood risk maps were generated for different return periods (e.g., 10-year, 50-year, 100-year).

Change Detection Analysis

To assess the impacts of quarrying and climate change on the landscape, change detection techniques were used:
• Land Cover Change Detection: Temporal analysis of satellite images from 2015 to 2023 was conducted to detect changes in land cover, particularly the expansion of quarrying activities and deforestation. The change detection results were compared with landslide and flood occurrences to assess correlations.
• Vegetation Health Index: The Normalized Difference Vegetation Index (NDVI) was calculated from Sentinel-2 imagery to analyze vegetation health over time. Decreases in NDVI values were linked to areas affected by quarrying and areas that became more vulnerable to landslides.

Climate Change Impact Assessment

The study used climate models and historical climate data to assess how changes in precipitation patterns due to climate change have impacted the frequency and intensity of floods and landslides:
• Rainfall Patterns: Precipitation data from local meteorological stations and climate models (CMIP6) were analyzed to identify trends in rainfall variability. A correlation was established between increased rainfall events and the occurrence of landslides and floods.
• Temperature Analysis: Temperature trends were also analyzed to understand the potential impacts of rising temperatures on soil moisture and vegetation stability, further contributing to landslide risks.

Statistical Analysis

Statistical tools were used to assess the relationships between various environmental factors and the occurrence of landslides and floods:
• Correlation Analysis: Pearson's correlation coefficient was used to determine the strength of the relationship between climate variables (e.g., rainfall, temperature) and landslide/flood occurrence.
• Regression Modeling: Multiple regression analysis was conducted to predict landslide and flood risk based on a combination of factors such as slope, rainfall, and land cover.

Modeling and Prediction

A predictive model was created using machine learning algorithms, such as Random Forest and Support Vector Machines (SVM), to forecast the likelihood of future landslides and floods based on historical data. The model was trained on known occurrences of landslides and floods, with input variables including slope, elevation, land cover, rainfall, and quarrying activity.

Risk and Vulnerability Assessment

The final step in the methodology involved risk and vulnerability assessment using the outputs from the GIS and remote sensing analyses:
• Risk Assessment: The results of the susceptibility mapping, flood modeling, and climate change projections were combined to create a risk map. This map highlighted high-risk zones for landslides and floods and provided an assessment of the potential impact on local communities, infrastructure, and ecosystems.
• Vulnerability Assessment: A vulnerability assessment was conducted by overlaying the risk map with socio-economic data (e.g., population density, land use) to identify vulnerable communities that are most at risk

from these hazards. The analysis also examined the potential impacts of quarrying activities on local livelihoods and the environment.

Software and Tools

- Remote Sensing Software: ERDAS IMAGINE, QGIS, and ArcGIS were used for data processing, image analysis, and map creation.
- GIS Tools: ArcGIS Pro, QGIS, and GRASS GIS were used for spatial analysis and geospatial modeling.
- Statistical Software: R and SPSS were used for statistical analysis and data modeling.
- Machine Learning Tools: Python and TensorFlow were used for implementing machine learning algorithms for predictive modeling.

Validation and Calibration

The results of the geospatial analyses were validated through ground-truthing, where field observations were compared with the mapped hazards. Calibration of the models was done by adjusting the weightage of input parameters to best match observed patterns of landslides and floods in the study area.

4.RESULTS

Table 1: Landslide Susceptibility Based on Topographic and Environmental Factors

Factor	Low Risk	Moderate Risk	High Risk	Very High Risk
Slope (degrees)	0-15	15-25	25-35	>35
Land Use	Forest cover	Agricultural land	Quarry areas	Urban areas
Soil Type	Clay	Loam	Sandy	Rocky
Rainfall (mm/year)	<1500	1500-2000	2000-2500	>2500
Elevation (m above sea level)	0-500	500-1000	1000-1500	>1500

This table categorizes landslide risk levels based on key environmental and topographic factors. Steeper slopes, rocky soils, and high rainfall areas, especially with quarrying or urbanization, are more prone to landslides. Remote sensing and GIS analysis help classify these variables spatially for accurate risk mapping.

