

# Deterministic Seismic Hazard Analysis (DSHA) and Peak Ground Acceleration Mapping in West Java (2018–2024)

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## ABSTRACT

West Java is a region with one of the most complex tectonic settings in Indonesia, influenced by the Sunda Megathrust subduction zone and an active inland fault system. This study aimed to estimate the Peak Ground Acceleration (PGA) values in the West Java region using a Deterministic Seismic Hazard Analysis (DSHA) approach with the Maximum of Maxima criteria. The data used is sourced from the BMKG earthquake catalog for the 2018–2024 period, which includes the most recent epicenter, hypocenter depth, and magnitude parameters. PGA calculations were performed using the Milne attenuation model for each grid point in the target area, followed by spatial interpolation using PyGMT software. The analysis results reveal a significant bimodal seismic hazard characteristic. An absolute maximum PGA value of 0.46 g was identified, triggered by a local shallow crustal earthquake with a magnitude of M 5.8 at a shallow depth within the inland region. Meanwhile, the southern coastal zone is dominated by the influence of a large Megathrust earthquake (M 8.7), although its shaking impact attenuates as it moves inland toward northern population centers. These findings confirm that while subduction sources possess greater energy potential, local active inland faults pose a more direct and destructive shaking threat to densely populated inland areas. The hazard map generated in this study is expected to serve as a crucial technical reference for resilient infrastructure planning and the updating of earthquake mitigation strategies in West Java Province.

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## 1. INTRODUCTION

West Java is one of the regions with the most complex seismic activity in Indonesia. This condition is triggered by active tectonic interactions between the Indo-Australian Plate, which subducts beneath the Eurasian Plate, forming the Sunda Megathrust zone in the south [1]. In addition to the threat from the subduction zone, the West Java mainland is also cut by various active fault systems, including the Cimandiri Fault, Lembang Fault, and Baribis Fault, which have the potential to trigger shallow crustal earthquakes with significant damage [2], [3], [4], [5]. As a result, this region has the potential for continuous seismic energy release, both from interplate and intraplate sources, which can produce significant ground acceleration [6].

Technically, the high frequency of seismic activity in West Java necessitates a measurable and up-to-date mapping of ground-shaking hazard potential. Earthquake catalog data covering the period 2018–2024 provide crucial information on the distribution of epicenters and hypocentral depths, which serve as the primary basis for evaluating the characteristics of seismic sources. The distribution of seismic activity in this region during that period can be observed in Figure 1, which shows a concentration of earthquake events along the subduction zone and active onshore faults. The accuracy of source location determination, as presented in the seismicity map, is critical for modeling wave propagation from bedrock to the surface through appropriate attenuation models [7].

This study applies the Deterministic Seismic Hazard Analysis (DSHA) method to estimate Peak Ground Acceleration (PGA) values across the entire West Java region. Unlike probabilistic approaches, DSHA focuses on deterministic scenarios derived from the most threatening seismic sources based on maximum magnitude and the shortest distance to the study site [8], [9]. While Probabilistic Seismic Hazard Analysis (PSHA) is widely utilized for national building codes, DSHA remains highly relevant for evaluating extreme, worst-case ground shaking scenarios for specific local critical infrastructure. In this baseline deterministic screening, the empirical Milne formulation was deliberately selected because it provides a conservative, generalized upper-bound hazard estimate across a mixed tectonic regime, without requiring the complex parameterizations of modern subduction or crustal-specific Ground Motion Prediction Equations (GMPEs). By utilizing the latest BMKG earthquake catalog and selecting relevant Ground Motion Prediction Equations (GMPEs), this research aims to produce a representative PGA hazard map to support infrastructure planning with adequate resistance to seismic dynamic loads. West Java's complex tectonic setting, characterized by the convergence of the Sunda Megathrust and various active inland faults, necessitates a detailed evaluation of seismic potential [10]. The deterministic approach remains a critical tool for infrastructure resilience by simulating the most extreme ground motion scenarios for specific sites [11].

