



Preliminary Seismic Hazard and Exposure Assessment of the Lombok Strait Strike-Slip Faults: A Comparative Analysis of the Mw 7.5 Southern and Mw 7.6 Northern Segments in Lombok Island

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Abstract: Lombok Island is situated within a complex tectonic environment shaped by subduction, back-arc thrusting, strike-slip faulting, and heterogeneous crustal structures. Despite this complexity, the ground-motion and population-exposure implications of the offshore Lombok Strait Strike-Slip Faults remain relatively understudied. This study presents a preliminary assessment of seismic hazard and population exposure associated with two offshore strike-slip fault scenarios derived from the 2024 Indonesian seismic-source framework (PuSGeN): an Mw 7.6 northern-segment scenario and an Mw 7.5 southern-segment scenario. Using the OpenQuake Engine and the Boore et al. (2014) ground-motion prediction equation, the study estimates Peak Ground Acceleration (PGA) and Modified Mercalli Intensity (MMI), which are spatially overlaid with high-resolution WorldPop 2026 population estimates to quantify and characterize population exposure across Lombok. The results indicate substantial differences in regional hazard severity and population exposure. The Mw 7.5 scenario yields a maximum PGA of 0.14g, with 99.3% of the population of Lombok experiencing light to moderate shaking (MMI IV-V). In contrast, the Mw 7.6 scenario produces PGA values up to 0.59g (MMI VIII) in Central Sekotong, exposing approximately 2.64 million people (65.65% of the total population) to strong, very strong, or severe shaking (MMI VI-VIII). Additionally, a transect line analysis identified significant spatial ground-motion amplification attributable to local geological site conditions. Ground motion increased by up to 19.83% in Mataram City and by 23.56% near Tanjung based on the Mw 7.6 scenario. These findings complement existing research on the Flores Back-Arc Thrust and other regional earthquake sources nearby Lombok, offering initial insights into the significance of oceanic strike-slip faulting for future earthquake hazard and risk assessment throughout the island.

Keywords: Seismic Hazard and Exposure Assessment; Lombok Strait Strike Slip Faults; Oceanic Strike-Slip Faulting; Ground-Motion Amplification

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Introduction

Lombok Island is situated within the complex eastern Sunda–Banda arc, where multiple active tectonic systems interact across a limited geographic area. To the south, the Indo-Australian Plate converges with the Sunda/Eurasian domain along the Sunda–Banda

subduction system, while the northern part is affected by the Flores Back-Arc Thrust. The island is bordered by significant strike-slip structures in the Lombok Strait to the west and the Sumbawa Strait to the east, and volcanic systems such as Rinjani are superimposed on this tectonic setting. Recent seismic tomography and

geophysical investigations highlight that the Sunda-Banda transition involves intricate interactions among subduction, arc-continent convergence, crustal deformation, and volcanism (Hasanah et al., 2024; Andikagumi & Bradley, 2024; Shah et al., 2024). The most recent national seismic-source framework, Peta Sumber dan Bahaya Gempa Indonesia Tahun 2024 (PuSGeN), reflects this complexity through significant updates to fault geometry, segmentation, slip rates, maximum magnitudes, and the inclusion of offshore earthquake sources. The 2024 model identifies 401 earthquake sources, incorporates additional active sources, and updates rupture scenarios, thereby providing the current national framework for seismic-source characterization in Indonesia (PuSGeN, 2024). Consequently, the seismic environment around Lombok cannot be characterized by a single dominant earthquake mechanism but instead consists of interacting subduction, back-arc thrust, strike-slip, and other crustal and offshore sources.

Within this context, offshore strike-slip systems need particular attention because significant earthquakes can occur within oceanic lithosphere, distant from conventional subduction interfaces. Research on oceanic intraplate deformation indicates that inherited fracture zones and other lithospheric weaknesses may be reactivated under evolving regional stress fields, resulting in substantial strike-slip earthquakes. For instance, in the eastern Indian Ocean, deformation within the Wharton Basin is distributed across a network of strike-slip and reverse faults, rather than being limited to a single plate boundary (Stevens et al., 2020; Coudurier-Curveur et al., 2020). Recent ocean-bottom seismic deployments in the Pacific further demonstrate that earthquakes can be spatially associated with pre-existing seafloor structures, such as fracture zones, seamounts, and other lithospheric heterogeneities (Park et al., 2024). Additionally, strike-slip seismicity along the Andaman-Sumatra system suggests that the reactivation of inherited oceanic fracture zones can significantly contribute to earthquake generation, with variations in lithospheric age and mechanical structure influencing seismic behavior (Jacob et al., 2021). These findings are pertinent to Lombok, as the Lombok Strait Strike-Slip Fault is identified as an offshore strike-slip source in the national seismic-source model. While the presence of an offshore source in a tectonically complex region does not alone determine its earthquake recurrence or rupture behavior, it provides a scientific foundation for assessing the ground-motion implications of credible scenario earthquakes.

The variability of earthquake sources around Lombok is evident from the 2018 earthquake sequence, which was primarily associated with the Flores Back-Arc Thrust system. Relocated seismicity, marine seismic

reflection, seismicity, and InSAR observations indicate that the sequence involved distinct rupture regions and shallow thrust structures beneath and adjacent to northern Lombok (Supendi et al., 2020; Yang et al., 2020; Salman et al., 2020). Subsequent local earthquake, and seismic attenuation tomography revealed heterogeneous and fractured crustal structures (Afif et al., 2021; Sarjan et al., 2021; Priyono et al., 2021). These findings demonstrate that Lombok's seismic hazard is influenced by complex fault geometry, segmentation, heterogeneous crustal structure, and spatial variations in near-surface site response (Santoso et al., 2026).

The 2018 sequence also demonstrates the potential for strong shaking to affect densely populated areas. USGS PAGER estimated that approximately 3.5 million people were exposed to Modified Mercalli Intensity VI or greater during the 5 August 2018 Mw 6.9 earthquake (USGS, 2018). Although this estimate relates to a specific historical event and is not directly representative of the scenarios examined here, it highlights the importance of integrating spatial ground-motion characterization with population exposure data (Petersen et al., 2024). Accordingly, this study focuses on earthquake hazard and population exposure, without estimating vulnerability, damage, casualties, or economic losses.

