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Spatial Analysis of Landslide Dynamics in Muara Enim Regency Based on Rainfall

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Abstract

Muara Enim Regency experiences significant landslide hazards requiring comprehensive understanding of rainfall dynamics and triggering mechanisms. This research investigates the spatial and temporal relationships between rainfall patterns and landslide occurrence using quantitative descriptive analysis with Geographic Information Systems. The study analyzed CHIRPS satellite rainfall data and institutional disaster records spanning 2017 to 2024, encompassing 75 documented landslide events across 96 monthly observations within Muara Enim Regency (7,483 square kilometers). Data analysis employed Inverse Distance Weighting interpolation with power parameter two to generate monthly rainfall surfaces, supplemented by descriptive statistics quantifying annual and monthly precipitation variations. Results revealed annual rainfall fluctuation ranging from 2,267 millimeters (2019) to 3,656 millimeters (2022), with pronounced seasonal patterns showing peaks in December (363 millimeters) and March (350 millimeters), contrasting with dry season minima in August (136 millimeters) and September (154 millimeters). Landslide occurrence clustered prominently during February, March, and November, recording eight to nine documented events respectively, while August and September with minimal rainfall showed zero to one landslide event. Analysis demonstrates strong correlation between rainfall intensity and landslide frequency, substantiating rainfall as a primary triggering mechanism for slope instability in mountainous tropical regions. This research provides foundational empirical evidence supporting subsequent integrated landslide hazard assessment and early warning system development in Muara Enim Regency and comparable Indonesian mountain regions.

Introduction

The digital transformation of the tourism and travel industry has fundamentally reshaped operational paradigms and customer engagement mechanisms across organizational contexts. Digital platforms have become instrumental in how travel companies establish competitive advantage by enabling real-time customer interaction, personalized service delivery, and comprehensive information accessibility (Aamir et al., 2025; Zeqiri et al., 2025; Mishra & Patnaik, 2024; Hussein et al., 2024). Contemporary consumers increasingly rely on digital resources and online applications to research destinations, evaluate service quality, and make purchasing decisions, creating a paradigm shift from traditional promotional methodologies such as printed materials and offline channels toward dynamic, user-centric digital platforms (Srivastava, 2025; Pal, 2024; Pelet, 2025; Karpii & Mykhailyk, 2025; Kotwal, 2025). This technological evolution reflects broader transformations in consumer behavior, where digital platforms serve not merely as promotional channels but as essential infrastructure for building

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organizational credibility, streamlining customer inquiries, and enhancing brand perception through strategic user interface and user experience design. The integration of digital technologies into business operations has created unprecedented opportunities for organizations to establish sophisticated customer engagement ecosystems that simultaneously enhance service delivery efficiency and market penetration capacity (Ho et al., 2020; Oladimeji & Owoade, 2024; Aksoy, 2023; Mızrak, 2023; Sklyar et al., 2019). For small and medium-sized enterprises operating within the travel sector, digital transformation represents a critical strategic imperative, as these organizations must compete against larger corporations despite operating with constrained marketing budgets and limited technological resources (Oladimeji & Owoade, 2024; Zaki, 2019; Aksoy, 2023; Mızrak, 2023; Das, 2024).

The digital transformation trajectory in tourism reveals substantial economic opportunities alongside significant organizational challenges. Global digital transformation initiatives in travel and tourism are forecast to expand from USD 162.25 billion in 2024 to USD 483.85 billion by 2033, generating a compound annual growth rate of 13.5 percent and demonstrating the sector's accelerating digitalization. Emerging technologies including artificial intelligence, advanced analytics, mobile applications, and interactive content formats have become normative within competitive tourism markets, with research indicating that more than 70 percent of travel industry leaders anticipate substantial artificial intelligence impact between 2024 and 2026. The convergence of technological innovation and consumer expectations has created market conditions where organizations lacking modern digital infrastructure face increasing competitive disadvantage and diminished market relevance (Kreiterling, 2023; Yellanki, 2025; Omowole et al., 2024; Rolando & Mulyono, 2025; Sposato & Dittmar, 2026). Simultaneously, digital platforms enable tourism enterprises to leverage data-driven insights for understanding customer preferences, optimizing marketing strategies, and facilitating operational efficiencies through automation and streamlined communication processes (Selvakumar, 2025; Theodorakopoulos, 2024; Gurgu et al., 2021; SONI, 2025; Onifade et al., 2024). For travel companies positioned within developing economies or operating as regional service providers, strategic adoption of digital promotional infrastructure has become essential for establishing market viability and accessing broader geographic markets.

