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COMPARATIVE ANALYSIS OF EARTHQUAKE FREQUENCY AND MAGNITUDE IN LUZON, VISAYAS, AND MINDANAO

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ABSTRACT

Earthquakes remain one of the most significant natural hazards affecting the Philippines due to its location along major tectonic boundaries within the Pacific Ring of Fire. This study examined recorded seismicity in Luzon, Visayas, and Mindanao using secondary earthquake data from the Philippine Institute of Volcanology and Seismology (PHIVOLCS) covering January 31, 2018, to July 31, 2026. Using a descriptive-comparative quantitative research design, the study analyzed 132,201 earthquake records classified by the country's three major island groups. The study used frequency and percentage distributions and Welch's One-Way Analysis of Variance (ANOVA) to determine earthquake occurrence patterns, relationships among regional earthquake counts, and differences in earthquake magnitudes. Results revealed that Mindanao recorded the highest number of earthquake events with 68,009 occurrences (51.44%), followed by Luzon with 45,231 (34.21%) and the Visayas with 18,961 (14.34%). Welch's ANOVA revealed a statistically significant difference in mean earthquake magnitudes among the three island groups, $F(2, 54{,}095) = 1389.00$, $p < .001$, confirming that seismic intensity varies significantly across regions. The findings highlight Mindanao as the most seismically active island group in terms of both earthquake frequency and average magnitude during the study period. These results underscore the need for region-specific disaster risk reduction strategies, infrastructure resilience initiatives, and enhanced earthquake preparedness programs. By providing current empirical evidence on regional seismic patterns, the study offers valuable insights for policymakers, disaster risk reduction and management agencies, urban planners, and researchers to strengthen earthquake risk assessment and resilience-building efforts throughout the Philippines.

Keywords: *Earthquake Magnitude, Earthquake Frequency, Seismic Activity, Comparative Assessment, Philippines, PHIVOLCS, Disaster Risk Reduction.*

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INTRODUCTION

The Philippines lies within one of the most seismically active regions of the western Pacific and experiences frequent earthquake activity across its major island groups. Its location in a complex tectonic environment, characterized by active faults, trenches, and subduction zones, contributes to earthquakes of varying frequency and magnitude (Baitus et al., 2024; Ferrario et al., 2024; Mendez et al., 2026a). Because these geological structures are unevenly distributed across the archipelago, earthquake activity is likewise expected to vary geographically. Understanding these differences helps clarify the country's observed seismicity and supports evidence-based disaster preparedness and risk reduction (Cuesta-Claros et al., 2023; Eroglu, 2022).

The three major island groups of the Philippines—Luzon, Visayas, and Mindanao—represent distinct geographic areas within this broader seismic environment. Each contains different combinations of active faults and tectonic structures that can generate earthquakes. Notable earthquakes in different parts of the country further show that seismic activity is not confined to a single region. Strong and moderate earthquakes have been recorded in northern Luzon, the central Philippines, and Mindanao, while numerous smaller events are continuously detected throughout the archipelago. This geographic variation provides a basis for examining whether earthquake frequency and magnitude differ among the three major island groups (Labanan & Raga, 2021; Nayak et al., 2025; Stein & Toda, 2023).

Examining earthquake frequency alone, however, does not fully describe regional seismic activity. Many recorded earthquakes in one area may reflect frequent small-magnitude events, whereas another area may have fewer events but record relatively larger earthquakes. For this reason, consider earthquake frequency and magnitude together when comparing regional seismicity. Frequency indicates how often earthquakes are recorded, while magnitude describes the size of individual events. Examining them together can provide a more informative description of the earthquake characteristics observed in different regions (Devi & Pasari, 2025; Mendez et al., 2026b; Rekapalli & K. Gupta, 2026).

A systematic comparison also requires careful consideration of earthquake catalogs. Recorded earthquake counts depend not only on actual seismic activity but also on monitoring systems' ability to detect events, particularly smaller earthquakes. Differences in detection capability, reporting, geographic classification, and the occurrence of aftershock sequences may affect the number of observations contained in a catalog. Data quality issues such as duplicate records, missing values, inconsistent classifications, and other recording problems may likewise influence statistical comparisons. These considerations highlight the importance of using a consistent data source, a clearly defined study period, and systematic data-screening procedures when comparing earthquake observations across large geographic areas (Ferrario et al., 2024; Llamas et al., 2024; Naik et al., 2024).