Although significant advances have been made in understanding Lombok's regional tectonics and the 2018 earthquake sequence, the ground-motion and population-exposure implications of the Lombok Strait Strike-Slip Faults remain relatively understudied. Previous research has focused primarily on the Flores Back-Arc Thrust, the 2018 earthquake sequence, crustal structure, deformation, and site response, whereas the offshore strike-slip system west of Lombok has received limited attention in scenario-based ground-motion analyses. This research gap is particularly pertinent given the updated PuSGeN seismic-source framework, which explicitly includes offshore active faults and revised source parameters.

Therefore, this study adopts the two principal Lombok Strait Strike-Slip Fault scenarios from the source framework, shown in Figure 1: an Mw 7.6 northern segment scenario and an Mw 7.5 southern segment scenario. These magnitudes are considered solely as adopted maximum-credible-earthquake scenario magnitudes, not as predictions, forecasts, or statements regarding earthquake probability or imminence. The intent is to provide physically defined earthquake scenarios for comparing the spatial distribution of ground motion and associated population exposure. This study therefore provides a preliminary comparative assessment of the two Lombok Strait Strike-Slip Fault scenarios. The objectives are to characterize the ground-motion hazard associated with

the Mw 7.6 northern-segment and Mw 7.5 southern-segment scenarios, map their respective spatial hazard distributions, quantify and spatially analyze population exposure, and compare the resulting patterns between the two sources. By focusing on these offshore strike-slip scenarios, the study complements existing research on the Flores Back-Arc Thrust and other regional earthquake sources, offering initial insights into the significance of oceanic strike-slip faulting for earthquake

hazard assessment in Lombok. The assessment is deliberately restricted to earthquake ground motion and population exposure; it does not address earthquake probability, recurrence, temporal prediction, structural vulnerability, economic losses, casualties, or fatalities. Accordingly, the results should be interpreted as a scenario-based preliminary hazard and exposure assessment, not as a comprehensive seismic-risk assessment or earthquake forecast.

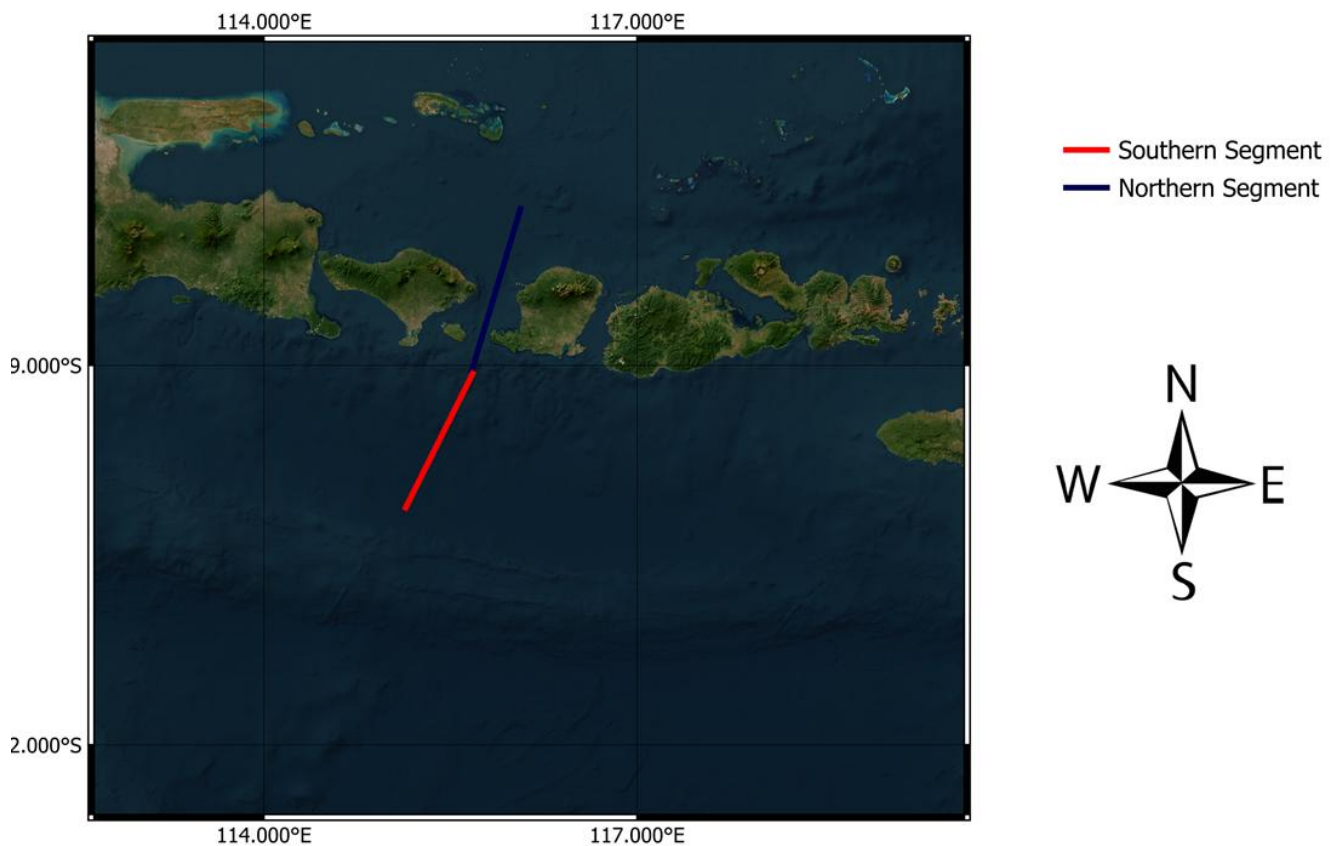


Figure 1. Lombok Strait Strike Slip Fault Location and Its Segmentation

Method

The methodological framework was developed as a scenario-based seismic hazard and population-exposure assessment of the two Lombok Strait Strike-Slip Fault segments. The workflow consists of four principal stages: (1) data preprocessing, (2) seismic hazard processing using the OpenQuake Engine, (3)

raster-based post-processing, and (4) spatial hazard and exposure analysis.

The analysis was conducted separately for the Mw 7.6 North Lombok Strait Strike-Slip Fault scenario and the Mw 7.5 South Lombok Strait Strike-Slip Fault scenario. The details of workflow can be seen in Figure 2.