Research Problem

Despite the established efficacy of digital marketing in the tourism sector, many small to medium-sized travel companies in Indonesia continue to rely primarily on conventional promotional methods, substantially limiting their capacity to reach broader markets and engage contemporary consumers. PT Harmoni Persada, a travel company with over 20 years of operational experience offering tourism packages, event organization, MICE activities, and specialized training services, currently lacks a structured digital platform to comprehensively present its company profile, diversified service offerings, and competitive capabilities to prospective clients. This absence of modern digital presence creates a significant competitive disadvantage, as potential customers cannot readily access standardized, professional information about the company's integrated services, which span tourism packages, event management, human resources development consulting, and legal services. The deficiency in digital promotional infrastructure directly constrains the company's capacity to reach target audiences effectively, particularly in market contexts where consumers have become normatively dependent on online platforms for evaluating and selecting service providers. Conventional promotional materials, while retaining residual relevance, cannot provide the interactive, dynamic, and personalized experiences that contemporary digital-native consumers expect. Furthermore, the absence of an integrated digital platform prevents the company from capturing data-driven insights about customer preferences and behavior patterns, which are essential for implementing evidence-based marketing strategies and optimizing customer engagement.

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The operational limitations resulting from inadequate digital infrastructure extend beyond market reach constraints to encompass internal communication inefficiencies. Prospective clients seeking information must navigate fragmented communication channels including email, telephone, and in-person visits, without access to a centralized, readily accessible digital repository consolidating company information, service specifications, pricing structures, and contact mechanisms. This operational fragmentation diminishes user experience quality while simultaneously diverting organizational resources toward repetitive, manually intensive information provision tasks that could be substantially automated through intelligent application interfaces. Current promotional approaches fail to leverage emerging technological capabilities including chatbot functionality for customer service automation, visual presentation formats for service portfolio demonstrations, and destination galleries showcasing previous organizational achievements. The organizational challenge extends to strategic positioning within competitive markets where service differentiation increasingly depends upon sophisticated digital engagement mechanisms rather than conventional marketing collateral. Additionally, the absence of professional digital infrastructure constrains the organization's capacity to establish thought leadership, communicate organizational expertise, and build stakeholder confidence through structured, accessible communication platforms.

Research Objectives, Urgency, and Novelty

This research aims to develop a functional company profile application prototype for PT Harmoni Persada using Research and Development methodology combined with user-centered prototyping approaches, thereby establishing a structured digital medium that enhances promotional effectiveness and competitive positioning within the travel industry. The urgency of this research is underscored by accelerating digital transformation within the tourism sector, where organizations fail to establish robust digital presence, risk progressive market obsolescence and diminished customer acquisition capacity. The novelty of this research derives from systematic integration of user-centered design principles combined with iterative prototyping methodologies to create an application prototype that not only satisfies documented business requirements but also incorporates validated user feedback through rigorous evaluation frameworks including System Usability Scale assessment and usability testing. This comprehensive methodological approach, encompassing structured needs analysis, user interface and user experience design through industry-standard digital tools, interactive prototype development, and systematic user evaluation, represents substantive advancement beyond conventional application development practices by prioritizing evidence-based design decisions grounded in user validation data. The resulting prototype provides an empirical foundation for full-scale system implementation while offering transferable methodological insights applicable to digital transformation initiatives within comparable travel enterprise contexts, particularly within the Indonesian regional market where SME digitalization remains characterized by significant capability gaps and limited access to structured development methodologies.

