Determination Of Earthquake Intensity Based On PGA (Peak Ground Acceleration) Using Multi-Event Earthquake Data

Teguh Hariyanto¹, Filsa Bioesita¹, Cherie Bhekty Pribadi¹, Chomia Nilam Safitri¹
¹Department of Geomatics Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia

Abstract. Pandeglang Regency is located in the southern coast of Java Island which is adjacent to the megathrust subduction zone. This zone originates from the meeting of the Indo-Australian Plate which is subducted under the Eurasian Plate. So that it can cause frequent earthquakes due to the movement of the plunging plates. Other than that, Pandeglang Regency is also bordered by the Sunda Strait in the western part where the region has Mount Krakatau which has the potential to cause earthquakes due to volcanic eruptions. Therefore, it is necessary to identify the level of earthquake hazard in Pandeglang Regency as a first step in disaster mitigation. Determination of earthquake hazard level in the study area is using the method of scoring the earthquake hazard level parameters based on “Peraturan Menteri Pekerjaan Umum No. 21/PRT/M/2007” and using spatial analysis. These parameters are the physical properties of rocks, slope, seismicity (magnitude, peak ground acceleration, and intensity), and the distance of the region to the fault zone. For the calculation of PGA (Peak Ground Acceleration) using the empirical equation from [10] and calculation of earthquake intensity using the empirical equation from [9]. The level of earthquake hazard is divided into three categories: low hazard level, medium hazard level, and high hazard level. The results of this study indicate that there is no low hazard category in Pandeglang Regency. For the category of medium hazard level has an area of 1719.404 km² (62.959%). And for the high hazard level category has an area of 1011.573 km² (37.041%). In almost all sub-districts there are medium and high hazard categories. Sub-districts that do not have medium level of hazard category are Patia and Sindangresmi Sub-district. And sub-districts that do not have high hazard level category are Cibaliung, Cimanuk, Karangtanjung, Koroncog, Mekarjaya, Menes, dan Pandeglang Sub-districts. The largest area in the medium hazard level category is in Cimanggu Sub-district, 344.394 km². And in the category of high hazard level is also in Cimanggu Sub-district, 396.980 km².

Keywords: Earthquake, Hazard Level, Pandeglang Regency

1. Introduction
The meeting of the Indo-Australian Plate which was subducted under the Eurasian Plate produced a subduction zone along the western part of the island of Sumatra, the southern part of Java, to the southern part of Nusa Tenggara, called the megathrust. As a result, tectonic earthquakes will occur frequently due to the movement of the sloping plates [3]. Through information obtained from geophysical, geodetic and seismic data, subduction zones (subduction / faults / faults) can be referred to as earthquake source zones or algerismic source zones that have the potential to cause earthquakes in the future.
Pandeglang Regency is located in the southern coast of Java Island which is adjacent to the megathrust subduction zone. In addition, earthquakes in the Pandeglang Regency can also occur due to volcanic eruptions in the Sunda Strait, namely Mount Krakatau which have the potential for...
earthquakes and tsunamis [8]. For this reason, research is needed on identifying the intensity of earthquakes in Pandeglang Regency as a first step in disaster mitigation. This process uses multi-event earthquake data in the period 2010 - 2018. The method used is the PGA (Peak Ground Acceleration) calculation using the empirical equation [10] and earthquake intensity using the empirical equation [9]. The determination of the PGA equation is largely derived outside of Indonesia because there is no specific PGA equation in Indonesia yet. Therefore, studies on the level of earthquake risk in an area in Indonesia, many still use equations obtained in other regions outside Indonesia with the assumption that there are similarities in geological and tectonic conditions with regions in Indonesia [6]. In addition, the selection of PGA equations is based on comparison of the results of data processing using existing PGA equations with ground vibration / accelerographic recording data found in Indonesia. These comparisons of 11 PGA equations for the source of subduction earthquakes with accelerographic recorded data from Java and Sumatra [1]. The results show that for the source of subduction earthquakes, the equation of [10], [2], [11] match the accelerographic data in Java and Sumatra.

2. Methods

2.1. Study Area
This study located in Pandeglang Regency, East Java. Based on the coordinates of the boundary line, the position of Banyuwangi Regency lies between 6°21’ – 7°10’ South Latitude and 104°48’ – 106°11’ East Longitude. Administratively, Pandeglang Regency is bordered by Serang Regency in north, Lebak Regency in east, Indian Ocean in south, and Sunda Strait in west.

![Figure 1. Map of The Research Location (Regional Government of Pandeglang District, 2016)](image1.png)

2.2. Data
The data used in this study are Earthquake Data of Pandeglang Regency in years 2010 – 2018, Map of Pandeglang Regency Administration, Geological Map of Pandeglang Regency, Map of Land Types in Pandeglang Regency.

