MAPPING OF EARTHQUAKE RISK AREAS BASED ON THE PROBABILISTIC SEISMIC HAZARD ANALYSIS (PSHA) METHOD FROM EARTHQUAKE SOURCES ON THE ISLAND OF BALI

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Abstract . because Indonesia is countries between three major plates—the Indo-Australian plate in the south, the Pacific plate in the northeast, and the Eurasian plate in the north—high-intensity earthquakes are common in this region. Indonesia has a high seismicity level both on land and at sea as a result of these three plates coming together. Bali is one of the provinces that is particularly susceptible to earthquakes. Seismic hazards can be used to plan buildings resistant to earthquakes and describe the effects of an earthquake at a location, which can help anticipate community preparedness and efforts to mitigate earthquake disasters. The probabilistic seismic hazard analysis (PSHA) method is used for seismic hazard data processing in this type of descriptive research, which entails obtaining data from the NEIC/USGS earthquake catalogue for the years 1900 through 2015. The earthquake parameters that cause the greatest ground motion serve as the foundation for PSHA. The PGA results got from the Megathrust seismic tremor source peril map for the long-term return time frame went from 0.10 g to 0.30 g and the long-term return time frame went from 0.12 g to 0.45 g. For the PGA results obtained on the source risk guide of the Benioff model for a return time of 500 years, specifically 0.10 g to 0.12 g and for a return time of 2500 years, a worth of 0.12 g to 0.25 g is acquired.

Keywords: Hazard, earthquake, psha.

1 INTRODUCTION

Indonesia is located between the confluence of 3 major plates (oceanic crust and continental crust) namely the Eurasian plate, the Indo-Australian plate and the Pacific plate, as well as the microplate namely the Philippine plate. This results in Indonesia having a high level of seismicity. This condition makes Indonesia highly vulnerable to earthquake hazards. One of the areas in Indonesia that has a high level of earthquake vulnerability is the island of Bali. This is by its tectonic records and conditions, where high earthquake activity has been recorded.

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Earthquake natural disasters cannot be prevented and cannot be predicted accurately in time, place and strength, but the impact of earthquakes can be reduced by mitigation measures. Disasters caused by earthquakes can have direct and indirect impacts. The collapse of buildings, material loss, loss of life and damage are some examples of the direct impacts of earthquakes. In addition, earthquakes can trigger other disasters such as landslides, fires, and industrial and transportation accidents as indirect impacts. This risk will increase if the area affected by the earthquake has a dense population and is also an area undergoing rapid development, such as Bali Island with a population of 4.32 million in 2020 (BPS).

2 RESEARCH METHODOLOGY

The first data processing is earthquake data processing using the PSHA method with the help of Ez Frisk 7.52 software. The data processing using PSHA goes through several stages, namely:

1. Earthquake data

The data used is historical earthquake data for 114 years with coordinates 1° - 14° South Latitude and 102° - 130° East Longitude from various earthquake catalog sources such as USGS, ISC etc. The data used is a maximum depth of 300 km and a magnitude ≥ 5 Mw. This is because the earthquakes that occurred with a depth of more than 300 km and a magnitude of less than 5 MW did not cause serious damage to the surface.

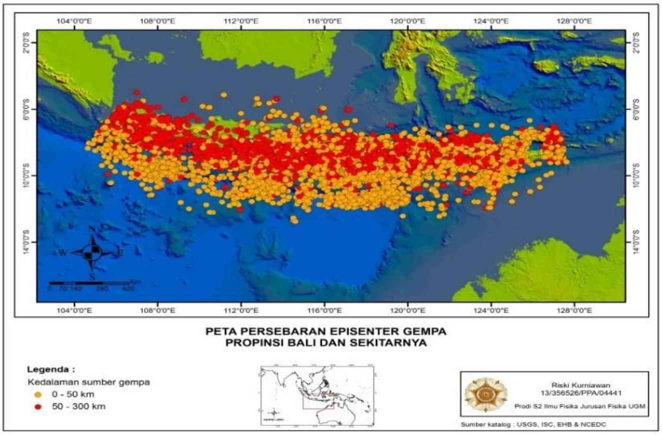

Fig. 1. Map of the distribution of epicenters in the study area.