Methods

Research Type and Design

This research adopted a quantitative descriptive approach using Geographic Information Systems and spatial analysis techniques to investigate rainfall dynamics and landslide occurrence patterns in Muara Enim Regency. The quantitative methodology emphasizes numerical data collection, statistical analysis, and empirical measurement of relationships between rainfall variables and landslide events, prioritizing objectivity and reproducibility in scientific inquiry. The research design is explicitly descriptive in nature, seeking to characterize and document the temporal and spatial variation of rainfall patterns alongside

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corresponding landslide occurrences without manipulating variables or establishing causal mechanisms through experimental intervention. This descriptive quantitative approach permits comprehensive documentation of meteorological phenomena and their spatial distribution across the study region, generating empirical evidence regarding rainfall characteristics that inform risk assessment and disaster mitigation planning. The integration of geographic information systems technology enables systematic spatial analysis, data integration, and visualization of multitemporal rainfall patterns, facilitating identification of geographic patterns and regional variations in precipitation that may contribute to slope instability. The temporal scope encompasses eight consecutive years from 2017 to 2024, permitting analysis of annual and monthly rainfall variability alongside historical landslide occurrence records maintained by the regional disaster management authority.

The methodological approach privileges multitemporal analysis as a central analytical strategy, recognizing that landslide hazard assessment requires understanding of both long-term climatic patterns and short-term precipitation intensity fluctuations. This temporal analytical perspective aligns with contemporary best practices in hydrometeorological research, where longitudinal monitoring enables detection of seasonal patterns, annual variability, and potential long-term trends in precipitation regimes. The research integrates secondary data sources including satellite-derived rainfall estimates and institutional disaster records, avoiding primary data collection through field surveys or instrumental measurements. This secondary data approach provides cost-effective access to spatially extensive and temporally continuous datasets covering the entire study region, although introducing limitations regarding data validation and completeness that require explicit acknowledgment.

Data Collection Instruments and Analytical Techniques

Rainfall Data Acquisition

The primary rainfall dataset derives from the Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS) product, a globally consistent precipitation dataset combining satellite infrared observations with ground-based rainfall gauge measurements across a spatial resolution of 0.05 degrees (approximately 5 kilometers at the equator). CHIRPS provides monthly rainfall data spanning 1981 to near-present across 50 degrees south to 50 degrees north latitude, with demonstrated performance in characterizing precipitation patterns across tropical and subtropical regions. The dataset employs intelligent interpolation algorithms integrating multiple data sources including NASA and NOAA satellite precipitation products with station-based observations, producing bias-corrected gridded precipitation fields suitable for trend analysis, drought monitoring, and hazard assessment applications. For this research, CHIRPS data covering the 2017-2024 period was downloaded for the geographic extent encompassing Muara Enim Regency and the immediately adjacent regions, ensuring complete spatial coverage of the study area.

Landslide Occurrence Data

Landslide event data derives from official records maintained by the Regional Disaster Management Authority of Muara Enim Regency, spanning the identical temporal period as rainfall observations (2017-2024). The disaster authority database documents the month and approximate location of confirmed landslide occurrences reported through institutional channels and field verification by disaster management personnel. This institutional dataset exhibits inherent limitations including potential underreporting of minor events not formally documented, variable reporting completeness across years, and spatial resolution limitations when landslides occur in remote areas with delayed or incomplete reporting. Nevertheless, this represents the most authoritative available record of verified landslide events within the study region and provides the empirical foundation for investigating temporal associations

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between rainfall patterns and slope failure occurrence. The landslide data encompasses 75 documented events distributed across the 96-month observation period.