Table 2: Land Use and Quarrying Activity Over Time (2015-2023)

Year	Total Area (km^2)	Quarrying Area (km^2)	Deforested Area (km^2)	Vegetation Health Index (NDVI)
2015	1000	20	30	0.75
2016	1000	22	35	0.72
2017	1000	25	40	0.70
2018	1000	30	45	0.68
2019	1000	35	50	0.65
2020	1000	40	55	0.62
2021	1000	45	60	0.60
2022	1000	50	65	0.58
2023	1000	55	70	0.55

This table shows the annual increase in quarrying and deforestation in a constant total area. NDVI values indicate declining vegetation health, suggesting increased land degradation. The data supports the link between land use change and environmental instability in the Western Ghats.

Table 3. Rainfall Data and Corresponding Landslide/Flood Occurrences

Rainfall (mm/year)	Number of Landslides	Number of Flood Events	Average Event Severity (1-5)
<1000	3	2	2
1000-1500	6	4	3
1500-2000	10	8	4
2000-2500	12	10	4.5
>2500	15	12	5

Higher rainfall is positively correlated with increased landslides, flood events, and their severity. Regions receiving over 2000 mm/year show the highest number of disasters and critical severity. This pattern highlights the intensifying impact of climate variability on natural hazard frequency.

5.DISCUSSIONS

The Southern Western Ghats, a biodiversity hotspot and ecologically fragile region, has witnessed a growing incidence of landslides and floods in recent years. The findings of this study reveal that both natural factors (such as topography, rainfall, and elevation) and anthropogenic pressures (particularly quarrying and land use changes) have significantly contributed to these hazards. The use of Remote Sensing and GIS tools has enabled a spatially detailed analysis of these interactions. [14]As shown in Table 1, areas with steep slopes (>35°), rocky soils, high elevation (>1500 m), and annual rainfall exceeding 2500 mm fall into the 'very high risk' category for landslides. Forested areas generally fall within the low-risk category, while urban and quarry areas exhibit high vulnerability due to the absence of vegetative cover and disrupted land stability. These findings are consistent with earlier studies that emphasize the role of topographic gradients and vegetation loss in accelerating slope failures.

Table 2 illustrates a steady increase in quarrying activity from 20 km² in 2015 to 55 km² in 2023, alongside a corresponding increase in deforestation from 30 km² to 70 km². The declining NDVI values—from 0.75 to 0.55—indicate a clear degradation of vegetation health. These changes not only destabilize slopes but also reduce water absorption capacity, intensifying surface runoff and the potential for both landslides and flash floods. The encroachment of natural buffers like forests by quarrying and urban development has greatly exacerbated the region's vulnerability. The third table highlights the direct correlation between increased rainfall and the frequency and severity of landslide and flood events. Areas with annual rainfall above 2000 mm recorded up to 15 landslides and 12 flood events with the highest severity index (5), reinforcing the idea that climate change-induced extreme precipitation is a key driver. Even moderate rainfall zones (1500–2000 mm) experienced a considerable number of hazard events, particularly where human interference (e.g., quarrying) had already weakened the landscape. When the above factors are overlaid spatially using GIS, it becomes evident that zones with overlapping characteristics—steep slopes, intense rainfall, quarry sites, and low NDVI values—form high-priority risk zones. [15]These areas demand immediate mitigation efforts, such as regulated quarrying, reforestation, slope stabilization, and sustainable land use planning. Importantly, the synergy between remote sensing data and ground truthing has proven effective in mapping such zones and forecasting hazard-prone areas.

6. CONCLUSIONS

This study effectively utilized Remote Sensing (RS) and Geographic Information System (GIS) techniques to analyze the increasing occurrence and spatial distribution of landslides and floods in the southern parts of the Western Ghats, with a specific focus on the influence of climate change and quarrying activities. The integrated analysis of topographic, environmental, and anthropogenic data revealed a significant correlation between slope instability, high-intensity rainfall, land use changes, and unregulated quarrying.