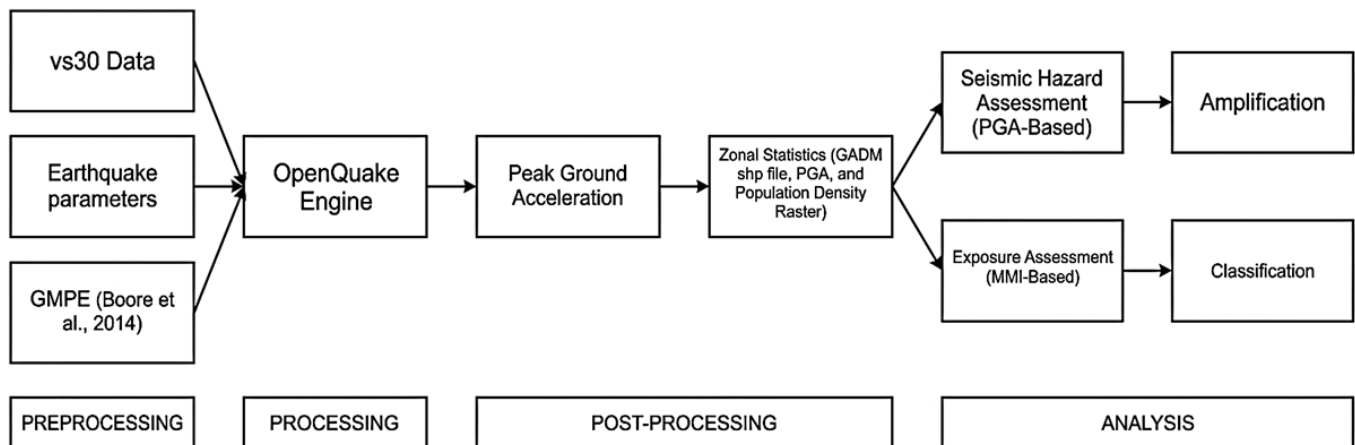


Figure 2. Methodology

Data Preprocessing

Vs30 Data for Site Response Analysis

Regional near-surface site conditions were represented using the Vs30 (time-averaged shear-wave velocity in the upper 30 m) dataset obtained from the United States Geological Survey (USGS) Vs30 mosaic (USGS, n.d.). The original dataset has a spatial resolution of 30 arc-seconds, corresponding to approximately 900 m at the equator. The Vs30 data were processed and resampled to a common 1×1 km assessment grid to provide spatially consistent site-condition information for the subsequent ground-motion assessment.

The Vs30 dataset was used to represent spatial variations in near-surface ground conditions and to account for the potential influence of site characteristics on predicted ground motion. The resulting 1-km grid was spatially aligned with the assessment domain and subsequently used in the post-processing and site-response analysis.

Earthquake Source Parameters

The detail for earthquake sources parameter can be seen in Table 1

Table 1. Earthquakes Parameter

Parameter	Scenario 1	Scenario 2
Scenario	Mw 7.6	Mw 7.5
magnitude		
Fault segment	Northern	Southern
Point 1	7.7708° S, 116.1506° E	10.2621° S, 115.1762° E
Point 2	9.1126° S, 115.7066° E	9.1729° S, 115.7111° E
Fault length	157 km	134 km
Strike	198.2°	205.9°
Dip angle	90°	90°
Epicenter	9.11° S, 115.70° E	10.26° S, 115.17° E

Distance from Mataram	80 km southwest	212 km southwest
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Two earthquake scenarios representing the Lombok Strait Strike-Slip Fault system were considered. The earthquake magnitudes and source representations were adopted from the 2024 Indonesian seismic-source framework (PuSGeN, 2024). The two scenarios were analysed independently to facilitate direct comparison of their resulting ground-motion patterns and population exposure. A 7 km upper seismogenic depth and 22 km lower seismogenic depth were adopted for the earthquake sources. The lower seismogenic depth was based on the recent assessment of the regional seismogenic structure by Jiao et al. (2026). Accordingly, the modeled seismogenic thickness was 15 km.

GMPE Selection

The Boore et al. (2014) Ground Motion Prediction Equation (GMPE) calculates the Peak Ground Acceleration (PGA) by setting the spectral period to $T = 0$ seconds, yielding intensity values expressed in units of gravity (g). The natural logarithm of the ground motion intensity ($\ln \ln Y$) is modeled through the baseline equation:

$$\ln Y = F_E(M, mech) + F_p(R_{JB}, M, region) + F_s(V_{S30}, R_{JB}, M, z_1) + \epsilon_n \sigma(V_{S30}, R_{JB}, M).$$

This equation combines distinct functions for the source mechanism (F_E), source distance (F_p), site conditions (F_s), and a combined standard deviation/uncertainty term ($\epsilon_n \sigma$). This GMPE is the suitable baseline for calculating PGA attenuation for strike slip fault mechanism in Indonesia (PuSGeN, 2024)

The details of GMPE parameters can be seen in Table 2.

Table 2. Boore et al. (2014) GMPE Coefficients and Variables

Baseline Equation (PGA Baseline Coefficients ($T = 0$ s))		
$\ln Y = F_E(M, mech) + F_p(R_{JB}, M, region)$ $+ F_S(V_{S30}, R_{JB}, M, z1)$ $+ \varepsilon_n \sigma(V_{S30}, R_{JB}, M)$		
Source Mechanism Function (F_E)		
$F_E(M, mech) = e_0 U + e_1 SS + e_2 NS + e_3 RS$ $+ e_6 (M - M_h)$		
With		
$e_0: 0.4473$ $e_1: 0.4856$ $e_2: 0.2459$ $e_3: 0.4539$ $e_4: 1.431$ $e_5: 0.05053$ $e_6: -0.1662$		
Path and Distance Function (F_p)		
$F_p(R_{JB}, M, region)$ $= [c_1 + c_2 (M - M_{ref})] \ln\left(\frac{R}{R_{ref}}\right)$ $+ (c_3 - \Delta c_3) (R - R_{ref})$		
Total distance (R) is calculated as: $R = \sqrt{(R_{JB}^2 + h^2)}$		
With		
$M_h: 5.5$ $c_1: -1.134$ $c_2: 0.1917$ $c_3: -0.00809$ $M_{ref}: 4.5$ $R_{ref}: 1$ km $h: 4.5$ km Δc_3 (Global CATW): 0		
Site Condition Function (F_S)		
$F_S(V_{S30}, R_{JB}, M, z1)$ $= \ln(F_{LIN}) + \ln(F_{NL})$ $+ F_{\delta z1}(\delta z1)$		
Linear	Component	(if $V_{S30} \leq V_c$): $\ln(F_{LIN}) = c * \ln\left(\frac{V_{S30}}{V_{ref}}\right)$
Linear	Component	(if $V_{S30} \geq V_c$): $\ln(F_{LIN}) = c * \ln\left(\frac{V_c}{V_{ref}}\right)$
Non-Linear	Component:	$\ln(F_{NL}) = f_1 + f_2 \ln\left(\frac{(PGA_r + f_3)}{f_3}\right)$
$f_2 = f_4 [\exp\{f_5 (\min(V_{S30}, 760) - 360)\} + \exp\{f_5 (760 - 360)\}]$		