Spatial Interpolation Methodology

The Inverse Distance Weighting (IDW) interpolation technique was applied to transform point-based rainfall measurements from CHIRPS gridded data into continuous spatial representations of precipitation distribution across Muara Enim Regency. Inverse Distance Weighting represents a deterministic spatial interpolation method that estimates values at unsampled locations as weighted averages of surrounding measurement points, with weighting coefficients inversely proportional to distance. The fundamental principle underlying IDW posits that spatial attributes exhibit distance decay relationships, such that nearby locations contribute substantially more to value estimation than distant locations, reflecting the geographic principle of spatial autocorrelation. Mathematically, IDW calculates estimated values according to the formula weighting each measurement point by the reciprocal of its distance raised to a power parameter, typically ranging from one to four. The IDW approach demonstrates particular utility for environmental variables including precipitation, as it operates deterministically without requiring assumptions regarding underlying statistical distributions or spatial covariance structures characteristic of geostatistical methods such as kriging. While IDW exhibits documented limitations when sample points are irregularly distributed or when strong spatial trends characterize the study phenomenon, the method remains widely adopted in hydrometeorological applications for producing smooth interpolated surfaces that visualize spatial patterns while avoiding extrapolation beyond observed data ranges.

The IDW interpolation employed a power parameter of two, representing a standard configuration that balances weight concentration among nearest neighbors while maintaining computational simplicity. Spatial interpolation was performed independently for each monthly rainfall surface covering the study period, generating 96 individual interpolated rainfall maps corresponding to the 96-month observation window. Each interpolated rainfall surface was classified into rainfall intensity categories according to standard thresholds: very low (0-100 mm), low (100-200 mm), moderate (200-300 mm), high (300-400 mm), and very high (greater than 400 mm), facilitating visual comparison and identification of monthly and seasonal patterns in precipitation distribution.

Population and Sampling Characteristics

The population for this research is defined geographically rather than demographically, encompassing all spatial units within Muara Enim Regency's 7,483 square kilometer administrative boundary, located at coordinates 3 degrees 30 minutes to 4 degrees 15 minutes South latitude and 103 degrees 35 minutes to 105 degrees 15 minutes East longitude. The study region encompasses diverse topographic features ranging from lowland plains to steep hills and mountains, with corresponding variations in lithology, soil characteristics, land use, and slope stability conditions. Administratively, Muara Enim Regency borders Lahat Regency to the west, Ogan Komering Ulu Regency to the east, and Pagar Alam City and Empat Lawang Regency to the south, occupying portions of South Sumatra Province within the Sumatra geological region characterized by active tectonic processes and high landslide susceptibility.

The sampling frame for rainfall analysis encompasses the CHIRPS 0.05 degree gridded dataset, which effectively represents the study region through 144 individual grid cells each corresponding to a 5 by 5 kilometer area. These grid cells constitute the unit of analysis for spatial rainfall characterization, with each grid cell providing monthly rainfall values throughout the 2017-2024 period. For temporal analysis, the sampling frame consists of 96 monthly time periods spanning from January 2017 through December 2024. Landslide

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occurrence sampling derives from the complete census of documented events recorded by the Disaster Management Authority during this identical temporal window, incorporating all verified landslide occurrences rather than employing probabilistic sampling procedures. This complete enumeration approach reflects the limited total number of documented events (n equals 75) and the research objective to characterize all documented slope failures rather than estimating population parameters through inferential statistics.

Data Analysis Procedures

Descriptive Statistical Analysis of Rainfall

Descriptive statistical analysis was applied to annual and monthly rainfall data, calculating central tendency measures including mean annual rainfall and mean monthly rainfall values across the study period, along with measures of dispersion including standard deviation and coefficient of variation documenting the degree of year-to-year and month-to-month fluctuation rainfall. Annual rainfall values were extracted by summing all monthly rainfall values for each calendar year, with annual values documented in millimeters per year. Monthly rainfall patterns were analyzed by calculating the mean monthly precipitation across all eight years for each calendar month, documenting seasonal patterns in precipitation distribution. These descriptive statistics provide foundational characterization of the rainfall climate in Muara Enim Regency, documenting the timing, intensity, and variability of precipitation that characterizes the regional hydrometeorological regime.