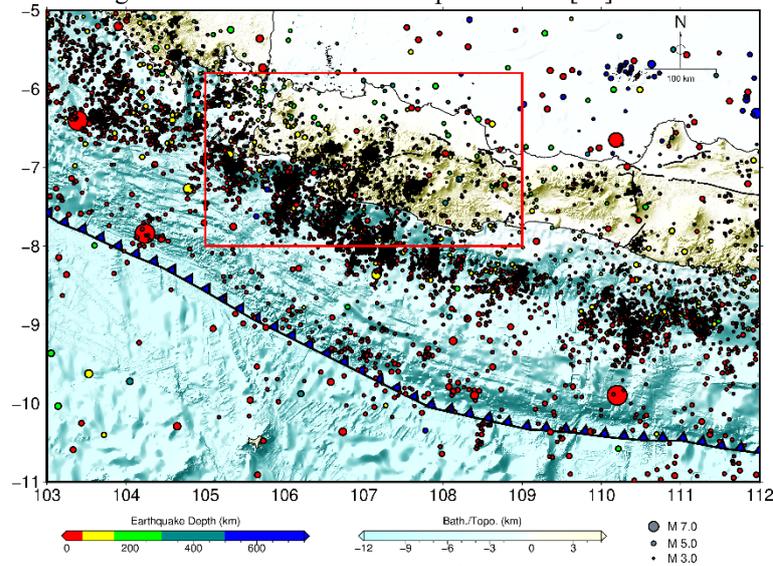


Fig. 1 Seismicity Map of West Java

## 2. RESEARCH METHOD

This study applies the Deterministic Seismic Hazard Analysis (DSHA) approach using the Maximum of Maxima criterion to determine the worst-case ground-shaking estimate. The research procedure systematically follows the stages presented in Figure 2, starting from data collection to the visualization of the final results. The primary data used consist of an earthquake catalog obtained from the Meteorology, Climatology, and Geophysics Agency (BMKG) for the observation period 2018–2024. This study utilized the updated seismic parameters and earthquake catalogs from BMKG to ensure accurate modeling of both subduction and crustal fault sources, following the latest seismotectonic research in the Indonesian region [12].

The boundaries of the seismic source region are defined within the coordinates 103°–112° E and 5°–11° S, encompassing subduction-related sources and onshore faults that tectonically influence West Java Province [1]. The seismic hazard calculation stage is conducted by dividing the target area into regular spatial grids with a resolution of 0.2 x 0.2 degree. The interpolation was performed using a continuous curvature algorithm in PyGMT. This study utilizes a historical-event DSHA approach directly over the 2018–2024 catalog without sequence declustering, focusing purely on identifying the extreme values. For each grid point, the Peak Ground Acceleration (PGA) value is estimated using an attenuation model or Ground Motion Prediction Equation (GMPE). In this study, the Milne Attenuation Model (Equation 1) is employed, which empirically calculates Peak Ground Acceleration (PGA) expressed in units of gravity (g) based on the earthquake moment magnitude (M) and the hypocentral distance (R) in kilometers [13].

$$PGA = 0.04e^M R^{-1.4} \quad (1)$$

In accordance with the workflow shown in Figure 2, the calculation process is performed for all earthquake events in the catalog at each observation point. The highest PGA value at each grid point is then selected as the representative deterministic scenario (Maximum of Maxima). While the inland hazard is

predominantly evaluated based on the extreme values from the recent historical seismic records [8], [14], a deterministic worst-case scenario (Maximum Credible Earthquake) for the Sunda Megathrust (M 8.7) was explicitly incorporated into the model. This combination ensures that the resulting hazard map reflects both the direct threat of active crustal faults and the maximum potential energy release from the subduction zone. Finally, the spatial distribution of PGA values is digitally interpolated and visualized using PyGMT software to produce a precise seismic hazard contour map [15].