![Figure 2. Earthquake Data of Pandeglang Regency 2010-2018 (Results of Data Processing, 2019)](image2.png)
2.3. Convert all types of magnitude into Moment Magnitude (Mw). The following is the magnitude conversion equation according to Irsyam, et al (2010):

\[
M_w = 0.114 \cdot m_b^2 - 0.556 \cdot m_b + 5.560 \quad (1)
\]

\[
mb = 0.125 \cdot ML^2 - 0.389 \cdot ML - 3.513 \quad (2)
\]

2.4. Determination of the calculation points in the form of a grid measuring 3 ‘x 3’ which covers the whole Pandeglang Regency area.

![Figure 3. Grid Point of Pandeglang Regency (Results of Data Processing, 2019)](image)

2.5. PGA (Peak Ground Acceleration) calculations use the [10] equation with the following form of equation:

a. For rocks:

\[
\ln (y) = 0.2418 + 1.414M + C \cdot \ln (R + 1.7818e0.554M) + 0.00607H + 0.3846ZT \quad (3)
\]

b. For land:

\[
\ln (y) = -0.6687 + 1.438M + C \cdot \ln (R + 1.097e0.617M) + 0.00648H + 0.3643ZT \quad (4)
\]

Information:

y = peak ground acceleration (g) value
C = -2.552 (for rocks) and -2.329 (for land)
R = hypocenter distance (km) M = Moment Magnitude (Mw)
ZT = source type (0 for earthquake interface, 1 for intraslab earthquakes)

The calculation is done at 1024 earthquake events at each calculation point. After that, determine the largest PGA value at each calculation point to be used in the interpolation process and calculation of
earthquake intensity. Because the whole area of Pandeglang Regency has rocks and soil, the results of the PGA calculation use an average PGA of rocks and soil.

2.6 **Interpolation of PGA calculations using GIS data processing software with IDW method to convert point data into polygons so that they can be classified according to PGA value ranges. Results in the form of "PGA Value Map Based on 2010-2018 Earthquake Data in Pandeglang Regency".**

Calculation of Earthquake Intensity using the [9] equation with the following equation: $I = 3.66 \log \text{PGA} - 1.66$ (5)

where $I$ is the earthquake intensity according to the MMI scale.

2.7 **Interpolation of Earthquake Intensity calculations using GIS data processing software with IDW method. The results are in the form of MMI scale I - XII presented in the form of "Intensity Map Based on 2010-2018 Earthquake Data in Pandeglang Regency".**

3. Result and Discussion

3.1. **PGA Calculation Results and Earthquake Intensity**
The following are the results of PGA calculations using the empirical equation [10] and earthquake intensity using the empirical equation [9].