2. Conversion of the magnitude scale

Earthquake data obtained from various catalog sources obtained various types of magnitude units used, so it is necessary to do a magnitude equalization. All earthquake data are converted to moment magnitude (Mw) because moment magnitude is the best and most consistent earthquake magnitude in showing the magnitude of an earthquake compared to other magnitudes.

Table 1. Correlation of conversions of various magnitudes (Irsyam, et al., 2010)

Korelasi Konversi	Range Data
$M_w = 0{,}85\ m_b + 1{,}03$	$3{,}5 \leq m_b \leq 6{,}2$
$M_w = 0{,}114\ m_b{}^2 - 0{,}556\ m_b + 5{,}560$	$4{,}9 \leq m_b \leq 8{,}2$
$M_w = 0{,}67\ M_s + 2{,}07$	$3{,}0 \leq M_s \leq 6{,}1$
$M_w = 0{,}99\ M_s + 0{,}08$	$6{,}2 \leq M_s \leq 8{,}2$
$m_b = 0{,}125\ M_L{}^2 - 0{,}389\ M_L + 3{,}513$	$3{,}0 < M_L < 6{,}2$
$M_L = 0{,}717\ M_D + 1{,}003$	$\leq M_D \leq 5{,}8$

3. Identification of earthquakes

The data obtained is then carried out in the decluster process (separation of earthquake data between the main earthquake and aftershocks). In the identification of the main earthquake using the help of ZMAP software[13] with the criteria of Gardner and Knopoff (1974)[7] to eliminate beforeshock and aftershock from the earthquake catalog. The results of this processing produce the main earthquake which is presented in Figure 2.

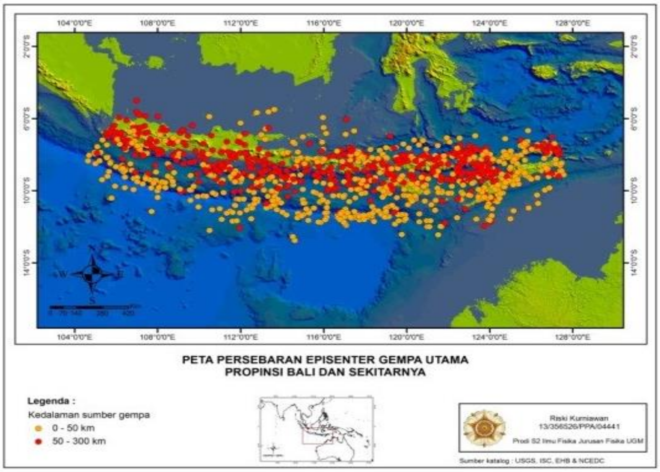

Fig. 2. Map of the distribution of the main earthquake epicenters in the study area.

4. Earthquake Source Modeling

Earthquake sources are classified into 2 types, namely subduction zones and Shallow Crustal zones. The subduction zone is divided into two mechanisms, namely Megathrust (interface) and Benioff (intraslab), then the Shallow Crustal zone is also divided into two, namely Fault and Shallow Background. For an explanation of the earthquake source zone model in this study using subduction earthquake source zones. Subduction earthquake modeling is earthquake modeling based on clearly identified seismic data. Within the subduction earthquake source zone it is divided into two, namely the Megathrust zone and the Benioff zone, namely:

- The source of the Megatrrust earthquake
  Depth limit, in subduction earthquakes with depths between 0-50 km is the Megathrust zone.
- Benioff earthquake source
  The source of the earthquake with a depth of more than 50 km is the Benioff zone. The source of the Benioff earthquake is a continuation of the Megathrust zone