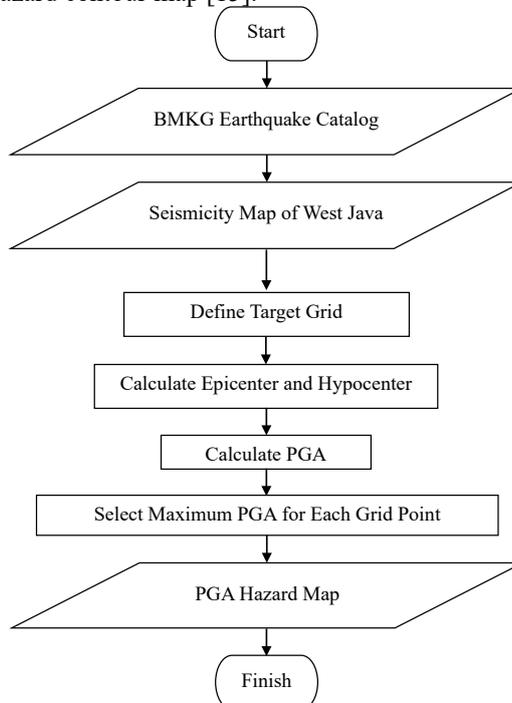


Fig. 2 Flowchart

### 3. RESULTS AND DISCUSSION

The interpolated PGA map for the West Java region shows heterogeneous seismic hazard characteristics influenced by two main earthquake sources, as presented in Figure 3. The spatial distribution of ground acceleration exhibits significant variation across the study area. The absolute maximum PGA value reaches 0.46 g, triggered by a local shallow earthquake with a magnitude of M 5.8 that occurred on 11 October 2020, with an epicenter located at approximately 108° E and 6.8° S. The concentration of high PGA values in the onshore area reflects the characteristics of shallow crustal earthquakes, which can produce strong ground shaking at local scales despite their relatively moderate magnitudes. From an engineering risk perspective, an absolute maximum PGA of 0.46 g is critical as it can exceed the design basis earthquake standards for typical residential structures, reflecting the massive structural failures seen during recent moderate-magnitude events like the 2022 Cianjur earthquake [3]. The calculated PGA values in these areas often pose a higher immediate threat to urban centers compared to distant megathrust events, as reflected in the recent seismic hazard assessments for Java Island [16].

Meanwhile, the high-hazard zone extending along the southern coast of West Java is controlled by a deterministic worst-case scenario of a Megathrust earthquake with a Maximum Credible Earthquake (MCE) magnitude of M 8.7, modeled at a potential source coordinate of 104.2° E and 7.8° S. The accumulation of PGA contours in this southern region confirms the significant hazard potential associated with the Sunda subduction zone [17]. These results emphasize that seismic risk in West Java is governed by two distinct sources: local shallow crustal earthquakes on land and subduction earthquakes originating from the Megathrust zone.

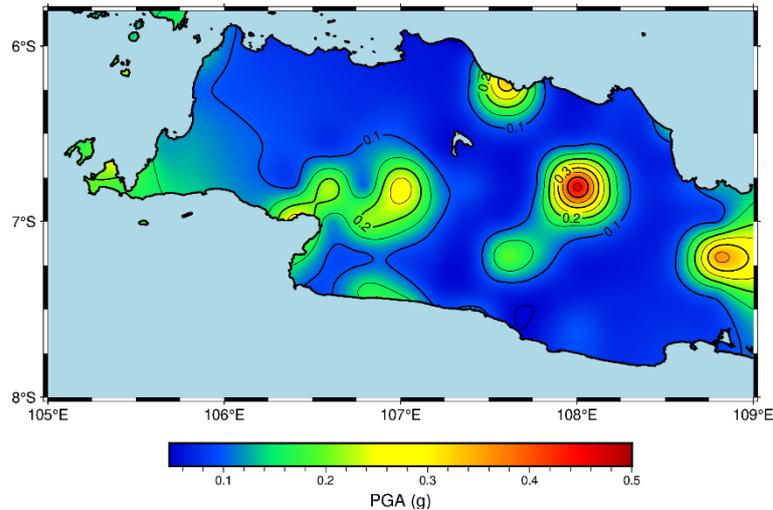


Fig. 3 PGA Hazard Map

The results of the DSHA analysis indicate a bimodal seismic hazard characteristic in the West Java region. The effect of distance is clearly illustrated in Figure 4, where despite the Megathrust earthquake releasing very large amounts of energy (M 8.7), its ground-shaking impact weakens toward inland areas due to the relatively large distance between the earthquake source and population centers in the northern part of the region. This attenuation phenomenon is consistent with the inverse square law in attenuation models, in which seismic energy decreases with increasing wave propagation distance [18].