Basin Depth Effect ($F_{\delta z1}$): For PGA ($T = 0$), because $T < 0.65$, $F_{\delta z1}(\delta z1) = 0$

With

$c: -0.6$

$V_c: 1500$ m/s

$V_{ref}: 760$ m/s

$f_1: 0$

$f_3: 0.1$

$f_4: -0.15$

Standard Deviation and Uncertainty ($\varepsilon_n \sigma$)

$$\varepsilon_n \sigma(V_{S30}, R_{JB}, M) = \sqrt{[\varphi^2(V_{S30}, R_{JB}, M) + \tau^2(M)]}$$

Inter-event Uncertainty (τ):For $M > 5.5$: $\tau(M) = \tau_2$ Intra-event Uncertainty Magnitude Dependency ($\varphi(M)$):For $M \geq 5.5$: $\varphi(M) = \varphi_2$ Intra-event Uncertainty Distance Dependency ($\varphi(R_{JB}, M)$):For $R_{JB} \leq R_1$: $\varphi(R_{JB}, M) = \varphi(M)$ For $R_1 < R_{JB} \leq R_2$: $\varphi(R_{JB}, M) =$

$$\varphi(M) - \Delta\varphi_R \left[\frac{\ln\left(\frac{R_{JB}}{R_1}\right)}{\ln\left(\frac{R_2}{R_1}\right)} \right]$$

For $R_{JB} \geq R_2$: $\varphi(R_{JB}, M) =$

$$\varphi(M) - \Delta\varphi_R$$

With

 $R_1: 110$ km $R_2: 270$ km $\Delta\varphi_R: 0.07$ $\Delta\varphi_V: 0.1$ $V_1: 225$ m/s $V_2: 300$ m/s $\varphi_1: 0.695$ $\varphi_2: 0.495$ $\tau_1: 0.398$ $\tau_2: 0.348$ **Data Processing**

In this step, the earthquake-source parameters, Vs30 information, and selected ground-motion prediction relationship in Table 2 were incorporated into the OpenQuake Engine, an open-source engine developed by Silva et al. (2014), to calculate scenario earthquake ground motion. The calculation was performed independently for the Mw 7.6 northern-segment and Mw 7.5 southern-segment scenarios.

A regional spatial grid was established across the study area to calculate Peak Ground Acceleration (PGA) at individual assessment locations. Each grid location represents a potential observation point at which the expected ground motion from the specified earthquake scenario was calculated.

The resulting PGA values provide the primary measure of seismic ground-motion hazard used in the subsequent spatial analysis. The same computational framework was applied to both earthquake scenarios to maintain consistency and facilitate direct comparison.

Data Post Processing

Conversion of OpenQuake Results to a Spatial Raster

The PGA results generated by the OpenQuake Engine were converted into a spatially referenced raster dataset for subsequent geographic analysis. The calculated PGA values were assigned to a regular 1×1 km grid, with each raster cell representing the calculated PGA at the corresponding assessment location. This raster format enabled the integration of the OpenQuake results with administrative boundaries (GADM, n.d.) and population datasets. The resulting PGA raster was produced separately for the Mw 7.6 northern and Mw 7.5 southern fault scenarios.

Zonal Statistics

Zonal statistical analysis was subsequently performed using administrative subdistrict boundaries as spatial zones. The PGA raster was overlaid with the administrative boundaries to derive summary ground-motion statistics for each subdistrict. For each subdistrict, the maximum and minimum PGA values were extracted from the intersecting 1×1 km grid cells. These statistics were used to characterize the spatial variability of scenario ground motion within each administrative unit and to facilitate comparison between the two earthquake scenarios. The zonal analysis also provided a spatial framework for linking the predicted ground-motion levels with the population distribution.

Population Exposure Assessment

Population Data

Population exposure was assessed using the 2026 WorldPop estimated population raster dataset, which provides gridded estimates of population distribution. The WorldPop dataset used in this study has a spatial resolution of 100 m, allowing the population distribution to be represented at substantially finer spatial resolution than the 1-km PGA assessment grid. For the study area, Lombok Island, the WorldPop dataset indicates an estimated population of approximately 4.02 million people.

The population raster was spatially integrated with the earthquake ground-motion results to identify the population located within areas affected by different levels of scenario ground motion. The population dataset was subsequently aggregated according to the ground-motion classification derived from the PGA results. This approach allowed population exposure to be quantified spatially rather than assuming that

population was uniformly distributed across administrative areas.

PGA-to-MMI Conversion and Exposure Classification

To facilitate interpretation of the ground-motion results in terms of potential shaking intensity, the calculated PGA values were converted to corresponding Modified Mercalli Intensity (MMI) classes using an established PGA-MMI relationship from Worden et al. (2012). The resulting MMI categories represent the approximate shaking intensity associated with the modeled PGA values. The MMI-classified raster was then overlaid with the WorldPop population raster. Population cells intersecting each MMI class were aggregated to estimate the number of people potentially exposed to each level of earthquake shaking. This analysis was performed independently for the Mw 7.6 northern and Mw 7.5 southern earthquake scenarios. The resulting population-exposure estimates provide a basis for determining how differences in fault location, geometry, and magnitude influence the spatial distribution of potentially affected populations.

Spatial Hazard and Exposure Analysis

The final analysis consisted of two complementary components: seismic hazard characterization and population exposure assessment.

For seismic hazard, the spatial distribution of PGA was examined to identify areas of relatively higher and lower modeled ground motion. Maximum PGA values within each subdistrict were extracted using zonal statistics, allowing the spatial variability of ground motion to be summarized at the administrative level. In addition, amplification for M 7.6 scenario were analyzed using parallel lines, 25 km relative to the M 7.6 faultline. The amplified PGA values will be compared with the corresponding PGA values along the same transect under a reference Vs30 value of 760 m/s. This reference condition represents a relatively stiff site condition and provides a consistent baseline for evaluating the influence of spatial variations in Vs30 on the resulting ground-motion estimates. The comparison therefore allows the degree of PGA amplification or attenuation associated with local site conditions to be quantified while keeping the earthquake-source and geometric conditions consistent.