| No | Bujur (º) | Lintan (º) | PGA (gal) | $I$ | $I$ (MMI) |
|----|-----------|------------|-----------|-----|----------|
| 1  | 105,793   | -6,811     | 118,691   | 5,932 | VI       |
| 2  | 105,843   | -6,411     | 154,548   | 6,352 | VI       |
| 3  | 105,343   | -6,711     | 150,611   | 6,311 | VI       |
| 4  | 105,893   | -6,211     | 112,385   | 5,846 | VI       |
| 5  | 106,043   | -6,411     | 85,565    | 5,412 | V        |
| 6  | 105,643   | -6,711     | 130,905   | 6,088 | VI       |
| 7  | 106,193   | -6,261     | 81,740    | 5,340 | V        |
| 8  | 105,593   | -6,661     | 138,025   | 6,172 | VI       |
| 9  | 105,093   | -6,611     | 131,718   | 6,098 | VI       |
| 10 | 105,743   | -6,761     | 140,113   | 6,196 | VI       |
| 11 | 105,843   | -6,811     | 92,991    | 5,544 | V        |
| 12 | 105,693   | -6,561     | 127,103   | 6,041 | VI       |
| 13 | 105,893   | -6,411     | 137,100   | 6,162 | VI       |
| 14 | 105,593   | -6,811     | 147,013   | 6,273 | VI       |
| 15 | 105,693   | -6,761     | 160,879   | 6,416 | VI       |
| 16 | 105,893   | -6,461     | 147,451   | 6,277 | VI       |
| 17 | 105,543   | -6,711     | 108,475   | 5,789 | VI       |
| No | Bujur (°) | Lintan (°) | PGA (gal) | I (MMI) | I (°) |
|----|------------|------------|-----------|---------|------|
| 18 | 105,743    | -6,611     | 140,165   | 6,197   | VI   |
| 19 | 105,293    | -6,811     | 153,266   | 6,339   | VI   |
| 20 | 105,993    | -6,361     | 111,448   | 5,832   | VI   |
| 21 | 105,843    | -6,461     | 169,275   | 6,497   | VI   |
| 22 | 105,793    | -6,661     | 125,139   | 6,016   | VI   |
| 23 | 105,943    | -6,411     | 110,896   | 5,824   | VI   |
| 24 | 105,793    | -6,711     | 100,074   | 5,661   | VI   |
| 25 | 105,893    | -6,311     | 103,417   | 5,713   | VI   |
| 26 | 105,243    | -6,811     | 167,477   | 6,480   | VI   |
| 27 | 105,343    | -6,761     | 141,488   | 6,212   | VI   |
| 28 | 105,643    | -6,511     | 127,880   | 5,851   | VI   |
| 29 | 105,843    | -6,711     | 97,899    | 5,626   | VI   |
| 30 | 106,093    | -6,261     | 133,469   | 6,119   | VI   |
| 31 | 105,543    | -7,061     | 167,070   | 6,476   | VI   |
| 32 | 105,743    | -6,661     | 115,962   | 5,895   | VI   |
| 33 | 105,893    | -6,261     | 113,340   | 5,859   | VI   |
| 34 | 105,793    | -6,561     | 179,980   | 6,594   | VII  |
| 35 | 105,593    | -6,761     | 137,998   | 6,172   | VI   |
| 36 | 105,843    | -6,611     | 152,443   | 6,330   | VI   |
| 37 | 105,643    | -6,761     | 159,841   | 6,405   | VI   |
| 38 | 105,493    | -6,861     | 172,698   | 6,528   | VII  |
| 39 | 105,893    | -6,611     | 132,938   | 6,113   | VI   |
| 40 | 106,043    | -6,311     | 138,049   | 6,173   | VI   |
| 41 | 106,093    | -6,361     | 98,330    | 5,633   | VI   |
| 42 | 105,943    | -6,461     | 116,746   | 5,906   | VI   |
| 43 | 105,793    | -6,511     | 177,433   | 6,571   | VII  |
| 44 | 105,743    | -6,711     | 118,691   | 5,932   | VI   |
| 45 | 105,243    | -6,561     | 151,353   | 6,319   | VI   |
| 46 | 106,093    | -6,311     | 118,981   | 5,936   | VI   |
| 47 | 105,693    | -6,661     | 103,621   | 5,717   | VII  |
| 48 | 105,843    | -6,261     | 101,488   | 5,683   | VI   |
| 49 | 105,593    | -6,711     | 117,303   | 5,914   | VI   |
| 50 | 105,493    | -6,811     | 149,695   | 6,301   | VI   |
| 51 | 105,943    | -6,511     | 117,170   | 5,912   | VI   |
| 52 | 105,793    | -6,961     | 100,993   | 5,676   | VI   |
| 53 | 105,643    | -6,661     | 122,649   | 5,985   | VI   |
| 54 | 105,743    | -6,561     | 157,525   | 6,382   | VI   |
| 55 | 105,643    | -6,811     | 173,734   | 6,538   | VII  |
| 56 | 105,793    | -6,761     | 113,371   | 5,859   | VI   |
| 57 | 106,093    | -6,411     | 79,036    | 5,286   | V    |
| 58 | 105,643    | -6,611     | 141,103   | 6,207   | VI   |
| No | Bujur (°) | Lintan (°) | PGA (gal) | I (MMI) |
|----|-----------|------------|-----------|---------|
| 59 | 105,393   | -6.761     | 141,103   | VI      |
| 60 | 105,843   | -6.661     | 123,251   | VI      |
| 61 | 105,193   | -6.561     | 138,187   | VI      |
| 62 | 105,193   | -6.661     | 135,968   | VI      |
| 63 | 105,693   | -6.811     | 175,055   | VII     |
| 64 | 105,543   | -6.761     | 111,324   | VI      |
| 65 | 105,693   | -6.711     | 131,511   | VI      |
| 66 | 105,943   | -6.311     | 126,010   | VI      |
| 67 | 105,743   | -6.811     | 149,523   | VI      |
| 68 | 105,393   | -6.811     | 168,197   | VI      |
| 69 | 105,993   | -6.411     | 87,282    | V       |
| 70 | 106,143   | -6.261     | 104,591   | VI      |
| 71 | 105,793   | -6.611     | 155,779   | VI      |
| 72 | 105,943   | -6.661     | 95,348    | VI      |
| 73 | 105,543   | -6.811     | 132,248   | VI      |
| 74 | 105,543   | -7.011     | 164,782   | VI      |
| 75 | 105,843   | -6.561     | 174,990   | VII     |
| 76 | 105,193   | -6.611     | 116,126   | VI      |
| 77 | 105,943   | -6.261     | 143,068   | VI      |
| 78 | 105,243   | -6.611     | 131,076   | VI      |
| 79 | 106,143   | -6.311     | 96,327    | VI      |
| 80 | 105,893   | -6.561     | 147,787   | VI      |
| 81 | 105,843   | -6.361     | 124,643   | VI      |
| 82 | 105,943   | -6.361     | 102,652   | VI      |
| 83 | 105,643   | -6.561     | 143,535   | VI      |
| 84 | 105,393   | -6.711     | 156,030   | VI      |
| 85 | 105,893   | -6.361     | 114,218   | VI      |
| 86 | 105,993   | -6.461     | 90,517    | VI      |
| 87 | 105,893   | -6.661     | 111,424   | VI      |
| 88 | 105,693   | -6.611     | 116,764   | VI      |
| 89 | 105,893   | -6.511     | 146,319   | VI      |
| 90 | 105,843   | -6.511     | 172,463   | VII     |
| 91 | 105,843   | -6.311     | 96,918    | VI      |
| 92 | 105,543   | -6.861     | 148,003   | VI      |
| 93 | 105,843   | -6.761     | 89,991    | V       |
| 94 | 105,993   | -6.311     | 141,341   | VI      |
| 95 | 105,893   | -6.711     | 91,200    | VI      |
| 96 | 105,243   | -6.761     | 155,789   | VI      |
| 97 | 105,943   | -6.561     | 117,992   | VI      |
| 98 | 105,293   | -6.761     | 151,563   | VI      |
| 99 | 106,043   | -6.361     | 109,632   | VI      |
For the value of earthquake intensity rounding is done according to the MMI scale. The results of the above calculation are then interpolated using the IDW (Inverse Distance Weighted) method in order to be a PGA Value Map and Pandeglang Earthquake Intensity Map.