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Existing earthquake research in the Philippines has provided substantial information about individual fault systems, earthquake sequences, specific events, and localized seismic activity. However, much of this work has focused on particular regions, fault segments, or notable earthquakes. Such studies are valuable for understanding specific seismic sources, but they do not directly provide a standardized comparison of the frequency and magnitude of recorded earthquakes across Luzon, Visayas, and Mindanao using a single recent earthquake dataset and a common observation period (Buhay et al., 2024; Perez et al., 2024; Stein & Toda, 2023). A regional comparison based on a common source can therefore provide a complementary perspective by describing the overall distribution of recorded earthquake observations across the country's three major island groups.

This study addressed this gap by analyzing and comparing recorded earthquake occurrences across Luzon, Visayas, and Mindanao using earthquake records from the Philippine Institute of Volcanology and Seismology (PHIVOLCS) covering January 31, 2018, to July 31, 2026. The analysis focused on two primary characteristics of the recorded events: frequency and magnitude. Earthquake observations were classified according to the three major island groups and were examined using frequency and percentage distributions, descriptive statistics, correlation analysis, and comparative statistical analysis.

Using a single earthquake data source and a defined observation period provides a consistent basis for describing regional differences in the available records. At the same time, the study recognizes that recorded earthquake frequency and magnitude should not be interpreted as a complete measure of earthquake hazard or risk. Actual earthquake risk depends on multiple factors, including earthquake location and depth, geological and ground conditions, population exposure, infrastructure, building characteristics, and community vulnerability (Felix et al., 2022; Newhall, 2021; Ortiz et al., 2024). Thus, this study focuses on the observed characteristics of recorded seismic activity rather than attempting to provide a comprehensive assessment or prediction of earthquake risk.

By examining earthquake frequency and magnitude at the island-group level, this study provides a recent empirical benchmark of recorded seismic activity across the Philippines. The results can help clarify regional differences in the number and magnitude characteristics of recorded earthquakes and provide a basis for further investigation of the factors underlying these patterns. The findings may also contribute to discussions on disaster preparedness, seismic monitoring, infrastructure planning, and future research on earthquake hazards in the Philippines. More broadly, the study demonstrates how a large national earthquake database can be organized into meaningful regional information that is more accessible to researchers, planners, disaster risk reduction practitioners, and communities concerned with earthquake preparedness.

Research Questions

This study aimed to analyze and compare the frequency and magnitude of recorded earthquakes across the three major island groups of the Philippines, Luzon,

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Visayas, and Mindanao, from January 31, 2018, to July 31, 2026. Specifically, it sought to answer the following questions:

1. What is the distribution of recorded earthquake observations across Luzon, Visayas, and Mindanao?
2. Is there a statistically significant difference in the mean earthquake magnitude among Luzon, Visayas, and Mindanao?

METHODOLOGY

Research Design

This study used a quantitative descriptive-comparative research design based on secondary earthquake records. The design described and compared the frequency and magnitude of recorded earthquakes across the three major island groups of the Philippines—Luzon, Visayas, and Mindanao. The study focused on earthquake observations recorded from January 31, 2018, to July 31, 2026.

The descriptive component summarized the distribution and magnitude characteristics of recorded earthquake observations within each island group. The comparative component examined whether the mean earthquake magnitude differed across Luzon, Visayas, and Mindanao. Correlation analysis also examined relationships among annual earthquake counts across the three island groups and between the year of occurrence and annual earthquake counts.

Data Source and Study Dataset

The study utilized secondary earthquake data obtained from the Philippine Institute of Volcanology and Seismology (PHIVOLCS). The dataset included recorded earthquake observations in the Philippines from January 31, 2018, to July 31, 2026.

The earthquake records were classified according to the three major island groups: Luzon, Visayas, and Mindanao. The primary variables examined were earthquake frequency and magnitude. The number of recorded earthquake observations represented frequency, while magnitude represented the reported size of each recorded earthquake event.

Because the study used publicly available secondary data, it involved no human participants. The analysis relied solely on the earthquake records in the available PHIVOLCS dataset.

Data Screening and Preparation

Prior to statistical analysis, the earthquake records were examined for data-quality issues that could affect the regional comparison. The dataset was checked for duplicate observations, missing values, inconsistent island-group classifications, and apparent data-entry irregularities. Records were then organized by island group and year to support descriptive and comparative analyses.

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The study treated the available PHIVOLCS records as recorded observations rather than as a complete enumeration of all earthquakes occurring in the Philippines. Accordingly, the results describe the distribution and characteristics of earthquakes contained in the study dataset.