Multitemporal Spatial Analysis

Multitemporal spatial analysis was conducted to document variations in rainfall distribution across geographic space and time. For each month in the 96-month observation period, spatial interpolation using the IDW method generated a continuous rainfall surface representing estimated precipitation across all locations within Muara Enim Regency at 0.05 degree resolution. These monthly surfaces were visualized cartographically to display spatial patterns in rainfall distribution, identifying geographic areas receiving disproportionately high or low precipitation within each month. The sequence of monthly maps permitted documentation of how spatial patterns in rainfall distribution shift seasonally, recognizing that some geographic areas may consistently receive higher precipitation due to topographic effects (such as windward slopes on mountains), while other locations experience more variable seasonal precipitation.

Rainfall and Landslide Occurrence Relationship Analysis

The temporal relationship between monthly rainfall patterns and landslide occurrence frequency was examined by cross-tabulating monthly rainfall values with the number of documented landslide events occurring in each calendar month across the entire 2017-2024 period. This analysis aggregated all landslide events across eight years into monthly frequency distributions, generating a single value representing the total number of landslides documented to occur during January across all eight years, an identical procedure applied to all twelve months. The resulting 12-month landslide occurrence distribution was graphically compared with corresponding monthly rainfall distributions to visually identify months where high rainfall frequency corresponds to high landslide occurrence rates. This comparative analysis recognizes that landslide triggering mechanisms operate through complex hydrogeological processes where rainfall effects on slope stability depend upon slope angle, soil infiltration characteristics, pore pressure development, and antecedent moisture conditions, yet documented evidence demonstrates consistent associations between high rainfall periods and increased landslide frequency at the regional scale.

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Spatial-Temporal Integration

Integration of spatial rainfall maps with landslide occurrence locations was conducted within the Geographic Information Systems environment, permitting overlay analysis examining whether landslides demonstrate spatial clustering in areas receiving particularly high rainfall. Landslide point locations, where geographic information permitted specification, were mapped and overlaid upon the series of monthly rainfall interpolation surfaces, enabling visual assessment of whether documented slope failures occur disproportionately in high-rainfall areas or whether landslide distribution appears independent of the spatial variation in precipitation. This integration recognizes that geographically variable rainfall distribution could produce localized hazard concentrations if certain areas consistently experience more intense precipitation than surrounding regions.

Research Procedures

Phase One: Data Acquisition and Preparation

The initial research phase involved downloading CHIRPS monthly rainfall data for the geographic bounding box encompassing Muara Enim Regency from the Climate Hazards Group data portal (https://www.chc.ucsb.edu/data/chirps). The resulting rainfall dataset was formatted as gridded arrays compatible with Geographic Information Systems software (ArcGIS or QGIS). Simultaneously, landslide occurrence records were requested from the Muara Enim Regency Regional Disaster Management Agency, obtaining the compiled dataset documenting 75 verified landslide events occurring during 2017-2024. Landslide records were organized into a tabular database specifying the occurrence month for each documented event, permitting aggregation into monthly frequency distributions.

Phase Two: Spatial Interpolation and Cartographic Representation

For each of the 96 months spanning 2017-2024, the CHIRPS monthly rainfall grid was subjected to IDW interpolation at 0.05 degree resolution using standard GIS interpolation functions. Power parameter for distance weighting was established at two, based on prior methodological literature documenting the effectiveness of this parameter value in precipitation interpolation. Following interpolation, each monthly rainfall surface was classified into five precipitation intensity categories and rendered as thematic maps using standard cartographic conventions (graduated color schemes, map legends, geographic reference systems, and scale indicators). The resulting 96 monthly maps provide comprehensive visual documentation of spatial-temporal rainfall patterns throughout the study period.

Phase Three: Statistical Analysis and Relationship Characterization

Monthly rainfall values were aggregated across all eight years, calculating mean monthly rainfall for each calendar month (January through December). Simultaneously, landslide event counts were aggregated by calendar month, generating 12 monthly frequency values representing the total number of documented landslides in each month across the entire observation period. These paired monthly values (mean rainfall and total landslide frequency) were compiled into a data table permitting calculation of descriptive statistics and visual comparison through dual-axis graphics displaying both rainfall intensity and landslide occurrence frequency. Annual rainfall totals were calculated and tabulated, with corresponding discussion of how year-to-year variation in total precipitation relates to annual landslide activity.

