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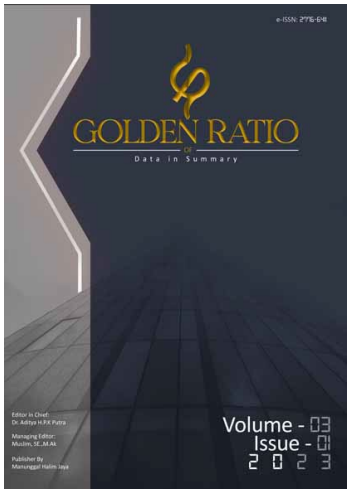

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Hypsometric Analysis and Tectonic Activity Evaluation in the Semangko Fault Zone: A Literature Review

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Abstract: This comprehensive review synthesizes and analyzes current literature on hypsometric analysis and its application in evaluating tectonic activity within the Semangko Fault Zone, a critical segment of the Sumatran Fault system. The study examines how hypsometric curves (HC) and hypsometric integrals (HI) serve as quantitative indicators of landscape evolution and tectonic deformation. By critically analyzing existing research, this review highlights the strong correlation between high HI values and areas of active tectonic uplift within the fault zone. The paper also explores the integration of hypsometric analysis with other geomorphic indices and its potential in seismic hazard assessment. Our findings underscore the significance of hypsometric analysis as a valuable tool in understanding the complex tectonic processes shaping the Semangko Fault Zone and its implications for regional seismic risk evaluation and land-use planning.

Keywords: Hypsometric Analysis, Tectonic Activity, Hypsometric Curves (HC), Hypsometric Integrals (HI), Tectonic Deformation, Geomorphic Indices, Land-Use Planning.

1. INTRODUCTION

The Semangko Fault, a significant component of the Sumatran Fault system, plays a crucial role in the tectonic framework of Sumatra Island. Extending approximately 65 kilometers through Lampung Province, this fault segment has been associated with substantial seismic activity and landscape deformation (Sieh & Natawidjaja, 2000). The fault is part of the larger Sumatran Fault system, which spans about 1,900 kilometers along the western side of Sumatra, accommodating the oblique convergence between the Indo-Australian and Eurasian plates (Natawidjaja & Triyoso, 2007). Understanding the tectonic processes shaping this region is essential for assessing seismic hazards and the ongoing evolution of the landscape. The complex interplay between tectonic uplift and erosional processes in the Semangko Fault Zone presents a unique opportunity to study active fault dynamics and their geomorphological expressions.

Hypsometric analysis, a quantitative method in geomorphology, has emerged as a valuable tool for evaluating tectonic activity in fault zones. This technique examines the distribution of elevation within drainage basins, providing insights into the balance between erosion and tectonic uplift (Strahler, 1952; Keller & Pinter, 2002). The hypsometric curve (HC) and hypsometric integral (HI) are key components of this analysis, offering a graphical and numerical representation of landscape evolution stages. This review synthesizes current literature on hypsometric analysis and its application in the Semangko Fault Zone. By examining how HC and HI values correlate with tectonic activity, we seek to provide a comprehensive understanding of the fault's behavior and its implications for regional seismic hazards. Furthermore, we explore the integration of hypsometric analysis with other geomorphic indices and remote sensing techniques to develop a more holistic approach to tectonic activity assessment in fault zones.

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2. RESEARCH METHODS

This study employs a systematic literature review approach, focusing on peer-reviewed articles, conference proceedings, and theses published between 2000 and 2024. The search was conducted using databases such as Web of Science, Scopus, and Google Scholar, using keywords including "hypsometric analysis," "Semangko Fault," "tectonic activity," "geomorphology," "Sumatran Fault system," and "seismic hazard assessment." The selection criteria for inclusion in this review were based on several factors. First, the review focused on studies that directly applied hypsometric analysis within the Semangko Fault Zone or similar fault systems. Additionally, research that integrated hypsometric analysis with other geomorphic indices for the assessment of tectonic activity was considered. Papers that discussed the theoretical foundations and methodological advancements in hypsometric analysis were also included. Lastly, studies that explored the relationship between hypsometric parameters and seismic activity in fault zones were reviewed, providing a comprehensive perspective on the intersection of geomorphology and seismic hazard assessment. The selected studies were critically analyzed for their methodological approaches, findings, and conclusions regarding the application of hypsometric analysis in tectonic activity assessment. Special attention was given to studies that provided quantitative data on HI values and their spatial distribution within the Semangko Fault Zone.