In contrast, the smaller-magnitude shallow local earthquake (M 5.8) dominates by producing an absolute maximum ground acceleration of 0.46 g in inland areas, primarily due to its proximity to the surface or very shallow hypocentral depth. This finding indicates that shallow crustal faults pose a more direct and potentially more hazardous ground-shaking threat to inland urban areas compared to distant subduction sources [7]. The implications of the results shown in Figure 4 suggest that building and infrastructure planning in West Java should not only consider the potential impact of Megathrust earthquakes, but must also pay close attention to active onshore faults, which often have shorter recurrence intervals and highly destructive local effects [2].

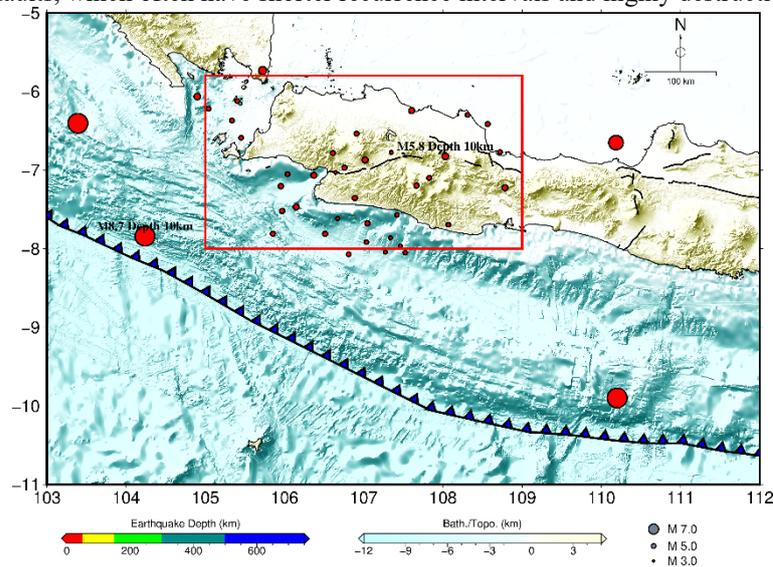


Fig. 4 Map of Maximum Credible Earthquake (MCE)

#### 4. CONCLUSION

This study successfully maps the potential ground-shaking hazard in West Java using the Deterministic Seismic Hazard Analysis (DSHA) approach based on the latest earthquake catalog for the 2018–2024 period. The analysis results indicate that the West Java region exhibits bimodal seismic hazard characteristics, influenced by the Sunda Megathrust subduction zone in the southern part of the region and active onshore fault systems inland. Although the Megathrust source has the potential to generate much larger

magnitudes, reaching up to M 8.7, the resulting ground acceleration tends to attenuate as it propagates toward inland areas due to the large hypocentral distances involved.

The main findings show that the absolute maximum Peak Ground Acceleration (PGA) of 0.46 g is instead triggered by a moderate-magnitude shallow crustal earthquake (M 5.8). This result emphasizes that the proximity of the seismic source to the ground surface plays a more dominant role in producing destructive ground shaking than a large earthquake magnitude originating from a distant source. Consequently, the hazard map produced in this study provides an important warning that inland and urban areas in West Java are subject to high risk from local ground shaking generated by active fault systems distributed across the region.

The resulting PGA hazard map is expected to serve as a technical reference for infrastructure planning and the updating of earthquake-resistant building standards in West Java Province. The integration of recent seismicity data with the Milne attenuation model provides a more realistic worst-case scenario for targeted disaster mitigation efforts. Risk-based spatial planning should therefore prioritize structural reinforcement in areas with high PGA values to minimize potential losses in the future. The results of this DSHA mapping provide a technical basis for updating local building codes and align with the national efforts to develop the latest Indonesian Seismic Hazard Maps for better disaster mitigation [19].