5. Data Completeness Analysis

Completeness analysis is very important for data on earthquake activity. If the completeness of the data for an earthquake event is incomplete, it will cause confusion in the calculation of the seismic hazard parameters in the form of parameters a and b. If the data used is incomplete in the earthquake risk analysis, the results obtained will be underestimated for small earthquakes and will result in overestimation for large earthquakes. Analysis to determine the completeness of an earthquake catalog that is used is quite complete or cannot use the Steep (1973) method

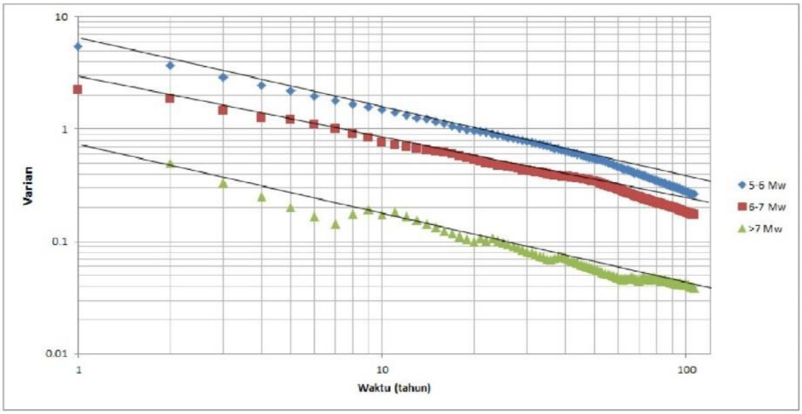

Fig. 3. Graph of completeness analysis of earthquake data in the study area

6. Determination of Parameters a and b

Parameters a and b are the parameters used to predict the maximum value of the earthquake from the earthquake source. This parameter is determined using the maximum likelihood method [1] with the help of ZMAP software.

7. Determination of the attenuation function

The attenuation function is a function that describes the relationship between ground motion intensity (I) and magnitude (M) and distance (R) from a point source within the source area. However, in the Indonesian region there is no data used to derive the attenuation function, so data is needed from other regions that have similar geological and seismotectonic characteristics to the areas to be studied in Indonesia. The attenuation function used in this study is shown in Table 2.

Table 2. Attenuation function for the earthquake source model [2]

Sumber Gempa	Fungsi Atenuasi
Subduksi inter-face (megathrust)	Youngs et al (1997)
	Zhao et al (2006)
	Atkinson-Boore, Worldwide (2003)
Subduksi in-traslab (benioff)	Atkinson-Boore, Worldwide (2003)
	Atkinson-Boore, Cascadia (2003)
	Youngs et al (1997)
Fault & shallow background	Campbell-Bozorgnia, NGA (2008)
	Boore-Atkinson, NGA (2008)
	Chiou-Youngs, NGA (2008)

8. Analisis Seismic Hazard

This theory proposes the assumption of earthquake magnitude M and distance R as continuous independent random variables. Mathematically the general probability theory can be expressed as:

$$P[I \geq i] = \iint_{RM} P[I \geq i[M,R] f_M(M) f_R(R) dMdR] \quad (1)$$

where f_M is the probability function of the magnitude, f_R is the probability function of the hypocentric distance, $P[I \geq i \mid M , R]$ are conditional probabilities of intensity I, at a location that is considered for earthquake events with magnitude M and hypocenter distance R. The analysis process of this processing with the help of EZ-Frisk 7.52 software.

3 RESULT

Data processing in this study uses Ez-Frisk software and produces hazard maps that are differentiated based on earthquake sources, namely Megathrust earthquake sources (interface subduction), Benioff earthquake sources (intraslab subduction), Fault earthquake sources, Shallow Background earthquake sources and combination earthquake sources. (all source) with respective maximum acceleration values in bedrock for return periods of 500 years and 2500 years.

Hazard Map for Megathrust Earthquake Sources.