3. RESULTS AND DISCUSSION

3.1. Hypsometric Analysis in Fault Zones

Numerous studies have demonstrated the efficacy of hypsometric analysis in evaluating tectonic activity within fault zones. Research by Hamdouni et al. (2008) in the Rif Mountains of Morocco showed a strong correlation between high HI values (>0.5) and areas of known active tectonic uplift. Similarly, Dehbozorgi et al. (2010) applied hypsometric analysis to the Zagros Mountains of Iran, revealing that drainage basins with high HI values (>0.5) were predominantly located along active fault lines, suggesting a direct relationship between tectonic activity and landscape morphology. These findings provide a foundation for applying similar methodologies to the Semangko Fault Zone. The consistent correlation between high HI values and active tectonic areas across different geological settings suggests that hypsometric analysis can be a reliable tool for identifying zones of ongoing tectonic deformation.

3.2. Application in the Semangko Fault Zone

Recent studies focusing on the Semangko Fault Zone have revealed significant insights into its tectonic activity through hypsometric analysis. Alif et al. (2020) examined 266 sub-watersheds within the fault zone and found an average HI value of approximately 0.5, indicating an overall active tectonic regime. A more detailed breakdown of their findings is summarized in Table 1.

Table 1. Summary of Hypsometric Integral (HI) Values in the Semangko Fault Zone Sub-Watersheds

Sub-Watershed Category	HI Value Range	Number of Sub-Watersheds	Percentage (%)	Tectonic Interpretation

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More Active Uplift Areas	HI ≥ 0.5	74	27.8%	Strong tectonic uplift, youthful landscape
Active Uplift Areas	0.4 ≤ HI < 0.5	192	72.2%	Ongoing tectonic activity, balanced uplift and erosion
Low Tectonic Activity Areas	HI < 0.4	0	0%	Not observed in the study area

No sub-watersheds exhibited HI values below 0.4, emphasizing the pervasive tectonic influence across the entire fault zone. The spatial distribution of HI values showed that sub-watersheds with the highest HI values (≥ 0.5) were predominantly located in the northwestern part of the fault zone, suggesting intense tectonic uplift in this area. The key findings from the analysis of the Semangko Fault Zone reveal that 74 sub-watersheds, representing 27.8% of the total, had HI values greater than or equal to 0.5, indicating areas experiencing more active tectonic uplift. Additionally, 192 sub-watersheds, accounting for 72.2% of the total, had HI values between 0.4 and 0.5, suggesting ongoing tectonic activity in these regions. These results highlight the widespread influence of tectonic forces across the fault zone.

3.3. Integration with Other Geomorphic Indices

While hypsometric analysis provides valuable insights into tectonic activity, integrating it with other geomorphic indices enhances the assessment of tectonic deformation. Studies by Fadilah et al. (2019) combined hypsometric analysis with the stream length-gradient index (SL) and the valley floor width-to-height ratio (VF), offering a more nuanced interpretation of the landscape's response to tectonic forces. Similarly, Rusydy et al. (2018) integrated hypsometric analysis with the asymmetry factor (AF) and the transverse topographic symmetry factor (T), highlighting zones of tectonic tilting and lateral crustal movement along the Semangko Fault.

3.4. Implications for Seismic Hazard Assessment

The correlation between high HI values and known earthquake data in the Semangko Fault region underscores the potential of hypsometric analysis in seismic hazard assessment. Prasetyo et al. (2021) combined hypsometric analysis with historical earthquake data and GPS-derived crustal deformation rates, finding a strong spatial correlation between areas of high HI values (>0.5) and clusters of shallow earthquakes. This approach offers several advantages in assessing tectonic activity and seismic hazards. First, it provides a long-term geomorphological perspective that complements short-term seismic data, offering a more comprehensive understanding of tectonic processes over time. Additionally, HI values are instrumental in identifying potentially active fault segments that may lack historical earthquake records, thereby highlighting areas at risk that might otherwise be overlooked. Moreover, regions with high HI values but low recorded seismicity can be recognized as potential seismic gaps, warranting closer monitoring for future seismic activity.

4. CONCLUSION

This review highlights the significant contribution of hypsometric analysis to understanding tectonic activity within the Semangko Fault Zone. The consistent findings of high HI values across multiple studies indicate ongoing tectonic deformation and uplift in the region. These results provide valuable insights for seismic hazard assessment and land-use planning.

In summary, hypsometric analysis has proven to be a reliable indicator of tectonic activity, particularly in fault zones like the Semangko Fault. High HI values, specifically those greater than 0.5, are consistently correlated with areas experiencing active uplift and tectonic deformation. The northwestern part of the Semangko Fault Zone stands out with the highest HI values, suggesting that this region is undergoing more intense tectonic activity compared to other areas. Furthermore,

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integrating hypsometric analysis with other geomorphic indices enhances the overall assessment of tectonic activity, offering a more comprehensive understanding of the landscape's response to tectonic forces. There is also a strong correlation between regions with high HI values and recorded seismic activity, underscoring the potential of hypsometric analysis as a valuable tool for seismic hazard assessment.

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