## REFERENCE

- [1] PuSGeN, *Buku Peta Sumber dan Bahaya Gempa Indonesia Tahun 2024*. Jakarta: Kementerian Pekerjaan Umum, 2024.
- [2] Z. Zulfakriza et al., "Seismic source analysis of the destructive earthquake Cianjur ( Indonesia ) from relocated aftershock Seismic source analysis of the destructive earthquake aftershock," *Sci. Rep.*, vol. 14, no. 1, p. 12142, 2024.
- [3] P. Supendi et al., "Analisis Gempabumi Cianjur (Jawa Barat) Mw 5.6 Tanggal 21 November 2022," *Badan Meteorologi, Klimatologi, dan Geofis.*, pp. 1–4, 2022.
- [4] P. Supendi and R. Purbayan, "Analysis of Local Active Faults in Western Java from Hypocenter Relocation Using BMKG Data," vol. 21, no. 01, pp. 2016–2018, 2023.
- [5] N. Sari, M. S. Rosida, and T. Anggonob, "Double Difference Hypocenter Relocation and Velocity Model Determination in Western Java 2010 - 2024 for Fault Identificat," *Positron*, vol. 15, no. 01, pp. 81–93, 2025, doi: 10.26418/positron.v15i1.91097.
- [6] R. Tauhidur and R. L. Chhangte, "Estimation of Peak Ground Acceleration ( PGA ) and Spectral Acceleration ( Sa ) Vertical Component for Interface Subduction Zone Earthquakes of Northeast India (NEI) and Adjacent Regions," *Res. Sq.*, 2021.
- [7] J. Nugraha, G. Pasau, B. Sunardi, and S. Widiyantoro, "Analisis Hazard Gempa dan Isoseismal untuk Wilayah Jawa–Bali–NTB," *J. Meteorol. dan Geofis.*, vol. 15, no. 1, pp. 1–11, 2014.
- [8] G. Aglia, M. Wijaya, and P. P. Rahardjo, "The Study of Seismic Hazard in Near-Fault Areas Using Probabilistic and Deterministic Approach," *J. Civ. Eng. Forum*, vol. 9, no. 2, pp. 117–126, 2023, doi: 10.22146/jcef.5469.
- [9] W. E. Prasetyo, L. Y. Irawan, R. Hartono, and E. Budi, "Seismic hazard analysis using Deterministic Seismic Hazard Analysis ( DSHA ) Method : A case study in Southern Malang District , East Java," *J. Pendidik. Geogr.*, vol. 28, no. 2, pp. 209–227, 2023, doi: 10.17977/um017v28i22023p209-227.
- [10] P. Supendi, A. D. Nugraha, N. T. Puspito, S. Widiyantoro, and D. Daryono, "Identification of active faults in West Java , Indonesia , based on earthquake hypocenter determination , relocation , and focal mechanism analysis," *Geosci. Lett.*, vol. 31, pp. 4–10, 2018, doi: 10.1186/s40562-018-0130-y.
- [11] R. Silvianis and L. Dwiridal, "Estimation of Earthquake Intensity and Peak Ground Acceleration in West Java Using the MC Guire and the Lin & Lee Method," *KAPPA J.*, vol. 8, no. 3, pp. 331–337, 2024.
- [12] P. Supendi, A. Muhari, and N. Rawlinson, "Potential megathrust earthquakes and tsunamis off the southern coast of West Java , Indonesia," *Res. Sq.*, pp. 1–9, 2020.
- [13] J. Douglas, *Ground Motion Prediction Equations*. 2022.
- [14] S. L. Kramer, *Geotechnical Earthquake Engineering*. Upper Saddle River, New Jersey: Prentice Hall, 1996.
- [15] P. Wessel et al., "The Generic Mapping Tools Version 6," *Geochemistry, Geophys. Geosystems*, vol. 20, no. 11, pp. 5556–5565, 2019, doi: 10.1029/2019GC008515.
- [16] M. Irsyam, M. Asrurifak, Hendriyawan, B. Budiono, W. Triyoso, and A. Firmanti, "Development of spectral hazard maps for a proposed revision of the Indonesian Seismic Building Code," *Geomech. Geoenjin.*, vol. 5, no. 1, pp. 35–47, 2010, doi: 10.1080/17486020903452725.
- [17] PuSGeN, *Pusat Studi Gempa Nasional (Indonesia) Pusat Penelitian dan Pengembangan Perumahan dan Permukiman (Indonesia)*. 2017.
- [18] J. Douglas, "Ground-motion prediction equations 1964–2010," Berkeley: Pacific Earthquake Engineering Research Center, 2011.
- [19] M. Irsyam et al., "Development of the 2017 national seismic hazard maps of Indonesia," *Earthq. Spectra*, vol. 36, no. 1, pp. 112–136, 2020, doi: 10.1177/8755293020951206.