In Table 1 above it can be seen that there is a relationship between the PGA value and earthquake intensity which is directly proportional. The greater the PGA value, the greater the intensity of the earthquake, and vice versa.

3.2. Map of PGA Value

The following are the results of the PGA (Peak Ground Acceleration) Value Map obtained from the interpolation of the points in Table 1 and then cut according to the study area. After that it is classified into 3 ranges of PGA (gal) values.

![Map of PGA Value](image)

Based on the map, it can be seen that the highest range of PGA values (146,332 - 179,969 gal) are found in the Districts of Angsana, Cibitung, Cigeulis, Cimanggu, Pagelaran, Panimbang, Patia, Picung, Sindangresmi, Sobang, Sukaresmi, and Sumur.

In Figure 5 the following is presented the percentage of the wide range of PGA values in Pandeglang Regency. The largest percentage (52.246%) is the PGA range 112,693 - 146,331 gal with a total area of 1436,249 km². While the smallest percentage (20.844%) is the PGA range 79,054 - 112,692 gal with a total area of 572,987 km².
3.3. Map of Earthquake Intensity
The following is the result of the Earthquake Intensity Map obtained from the interpolation of the points in Table 1 and then cut according to the study area. After that it is classified into 3 intensity values (MMI) in Pandeglang Regency, namely V - VII MMI.

Based on the map, it can be seen that the highest intensity values (VII MMI) are found in the Districts of Angsana, Cibitung, Cimanggu, Pagelaran, Panimbang, Patia, Sindangresmi, Sobang, and Sukaresmi. Percentage of area of each intensity value is illustrated through the following diagram.
with the largest percentage (91.463%) is VI MMI with an area of 2513,526 km² and the smallest percentage (0.301%) is V MMI with an area of 8.27 km². Whereas for VII MMI it has a percentage of 8.236% with an area of 226.325 km².

4. Conclusions
Based on the results and analysis of this study, it can be concluded that:
   a. The largest percentage of the area of the PGA range is 52,246% (1436,249 km²) with a PGA range of 112,693 - 146,331 gal. While the smallest percentage is 20,844% (572,987 km²) with a range of PGA 79,054 - 112,692 gal.
   b. The biggest percentage of intensity value is 91,463% (2513,526 km²) with VI MMI intensity. While the smallest percentage is 0.301% (8.27 km²) with V MMI intensity.
   c. There is a proportional relationship between PGA and earthquake intensity. The greater the value of the PGA, the greater the value of earthquake intensity, and vice versa. This is shown in Table 1 which is the result of PGA calculation and earthquake intensity. In addition, the relationship between PGA and earthquake intensity can also be shown as a percentage of area. The largest percentage of the PGA range is in the medium category (112,693 - 146,331 gal), as well as the largest percentage of area intensity value (VI MMI). The smallest area percentage of the PGA range is in the low category (79,054 - 112,692 gal), as well as the smallest percentage of the area of intensity value (V MMI).
   d. Districts in Pandeglang Regency that have the highest intensity of earthquakes are Angsana, Cibitung, Cimanggu, Pagelaran, Panimbang, Patia, Sindangresmi, Sobang, and Sukaresmi Districts.

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