For exposure, the PGA-derived MMI classes were spatially intersected with the WorldPop 2026 population distribution estimation by Bondarenko et al. (2025). The population within each MMI category was then calculated to determine the number and spatial distribution of people potentially exposed to different levels of scenario shaking. The two scenarios were compared in terms of:

1. Spatial PGA Distribution;

2. Maximum PGA Within Administrative Subdistricts;
3. Spatial Distribution Of MMI Classes;
4. Population Exposed To Each MMI Category

Overall, the assessment represents a scenario-based seismic hazard and population-exposure analysis. It does not estimate earthquake occurrence probability, recurrence intervals, vulnerability, structural damage, economic losses, casualties, or fatalities. Consequently, the resulting exposure estimates should not be interpreted as estimates of seismic risk or expected losses, but rather as an assessment of the population located within the modeled ground-motion environment of the two specified earthquake scenarios.

Limitations

This study is confined to assessing seismic hazard, specifically ground motion, and the spatial distribution of population exposure related to the selected earthquake scenarios. It does not evaluate structural vulnerability, potential structural damage, economic losses, casualties, or fatalities. Consequently, population exposure should not be regarded as a direct indicator of seismic risk, since exposure alone does not incorporate the vulnerability or adaptive capacity of the affected population and built environment. The results therefore

provide a preliminary evaluation of the spatial distribution of ground-motion hazard and population exposure, rather than a comprehensive seismic risk assessment or a forecast of potential losses.

Additionally, this research utilizes a scenario-based methodology and does not serve as an earthquake forecast. The earthquake magnitudes of Mw 7.5 and Mw 7.6 are used exclusively as physically defined maximum credible earthquake scenarios for ground-motion modeling. These scenarios are designed to explore potential spatial variations in seismic hazard under specified source conditions and should not be construed as predictions that earthquakes of these magnitudes will occur. The study does not evaluate earthquake occurrence probabilities, recurrence intervals, or the likelihood or imminence of either scenario.

Result and Discussion

The analysis reveals a significant difference in ground-motion intensity and population exposure between the M7.5 southern segment and M7.6 northern segment scenarios. The M7.6 scenario generates substantially stronger shaking across Lombok, especially in the western and northern regions, while the M7.5 scenario is characterized by moderate to light shaking. The details can be seen in Figure 3 and Table 3.

Table 3. Details of Maximum PGA per Sub-District in Lombok (g)

Regency	Sub-District	Min PGA M76	Max PGA M75	MMI Max M76	MMI Max M75
Central Lombok	Batukliang	0.15	0.07	VI	V
Central Lombok	Central Praya	0.16	0.1	VI	V
Central Lombok	East Praya	0.14	0.09	VI	V
Central Lombok	Janapria	0.14	0.08	VI	V
Central Lombok	Jonggat	0.19	0.1	VI	V
Central Lombok	Kopang	0.14	0.08	VI	V
Central Lombok	North Batukliang	0.15	0.07	VI	V
Central Lombok	Praya	0.16	0.09	VI	V
Central Lombok	Pringgarata	0.19	0.08	VI	V
Central Lombok	Pujut	0.16	0.11	VI	V
Central Lombok	Southwest Praya	0.2	0.12	VI	VI
Central Lombok	West Praya	0.18	0.13	VI	VI
East Lombok	Aikmel	0.1	0.05	V	IV
East Lombok	East Sakra	0.1	0.06	V	IV
East Lombok	Jerowaru	0.12	0.09	VI	V
East Lombok	Keruak	0.11	0.07	V	V
East Lombok	Labuhan Haji	0.09	0.06	V	IV
East Lombok	Masbagik	0.12	0.06	VI	IV
East Lombok	Montong Gading	0.12	0.06	VI	V
East Lombok	Pringgabaya	0.1	0.05	V	IV
East Lombok	Pringgasela	0.11	0.05	V	IV
East Lombok	Sakra	0.11	0.06	V	V
East Lombok	Sambelia	0.12	0.04	VI	IV
East Lombok	Selong	0.11	0.06	V	IV

Regency	Sub-District	Min PGA M76	Max PGA M75	MMI Max M76	MMI Max M75
East Lombok	Semalun	0.13	0.05	VI	IV
East Lombok	Sikur	0.12	0.07	VI	V
East Lombok	Suela	0.08	0.04	V	IV
East Lombok	Sukamulia	0.11	0.06	V	IV
East Lombok	Suralaga	0.1	0.05	V	IV
East Lombok	Terara	0.13	0.07	VI	V
East Lombok	Wanasaba	0.09	0.05	V	IV
East Lombok	West Sakra	0.11	0.06	V	V
Mataram	Ampenan	0.26	0.09	VII	V
Mataram	Cakranegara	0.24	0.09	VII	V
Mataram	Mataram City	0.25	0.1	VII	V
Mataram	Sandubaya	0.23	0.09	VII	V
Mataram	Sekarbela	0.26	0.1	VII	V
Mataram	Selaparang	0.26	0.1	VII	V
North Lombok	Batu Layar	0.29	0.09	VII	V
North Lombok	Bayan	0.17	0.06	VI	IV
North Lombok	Gangga	0.24	0.07	VII	V
North Lombok	Kayangan	0.2	0.05	VI	IV
North Lombok	Pemenang	0.39	0.07	VII	V
North Lombok	Tanjung	0.3	0.07	VII	V
West Lombok	Central Sekotong	0.59	0.14	VIII	VI
West Lombok	Gerung	0.25	0.11	VII	V
West Lombok	Gunung Sari	0.27	0.09	VII	V
West Lombok	Kediri	0.23	0.1	VII	V
West Lombok	Kuripan	0.21	0.1	VI	V
West Lombok	Labu Api	0.25	0.1	VII	V
West Lombok	Lembar	0.24	0.11	VII	V
West Lombok	Lingsar	0.23	0.08	VII	V
West Lombok	Narmada	0.2	0.08	VI	V

Spatial variation of PGA and MMI

For the M7.5 scenario, the maximum PGA among the assessed sub-districts ranges from 0.04 to 0.14g. Most areas experience MMI IV–V, corresponding to light to moderate shaking. However, several western Central Lombok and West Lombok areas reach MMI VI, indicating strong shaking. The highest M7.5 PGA is observed in Central Sekotong (0.14g), followed by West Praya (0.13g) and Southwest Praya (0.12g).