Phase Four: Integration and Interpretation

The final research phase integrated findings from spatial mapping, statistical analysis, and landslide record review to synthesize comprehensive understanding of rainfall dynamics and

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their relationship to slope failure processes in Muara Enim Regency. Findings were interpreted within the context of established literature regarding rainfall-induced landslide mechanisms, documented threshold rainfall intensities that trigger slope failures, and regional geomorphological and geological characteristics conditioning slope stability. The analysis explicitly acknowledges the limitations inherent in the dataset, including potential underreporting of landslides, incomplete spatial specification of some events, and the simplified treatment of rainfall as a single parameter when landslide occurrence typically depends upon multiple interacting factors. Nevertheless, the research provides evidence-based characterization of rainfall patterns and temporal associations with documented landslide occurrence, generating foundational information suitable for subsequent integrated hazard assessment incorporating additional conditioning variables.

Results and Discussion

Annual Rainfall Data for the Period 2017 – 2024

Annual rainfall data for Muara Enim Regency for the 2017–2024 period shows varying rainfall values each year. In 2017, rainfall was recorded at 3095 mm, then in 2018 at 2807 mm, and in 2019 at 2267 mm. Furthermore, rainfall in 2020 was 3122 mm, followed by 3217 mm in 2021. 2022 was the year with the highest rainfall value during this period, at 3656 mm. After that, rainfall in 2023 was recorded at 2485 mm, and in 2024 at 3030 mm. All these values can be seen in Table 3.1, which presents complete annual rainfall data for the 2017–2024 period.

Table 1. Average annual rainfall in Muara Enim Regency

Year	CH (mm/year)
2017	3095
2018	2807
2019	2267
2020	3122
2021	3217
2022	3656
2023	2485
2024	3030

Source: Data processing (2025)

Rainfall Dynamics on Landslides

The landslide data and average monthly rainfall presented in Table 3.2 show variations in conditions each month during the observation year. In January, five landslides were recorded with an average rainfall of 310 mm, while in February, nine landslides occurred with a rainfall of 271 mm. March recorded eight landslides with a rainfall of 350 mm, followed by April with seven landslides and a rainfall of 317 mm. In May, two landslides occurred with a rainfall of 260 mm, and June recorded eight landslides with a rainfall of 172 mm.

In July, there were four landslides with a total rainfall of 288 mm, while in August there were no landslides (0 incidents) with a total rainfall of 136 mm. September recorded one landslide with a total rainfall of 154 mm, while October recorded three landslides with a total rainfall of 219 mm. Furthermore, November recorded nine landslides with a total rainfall of 288 mm, and December recorded four landslides with an average rainfall of 363 mm.

Thus, Table 2 provides a complete picture of the distribution of landslide events and variations in rainfall in each month during the period.

Table 2. Relationship between Number of Incidents and Rainfall (mm/month)

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Month	Number of Events	Average Rainfall
January	5	310
February	9	271
March	8	350
April	7	317
May	2	260
June	8	172
July	4	288
August	0	136
September	1	154
October	3	219
November	9	288
December	4	363

Source: Data processing (2025)