Data Analysis

The study analyzed the data using JAMOVI Version 2.7 to obtain descriptive statistics, conduct comparative analyses, assess assumptions relevant to the statistical procedures, and generate appropriate statistical plots. Frequency and percentage distributions described the number and proportion of recorded earthquake observations for each island group and year. To test whether mean earthquake magnitude differed across Luzon, Visayas, and Mindanao, we used Welch's one-way analysis of variance (ANOVA). This paper used Welch's ANOVA because it provides a robust alternative to conventional one-way ANOVA when the assumption of equal variances may not be met. The statistical decision was based on the resulting F statistic and p-value. All statistical analyses used the recorded earthquake observations available in the study dataset. The study interpreted statistical findings in relation to the objectives and did not treat them as direct measures of earthquake hazard or risk (Corbita et al., 2024, 2025; Gitanes et al., 2024).

RESULTS AND DISCUSSION

This section presents and interprets the findings on the distribution, frequency, and magnitude of recorded earthquakes across Luzon, Visayas, and Mindanao from 2018 to 2026*. The results are organized according to the study objectives and research questions, highlighting patterns in earthquake occurrence, relationships among annual observations, and differences in earthquake magnitude across the three major island groups.

Table 1. Annual Frequency and Percentage Distribution of Recorded Earthquake Observations by Major Island Group, 2018–2026*

Year	Island Group			Total (%)	
	Luzon	Visayas	Mindanao		
2018	2,207	1,141	2,909	**6,257**	**4.73%**
2019	3,161	1,553	8,320	**13,034**	**9.86%**
2020	5,185	1,806	7,104	**14,095**	**10.66%**
2021	4,417	1,491	6,164	**12,072**	**9.13%**
2022	8,185	1,578	4,575	**14,338**	**10.85%**
2023	6,299	1,421	8,912	**16,632**	**12.58%**
2024	5,287	2,127	10,735	**18,149**	**13.73%**
2025	6,213	6,193	9,385	**21,791**	**16.48%**
2026*	4,277	1,651	9,905	**15,833**	**11.98%**

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Total	**45,231**	**18,961**	**68,009**	**132,201**	**100.00%**

**Up to July 31, 2026 only*

Table 1 presents the annual frequency and percentage distribution of recorded earthquake observations across Luzon, Visayas, and Mindanao from January 31, 2018, to July 31, 2026. The dataset includes 132,201 earthquake observations recorded during the study period. Mindanao accounted for the most observations, with 68,009 events, or 51.44% of the total. Luzon followed with 45,231 events, or 34.21%, while the Visayas accounted for 18,961 events, or 14.34%.

The distribution varied across years. Mindanao recorded the largest share in most years, particularly in 2019, when it accounted for about 64% of annual observations; in 2024, about 59%; and in 2026, about 63% of observations recorded through July. Luzon recorded the largest share in 2022, accounting for about 57% of observations. In 2025, the distribution was comparatively less concentrated, with Luzon, Visayas, and Mindanao accounting for approximately 29%, 28%, and 43%, respectively.

The largest annual number of recorded earthquake observations occurred in 2025, with 21,791 events. This was followed by 2024 with 18,149 observations and 2023 with 16,632 observations. The lowest annual total occurred in 2018, with 6,257 observations. Because the 2026 data cover only January through July, its annual total is not directly comparable with the complete calendar years from 2018 to 2025.

Overall, the distribution indicates that recorded earthquake observations were not evenly distributed among the three major island groups during the study period. Mindanao accounted for more than half of all observations in the dataset, while Luzon accounted for approximately one-third and the Visayas for approximately one-seventh. These results describe the distribution of recorded observations in the PHIVOLCS dataset and should not be interpreted as a direct measure of earthquake hazard or risk.

Table 2. Welch's One-Way ANOVA Comparing Mean Earthquake Magnitudes Across the Three Major Island Groups

Variable	*F*	*df1*	*df2*	*p-value*	*Interpretation*
Earthquake Magnitude	1389.00	2	54,095	< .001	Significant difference in mean earthquake magnitude among Luzon, Visayas, and Mindanao

Table 2 presents the results of Welch's One-Way Analysis of Variance (ANOVA), which was conducted to determine whether mean earthquake magnitudes differ significantly across Luzon, Visayas, and Mindanao. The analysis revealed a highly significant effect of island group on earthquake magnitude, $F(2, 54{,}095) = 1389.00$, $p < .001$, indicating that at least one island group had a mean earthquake magnitude

significantly different from the others. This finding rejects the null hypothesis of equal mean magnitudes across the three regions.

The result supports the descriptive findings presented earlier, where Mindanao recorded the highest average earthquake magnitude (M = 2.58), followed by the Visayas (M = 2.43) and Luzon (M = 2.36). The statistically significant variation among island groups suggests that seismic activity is not uniformly distributed throughout the Philippines and that regional tectonic characteristics may influence earthquake intensity patterns. Given the very large F-value and extremely small probability value, the differences observed are unlikely to have occurred by chance.