The M7.6 scenario produces substantially higher PGA values, ranging from 0.08 to 0.59g. The strongest value occurs in Central Sekotong (0.59g), followed by Pemenang (0.39g) and Tanjung (0.30g). This corresponds to MMI VIII (severe shaking) in Central Sekotong and MMI VII (very strong shaking) in several areas of Mataram, North Lombok, and West Lombok. Therefore, the M7.6 scenario demonstrates not only a higher maximum ground motion but also a broader spatial distribution of damaging shaking.

Regional pattern

Under the M7.5 scenario, Central Sekotong reaches MMI VI, while other western areas such as

Gerung, Gunung Sari, Kediri, Kuripan, Labu Api, Lembar, Lingsar, and Narmada generally reach MMI V. Under M7.6, however, Central Sekotong increases dramatically to MMI VIII, while most other West Lombok locations reach MMI VI–VII.

The Mataram urban area also exhibits a substantial increase in shaking intensity. This later be explained in the Amplification Factor subchapter. All assessed Mataram sub-districts reach MMI VII (very strong shaking) under the M7.6 scenario, compared to only MMI V (moderate shaking) under M7.5. This finding is significant because Mataram contains a major population concentration, resulting in increased hazard intensity translating into substantially greater population exposure.

North Lombok similarly experiences a pronounced increase in shaking intensity. For instance, Pemenang increases from MMI V under M7.5 to MMI VII under M7.6, while Tanjung also rises from MMI V to VII. These results indicate that the M7.6 scenario has a substantially greater potential to impact communities in the western and northern regions of Lombok.

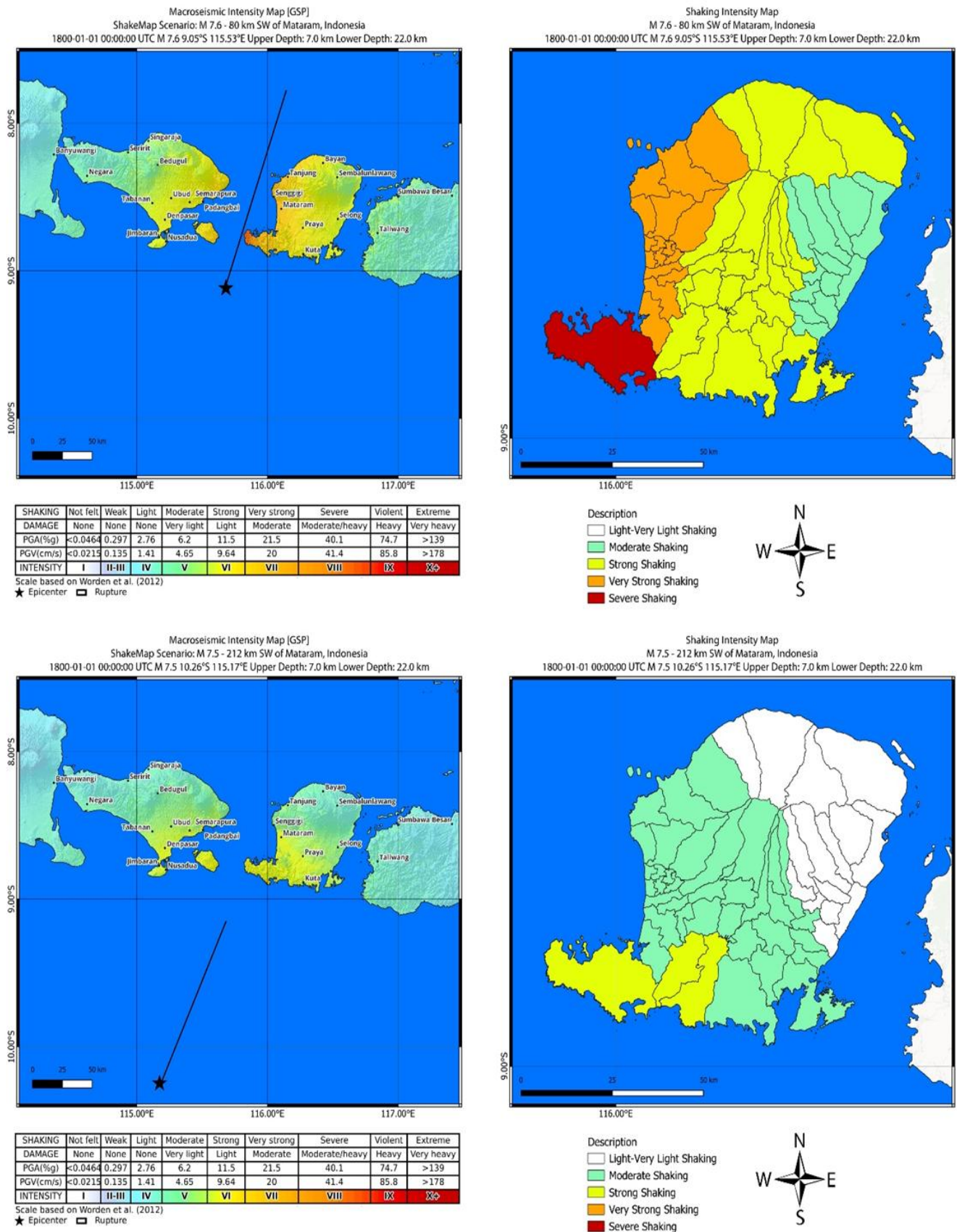


Figure 3. Shaking Interpretation of M 7.6 Scenario (Upper Left), M 7.5 Scenario (Lower Left) and Maximum Shaking per Sub-District for M 7.6 (Upper Right) and M 7.5 (Lower Right)

Population exposure

The population exposure results corroborate the spatial distribution of PGA and MMI. This consistency

is evident in Table 4. The table illustrates the distribution of the exposed population across areas with varying levels of seismic intensity.