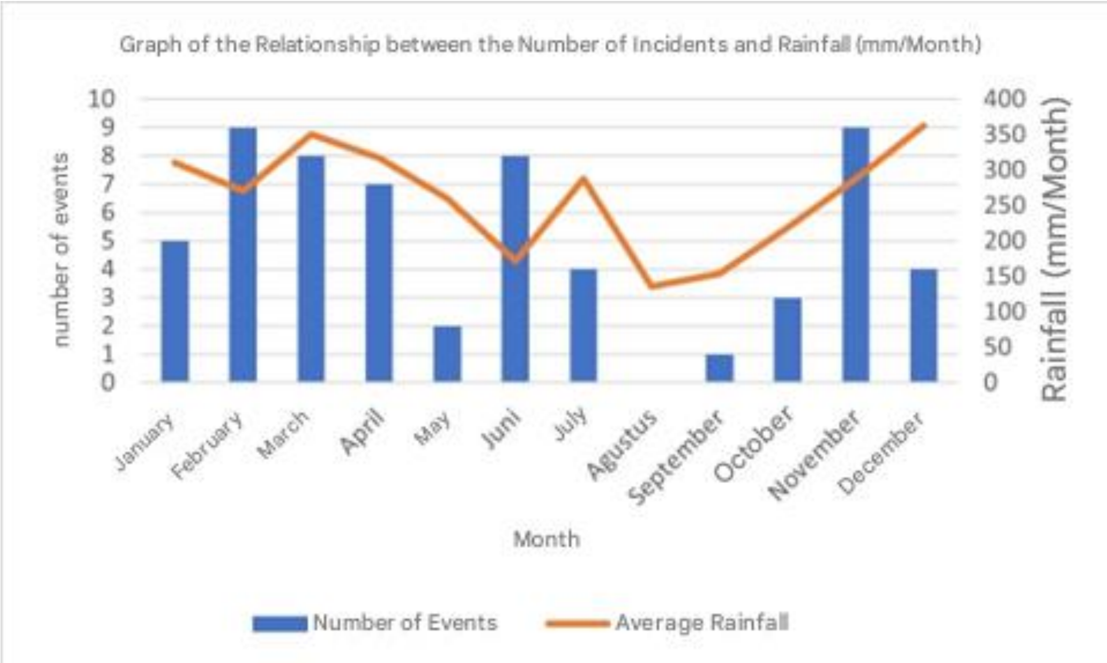

Figure 1. Graph of the Relationship between the Number of Incidents and Rainfall (mm/month)

The graph in Figure 1 shows a comparison between the number of landslide events and the average monthly rainfall based on combined data for the period 2017–2024. The bar graph (blue) depicts the total number of landslide events in each month for eight years, while the line (orange) shows the average monthly rainfall for the same period. From January to March, the number of landslide events ranged from 5–9, with an average rainfall of around 271–350 mm. Entering April to June, the variation in landslide events appeared more fluctuating, where May recorded the lowest number of events, namely 2 events with a rainfall of 260 mm, while June increased again to 8 events.

From July to October, the frequency of landslides tended to be low, with 0–4 incidents, in line with rainfall ranging from 136–288 mm. Furthermore, in November, the number of incidents increased again to 9 incidents, accompanied by 288 mm of rainfall. In December, 4 incidents occurred, despite rainfall reaching its highest value of the year at 363 mm. Overall, this graph shows that months with relatively high rainfall tended to have a higher number of landslides, while months with low rainfall experienced few or no incidents at all. This is consistent with

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the pattern in Table 2, which illustrates the general relationship between rainfall intensity and the number of landslides in the period 2017–2024.

Rainfall data for Muara Enim Regency for the 2017–2024 period shows a fluctuating pattern from year to year. In 2017, rainfall was recorded at 3,095 mm, decreasing in 2018 to 2,807 mm, and reaching its lowest point in 2019 at 2,267 mm. In 2020, rainfall increased again to 3,122 mm, then to 3,217 mm in 2021, and peaked at 3,656 mm in 2022. Subsequently, rainfall decreased in 2023 to 2,485 mm, before increasing again in 2024 to 3,030 mm. All these values are presented in Table 1, which shows the dynamics of annual rainfall in Muara Enim Regency.

When viewed based on monthly averages, seasonal patterns are clearly visible. The highest rainfall occurs in December (363 mm) and March (350 mm), while the lowest rainfall occurs in August (136 mm) and September (154 mm). Other months fall in the intermediate range, such as January (310 mm), February (271 mm), April (317 mm), May (260 mm), June (172 mm), July (288 mm), October (219 mm), and November (288 mm).

Based on combined data on landslide occurrences and monthly rainfall from 2017–2024, presented in Table 3.2, the distribution of landslides varies by month. In January, there were five landslides with a rainfall of 310 mm, while February recorded nine landslides with a rainfall of 271 mm. March recorded eight landslides, April seven landslides, and May saw a decrease to two landslides. The number of landslides increased again in June to eight landslides. From July to October, landslide occurrences tended to be lower, with 0–4 landslides. In November, the number of landslides increased again to nine landslides, and December recorded four landslides with the highest rainfall of 363 mm.