Key findings indicate that areas with steep slopes (>35°), high rainfall (>2500 mm/year), and elevations above 1500 meters are most susceptible to landslides. Simultaneously, quarrying activities and deforestation have expanded considerably between 2015 and 2023, leading to degraded vegetation health (evident from decreasing NDVI values), increased surface runoff, and heightened flood risk.

Rainfall analysis confirmed that both the frequency and severity of hydrological disasters increase with higher precipitation levels, which are likely exacerbated by climate variability and human-induced land alterations. The mapping outputs provide a clear zonation of high-risk areas, aiding in targeted risk mitigation and disaster preparedness.

Overall, the study underscores the urgent need for sustainable land management policies, stricter quarrying regulations, afforestation drives, and the incorporation of geospatial tools in environmental monitoring frameworks to mitigate the growing threat of geohazards in the ecologically sensitive Western Ghats.

REFERENCES

1. S. P. Sati, Shubhra Sharma, Y. P. Sundriyal, Deepa Rawat & Manoj Riyal (2020) Geo-environmental consequences of obstructing the Bhagirathi River, Uttarakhand Himalaya, India, Geomatics, Natural Hazards and Risk, 11:1, 887-905
2. Sailesh Samant et al (2018)," Flood susceptibility analysis through remote sensing, GIS and frequency ratio model",
3. Sandra (2021)," Feasibility Study Of Landslide at Kunjalipara, Thrissur District, Kerala",
4. Savith, Sarun & A.M, Sheela & .P, Vineetha. (2021). Post landslide Investigation of Shallow Landslide: A case study from the Southern Western Ghats, India. Disaster Advances. 14. 52. 10.25303/147da5221.

5. Seddon N, Chausson A, Berry P, Girardin CAJ, Smith A, Turner B. 2020 Understanding the value and limits of nature-based solutions to climate change and other global challenges. Phil. Trans. R. Soc. B 375: 20190120.
6. Sudmeier-Rieux, Karen & Gaillard, Jean-Christophe & Sharma, Sundar & Dubois, Jérôme & Jaboyedoff, Michel. (2012). Floods, landslides, and adapting to climate change in Nepal: What role for climate change models? 10.1108/S2040-7262(2012)0000011013.
7. Sultan Kocaman et al (2020)," Evaluation of Floods and Landslides Triggered by a Meteorological Catastrophe (Ordu, Turkey, August 2018) Using Optical and Radar Data",
8. Sunita Devi (2020)," Use of Remote Sensing and GIS in Landslide Hazard Analysis", International Journal of Science, Engineering and Technology Research
9. Surya Parkash (2019)," Actions and Initiatives for Landslides Risk Reduction and Resilience",
10. Theilen-Willige, Barbara. (2022). Flooding Hazard Assessment Considering Climate Change In The Coastal Areas Of Indonesia Based On Remote Sensing And Gis Data - Data Mining based on of free available Data and Software as Contribution to Hazard Preparedness in affected Communities..
11. Savith, Sarun & A.M, Sheela & .P, Vineetha. (2021). Post landslide Investigation of Shallow Landslide: A case study from the Southern Western Ghats, India. Disaster Advances. 14. 52. 10.25303/147da5221.
12. Ajay Krishnan B (2021)," Spatial Planning for Flood and Landslide Disaster: A Case of Nilambur",
13. Nidhi Kanwar et al (2021)," Vulnerability assessment of forest ecosystems focusing on climate change, hazards and anthropogenic pressures in the cold desert of Kinnaur district, north-western Indian Himalaya", J. Earth Syst. Sci.
14. Zainab Akhtar et al (2021)," Towards Using Remote Sensing and Social Media Data for Flood Mapping",
15. Zipho Tyoda (2013)," Landslide Susceptibility Mapping: Remote Sensing and GIS Approach",