Table 4. Estimation of Population Exposure

MMI	Description	Scenario 1	Scenario 2
		M 7.6 Population Exposure	M 7.5 Population Exposure
VIII	Severe Shaking	8,047	0
VII	Very Strong Shaking	1,015,921	0
VI	Strong Shaking	1,616,224	15,601
V	Moderate Shaking	1,380,023	2,361,999
IV	Light Shaking	1,177	1,630,047
III	Very Light Shaking	0	13,745

The total assessed population is approximately 4.02 million people for both scenarios. Under the M7.5 scenario, exposure is concentrated primarily in:

1. MMI V (moderate shaking): 2,361,999 people (58.74%)
2. MMI IV (light shaking): 1,630,047 people (40.53%)
3. MMI VI (strong shaking): 15,601 people (0.39%)
4. MMI III (very light shaking): 13,745 people (0.34%)
5. MMI VII–VIII: 0 people

Therefore, the M7.5 scenario is predominantly characterized by moderate shaking, with approximately 99.3% of the population experiencing MMI IV or V. The M7.6 scenario produces a fundamentally different exposure profile:

1. MMI VI (strong shaking): 1,616,224 people (40.19%)
2. MMI V (moderate shaking): 1,380,023 people (34.32%)
3. MMI VII (very strong shaking): 1,015,921 people (25.26%)
4. MMI VIII (severe shaking): 8,047 people (0.20%)
5. MMI IV (light shaking): 1,177 people (0.03%)

Consequently, approximately 65.65% of the population in the M7.6 scenario is exposed to MMI VI or higher, compared to only 0.39% in the M7.5 scenario. The primary finding is not only that the M7.6 scenario produces a higher PGA than M7.5, but also that the increased magnitude leads to a significant shift in the population exposure distribution. Under M7.5, nearly the entire population remains within the light to moderate shaking classes (MMI IV–V). In contrast, under M7.6, approximately 2.64 million people are exposed to strong, very strong, or severe shaking (MMI VI–VIII).

Table 5. Comparative Interpretation

Scenario		Scenario 1 (M 7.6)	Scenario 2 (M 7.5)
Maximum PGA		0.59 g	0.14 g
Maximum MMI		VIII	VI
Population at MMI VI+	at	2,640,192 (65.65%)	15,601 (0.39%)
Population at MMI VII+	at	1,023,968 (25.46%)	0
Population at MMI VIII	at	8,047 (0.20%)	0
Dominant exposure		MMI VI–VII	MMI V

The M7.6 scenario should be considered the more critical scenario from a population impact perspective. Its effects are especially significant because the strongest shaking coincides with densely populated areas. For example, the Mataram area reaches MMI VII throughout all assessed sub-districts under M7.6. Similarly, parts of West Lombok and North Lombok experience MMI VII or VIII.

The results also demonstrate that earthquake magnitude alone does not adequately describe the spatial consequences of the two scenarios. The combination of source characteristics, distance from the fault, and local site conditions produces considerable spatial variation in PGA and MMI (Baltay et al., 2020; Rezaeian et al., 2024). Central Sekotong is a notable example, with PGA increasing from 0.14g to 0.59 g between the M7.5 and M7.6 scenarios and the corresponding intensity increasing from MMI VI to VIII.

Overall, the comparison indicates that the M7.5 southern-segment scenario is associated primarily with moderate population exposure, while the M7.6 northern-segment scenario constitutes a substantially more severe regional earthquake scenario. The latter is

characterized by widespread strong to very strong shaking and localized severe shaking.

This distinction is crucial for subsequent exposure, vulnerability, and risk assessments, as the M7.6 scenario places a significant proportion of

Lombok's population within shaking levels where structural damage and disruption to critical infrastructure are major concerns.

Amplification Factor

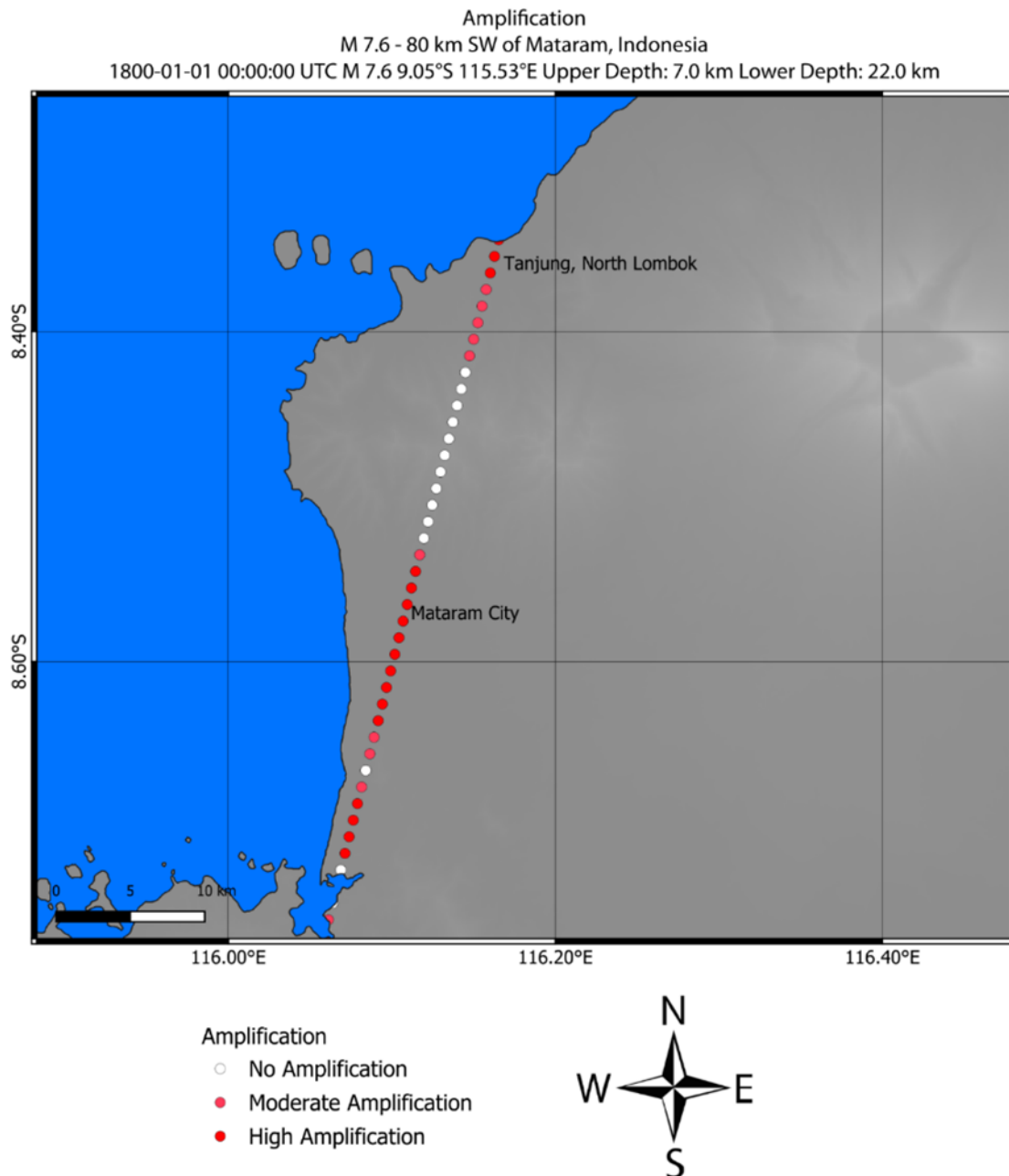


Figure 4. Amplification using Transect Line

A straight-line transect was established 25 km from the modeled fault line to investigate spatial variation in site amplification associated with the M7.6 earthquake scenario. The transect was divided into discrete points to evaluate ground-motion amplification while maintaining a consistent source-to-site distance.