The relationship between monthly rainfall and total landslide occurrences can be seen more clearly in Figure 1. The graph shows that months with relatively high rainfall, such as January, February, March, and November, generally have a greater number of landslide occurrences, while months with low rainfall, such as August and September, show no landslide occurrences. Meanwhile, months with moderate rainfall, such as April, June, and July, show moderate variations in landslide occurrences. Overall, the combined data for 2017–2024 shows that rainfall has a strong relationship with the frequency of landslide occurrences in Muara Enim Regency.

The findings of this study are also supported by several previous studies. The Balai Sabo study byYuniawan et al. (2022). Research conducted through the Indonesia Landslide Early Warning System (ILEWS) shows that daily and three-day cumulative rainfall thresholds can be effective indicators for predicting landslide occurrences in various regions in Indonesia. This confirms that rainfall is the primary trigger for landslides. Another study in the Tinalah Watershed, Kulon Progo, found that rainfall intensity plays a significant role in increasing landslide occurrences, particularly in areas with steep slopes and changing land use.(Arrisaldi et al., 2023). In addition, recent research in China shows that rainfall threshold-based early warning models are effective in predicting daily landslide potential, especially in areas with unstable geomorphological characteristics (Dou et al., 2024; Huang et al., 2022; Thapa et al., 2023; Segoni et al., 2018).

Thus, the research findings in Muara Enim Regency align with the findings of various previous studies, which consistently show that rainfall, both intensity and accumulation, are closely related to increased landslide occurrences. The rainfall dynamics shown in the 2017–2024 data affect soil saturation levels, slope stability, and the potential for landslides during months with high rainfall accumulation. This confirms that rainfall is a key factor to consider in landslide vulnerability analyses in hilly areas such as Muara Enim Regency.

Conclusion

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This research demonstrates that rainfall dynamics in Muara Enim Regency exhibit distinct temporal patterns significantly associated with documented landslide occurrence frequency during the 2017-2024 period. Analysis of annual precipitation data reveals fluctuations ranging from 2,267 millimeters (2019) to 3,656 millimeters (2022), with monthly data indicating clear seasonal variation characterized by precipitation peaks in December (363 millimeters) and March (350 millimeters), contrasting sharply with dry season minima in August (136 millimeters) and September (154 millimeters). Aggregate landslide data across the eight-year period shows highest occurrence during February, March, and November (8-9 documented events), corresponding with moderate to high rainfall periods, while months with minimal precipitation such as August and September recorded zero to one landslide event. The consistency between observed rainfall patterns and landslide temporal distribution substantially establishes understanding that precipitation intensity and accumulation function as primary triggering mechanisms for slope instability in mountainous tropical regions. These findings align with previously documented research demonstrating rainfall thresholds as effective indicators for predicting rainfall-induced landslides in comparable Indonesian geographic and climatic contexts.

However, this research acknowledges several methodological limitations requiring explicit recognition when interpreting findings and implementing practical applications. The analysis employs rainfall as a singular parameter while recognizing that landslide initiation operates through complex multi-factorial hydrogeological processes where in slope angle, soil properties, geological characteristics, land use patterns, and antecedent moisture conditions collectively determine slope stability. Additionally, potential underreporting of minor landslide events by disaster management authorities, incomplete spatial specification of some documented occurrences, and reliance on satellite-derived rainfall data create inherent uncertainty in quantifying precise rainfall-landslide relationships. These limitations notwithstanding, the research provides foundational empirical evidence suitable for informing subsequent integrated hazard assessment incorporating geological conditioning factors, slope stability analysis, and machine learning approaches for establishing location-specific rainfall thresholds. Future research should prioritize coupling this rainfall characterization with susceptibility mapping, soil mechanics analysis, and real-time early warning system development to advance landslide risk reduction and enhance community preparedness in Muara Enim Regency and comparable Indonesian mountain regions.

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