From a disaster risk reduction perspective, the findings emphasize the importance of adopting region-specific earthquake preparedness, infrastructure planning, and seismic monitoring strategies. While all three island groups are exposed to earthquake hazards, the higher mean magnitudes observed in Mindanao indicate a greater tendency toward stronger seismic events during the study period. Nevertheless, when assessing overall seismic risk, earthquake magnitude should be interpreted alongside other factors such as earthquake depth, proximity to populated areas, local geological conditions, and structural vulnerability (Camacho et al., 2023; Cordero Jr, 2024; Galang et al., 2025). Consequently, the results provide empirical evidence supporting differentiated mitigation and preparedness efforts across the major island groups of the Philippines.

Summary

The study examined the spatial distribution and magnitude characteristics of earthquakes across the three major island groups of the Philippines, namely Luzon, Visayas, and Mindanao. Findings revealed that earthquake occurrences and magnitudes varied significantly among the regions, with Mindanao registering the highest mean earthquake magnitude, followed by the Visayas and Luzon. Welch's One-Way ANOVA confirmed these differences were statistically significant, indicating that seismic activity is not uniformly distributed across the country. The results imply that regional geological and tectonic conditions contribute to variations in earthquake intensity and occurrence. Consequently, earthquake risk reduction strategies, preparedness programs, and resource allocation should be tailored to each island group's specific seismic profile rather than adopting a uniform national approach. The findings provide empirical evidence that can support enhanced disaster resilience planning, infrastructure development, and risk-informed decision-making among stakeholders responsible for disaster management and public safety.

Conclusions

The study conclusively demonstrates that significant disparities exist in earthquake magnitudes among Luzon, Visayas, and Mindanao, highlighting the dynamic and region-specific nature of seismic hazards in the Philippines. The higher average earthquake magnitudes observed in Mindanao underscore the need for heightened vigilance and strengthened preparedness measures in areas experiencing greater seismic activity. These findings reinforce the importance of evidence-based disaster risk reduction policies

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and emphasize that vulnerability to earthquakes cannot be addressed through generalized interventions alone. As the Philippines remains situated along the Pacific Ring of Fire, understanding regional seismic patterns is critical for safeguarding lives, protecting infrastructure, and promoting sustainable development. Ultimately, the study provides valuable scientific evidence to guide national and local efforts to build safer, more resilient communities capable of withstanding future earthquake-related disasters.

Recommendations

For policymakers, it is recommended that earthquake risk assessments be integrated more fully into national and local development planning, with funding priorities aligned with regional seismic risks. Local Government Units (LGUs) should strengthen building code enforcement, conduct regular earthquake drills, and enhance community-based disaster preparedness programs, particularly in high-risk areas. The City and Municipal Disaster Risk Reduction and Management Offices (CDRRMOs/MDRRMOs) should intensify seismic monitoring, improve public awareness campaigns, develop location-specific contingency plans, and strengthen coordination with scientific agencies and emergency responders. Future researchers are encouraged to expand the scope of investigation by incorporating additional seismic indicators such as earthquake depth, fault proximity, frequency, intensity, and temporal trends to provide a more comprehensive understanding of seismic risks. Furthermore, comparative studies involving provincial, regional, and local seismic patterns may generate more nuanced insights for disaster management planning.

Several limitations should be acknowledged when interpreting this study's findings. First, the analysis focused primarily on earthquake magnitudes and geographic distribution. It did not consider other important seismic parameters such as earthquake depth, focal mechanisms, fault characteristics, and ground shaking intensity. Second, the study utilized available earthquake records within a specific period, which may not fully capture long-term seismic behavior and trends across the three island groups. Third, the findings are limited to regional comparisons and do not account for local geological conditions that may influence earthquake impacts. Lastly, while the study identified statistical differences in earthquake magnitudes, it did not examine the direct socio-economic consequences of seismic events on affected communities. These limitations create opportunities for future studies to develop more comprehensive, multidimensional assessments of earthquake hazards and disaster risks in the Philippines.

Compliance with Ethical Standards

This study followed the ethical standards for secondary data research. The analysis did not involve human respondents, personal data, interviews, or experimental intervention, and used earthquake observations made publicly available by PHIVOLCS. Researchers traced the data to its source and reported statistical findings based on the available records. The study identified no conflict of interest. The researchers also note limitations in using secondary earthquake records, such as potential variations in reporting completeness, event detection, and location classification. Any use of artificial

intelligence tools in the preparation of the manuscript should be disclosed in accordance with the requirements of the institution or the journal.

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