At each point, the amplified PGA was compared with the corresponding PGA calculated using a reference V_{s30} value of 760 m/s to provide a consistent baseline for assessing the effect of local site conditions. This approach facilitates examination of spatial variability in calculated peak ground acceleration (PGA) as a function

of local site-response conditions, rather than differences in fault distance. The value of referenced PGA is 0.208g. The results demonstrate substantial spatial variability in amplification factors along the transect. Calculated amplification values range from approximately -18.87% to +23.56% relative to the transect-average PGA. Negative values indicate locations where estimated ground motion is lower than the average, while positive values represent locations with amplified ground motion. The spatial distribution shows that amplification is not uniform, with several localized zones exhibiting significantly higher ground-motion values. The details can be seen in Table 6 Below.

A prominent amplification zone is identified in Mataram and its surrounding area. Eight points within

this area consistently exhibit positive amplification, ranging from +16.00% to +19.83%. The corresponding PGA values range from approximately 0.241 to 0.249g, compared with the transect-referenced PGA of approximately 0.208g. The maximum amplification in this area is +19.83%, corresponding to a PGA of approximately 0.249g at 116.11°E and 8.55°S. The consistent positive amplification across the Mataram segment indicates that the observed increase represents a broad spatial pattern of enhanced site response, rather than an isolated anomaly.

Amplification decreases outside this zone at subsequent points to the northeast. This transition demonstrates that amplified ground motion around Mataram is spatially concentrated.

Table 6. Amplification

Point	Value (g)	Percent Amplification
Point (116.09 -8.63) Mataram and Its Surrounding	0.246	18.18%
Point (116.10 -8.62) Mataram and Its Surrounding	0.241	16.00%
Point (116.10 -8.61) Mataram and Its Surrounding	0.244	17.22%
Point (116.10 -8.60) Mataram and Its Surrounding	0.246	18.19%
Point (116.10 -8.59) Mataram and Its Surrounding	0.248	18.94%
Point (116.11 -8.58) Mataram and Its Surrounding	0.244	17.21%
Point (116.11 -8.57) Mataram and Its Surrounding	0.246	18.02%
Point (116.11 -8.56) Mataram and Its Surrounding	0.247	18.67%
Point (116.11 -8.55) Mataram and Its Surrounding	0.249	19.83%
Point (116.16 -8.37) Tanjung and Its Surrounding	0.229	10.29%
Point (116.16 -8.36) Tanjung and Its Surrounding	0.240	15.46%
Point (116.16 -8.35) Tanjung and Its Surrounding	0.257	23.56%
Point (116.17 -8.34) Tanjung and Its Surrounding	0.253	21.51%

The second significant amplification zone is observed around Tanjung and its surrounding area. Amplification values in this zone range from +10.29% to +23.56%, with PGA values between approximately 0.229 and 0.257g. Although fewer points were sampled in the Tanjung zone compared to Mataram, the results indicate a distinct localized amplification peak. The maximum amplification at Tanjung exceeds that observed in the Mataram area, suggesting a stronger localized site-response effect. These differences demonstrate that similar earthquake-source distances do not necessarily produce uniform ground-motion levels across the study area. Instead, local site conditions can significantly modify the spatial distribution of PGA (Ramos-Sepulveda et al., 2024).

The overall transect further highlights this spatial variability. The southwestern portion initially exhibits predominantly negative amplification. Amplification increases toward the central portion, reaching positive values before developing into the pronounced Mataram amplification zone. After Mataram, amplification decreases considerably before increasing again toward the Tanjung area. This pattern demonstrates alternating

zones of ground-motion attenuation and amplification along the transect, reflecting the spatial variability of local site response (Fang et al., 2023).

Because the transect was constructed at a consistent 25-km distance from the M7.6 fault, the observed variations cannot be attributed solely to changes in source-to-site distance. The results indicate that spatial differences in local site conditions and corresponding site-response characteristics contribute substantially to the variation in predicted PGA. This finding is particularly relevant for seismic hazard assessment, as areas with similar distances from an earthquake source may experience significantly different ground-motion levels due to local geological and geotechnical conditions.

The amplification results are particularly significant when considered alongside the population exposure analysis. The Mataram area, exhibiting approximately 16–19.83% amplification, coincides with a densely populated urban region. Enhanced site response in this area may contribute to the relatively high seismic intensity and population exposure predicted under the M7.6 scenario. Similarly, the

pronounced amplification around Tanjung, reaching +23.56%, identifies a localized area where ground motion may be substantially greater than the average value along the transect. These findings emphasize that population exposure assessments should account for spatial variations in site response, rather than relying solely on earthquake magnitude or distance from the fault. Thus, these results provide evidence that local site conditions significantly influence the regional distribution of earthquake ground motion and should be incorporated into future assessments of seismic hazard, population exposure, and potential earthquake impacts across Lombok.

Conclusion

In conclusion, this scenario-based assessment shows that the Mw 7.6 northern-segment earthquake presents a significantly greater regional threat to Lombok than the Mw 7.5 southern-segment scenario. The Mw 7.5 event results in moderate or light shaking for nearly the entire assessed population, while the Mw 7.6 scenario exposes over 2.64 million people to strong-severe ground motion (MMI VI to VIII). Spatial analysis indicates that ground-motion severity is not determined solely by earthquake magnitude or fault distance, as local geological conditions can cause substantial localized amplification. In the densely populated Mataram urban area, modeled ground motion is consistently amplified by 16% to 19.83%, increasing the hazard for major population centers. These findings highlight that the offshore oceanic strike-slip faults in the Lombok Strait can generate highly destructive ground motion and extreme population exposure. Their inclusion in future vulnerability, structural damage, and comprehensive risk assessments is essential.

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