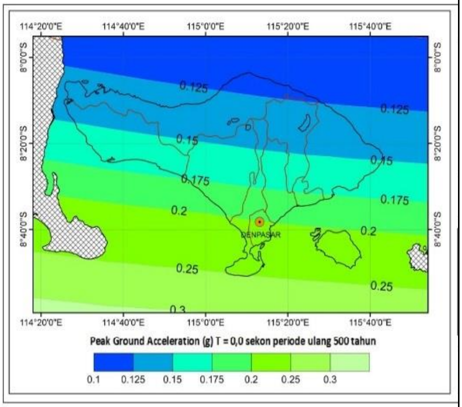

Fig. 4. Megathrust earthquake source hazard map with PGA in bedrock for a return period of 500 years

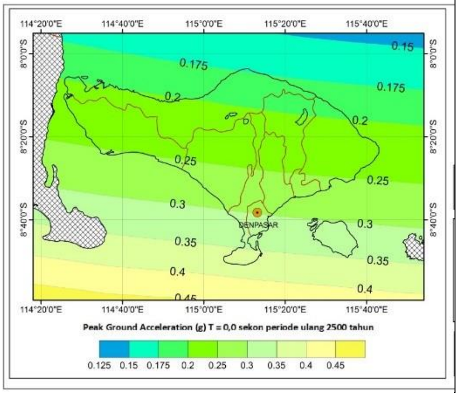

Fig. 5. Hazard map of Megathrust earthquake sources with PGA in bedrock for a return period of 2500 years

Judging from Figure 5.1 and Figure 5.2 which are hazard maps for Megathrust earthquake sources, the highest PGA values are in the southern part of Bali Island, due to the closer distance to the Megathrust zone which is in the south of Bali Island.

Hazard Map for Benioff Earthquake Sources.

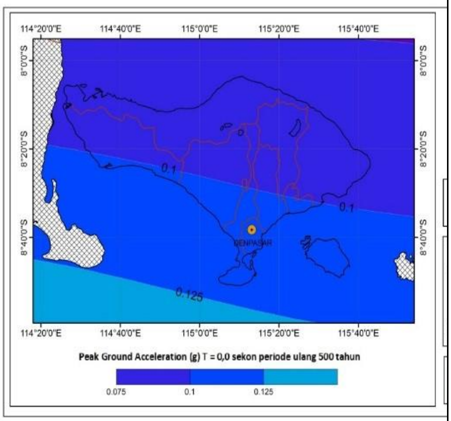

Fig. 6. Source hazard map of the Benioff earthquake with PGA in bedrock for a return period of 500 years.

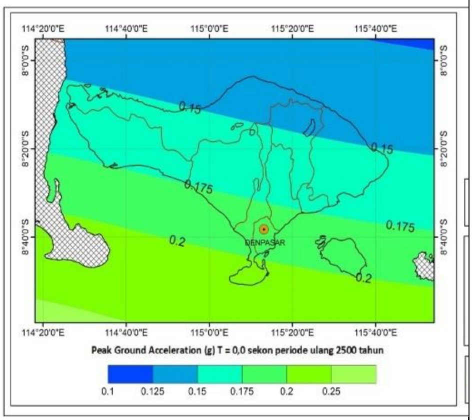

Fig. 7. Source hazard map of the Benioff earthquake with PGA in bedrock for a return period of 2500 years

The high PGA value on the Benioff earthquake source hazard map is found in the southern area of Bali Island, due to the location of the area in the Benioff zone which is shallower than the northern region of Bali Island. In the Benioff earthquake source model the distribution pattern shows the same pattern as the distribution pattern for Megathrust but with a value smaller one. This difference is due to the fact that the Benioff zone is at a depth of 50 km to 300 km compared to the Megathrust zone, where the maximum earthquake occurs at a depth of 50 km.

4 CONCLUSION

Based on the results of research using the probabilistic seismic hazard analysis method at each earthquake source for the area of Bali Island, the conclusions are as follows:

1. PGA results obtained from the hazard map of the Megathrust earthquake source with a return period of 500 years ranging from 0.10 g to 0.30 g and a return period of 2500 years ranging from 0.12 g to 0.45 g.
2. The PGA results obtained on the source hazard map of the Benioff model for a return period of 500 years are 0.10 g to 0.12 g and for a return period of 2500 years a value of 0.12 g to 0.25 g is obtained.

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