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Evaluation of Earthquake Territory in Lombok using Statistical Method

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Abstract
Lombok Island is one of the regions in Indonesia which has relatively intermediate to high seismicity level. Therefore, researches on earthquake evaluation are needed in Lombok. The study aims to determine and map seismotectonic parameter and reoccurrence period of earthquake in Lombok Island which is located at 8^o $10^{'}$ $00^{"}$ – 9^o $05^{'}$ $00^{"}$S and 115^o $46^{'}$ $00^{"}$ – 117^o $05^{'}$ $00^{"}$E. This means that Lombok is an area with medium to large earthquake. The study focuses to evaluate and observe seismicity level change before large earthquake happens in Lombok Island based on statistical method. In this study, identification of activities, collection and data analysis of earthquake source location in Lombok Island is conducted. The value of b is found by applying the method of maximum likelihood whereas the value of PGA is obtained by conducting a calculation which uses empirical method of ground acceleration and Esteva empirical formulation in order to find a new empirical formulation. The result of the value of b is around 0.502. This shows that most of the researched area has quite high seismicity activism and the result is in line with calculation conducted by B.Guttenberg and C.F. Ritcher with constant values a and b are 8.63 and 0.502.

Introduction

Lombok Island is one of the regions in Indonesia which has relatively intermediate to high seismicity level. Therefore, studies on evaluation of earthquake source are important to do in Lombok Island. Earthquake may hit at any time and in any season. However, earthquake tends to happen at certain places such as the border of Pacific Plate. Earthquake has impact on public facilities such as hospitals, campus, airports, etc. or private facilities such as houses or personal buildings [1]. The closer the area to the source of earthquake, the bigger the potency of the earthquake[2]. Tectonically, Lombok Island which is located in West Nusa Tenggara is at the area of eastern Sunda Arch extending from Sunda Straitto east until Sumba Island[3]. The high level of seismic activity in Lombok Island is caused by the location of Lombok Island where it lies between two generators of earthquake source which are Indo Australian plate subduction from the southern Sumbawa and the active fault of back arch from the northern of Sumbawa (Flores Thrust). The high level of seismic activity needs to get serious attention because it often causes death and big loss. This study is aiming at evaluating, determining, and mapping sesimotectonic parameter and reoccurrence period of earthquake in Lombok Island. The purpose of the study is to do analysis of seismotectonic parameter in Lombok Island which is represented in value of *a* and value of *b*, relation of Gutenberg–Richter [4].

The Method of the Study

Earthquake catalogue which was used in the study was derived from BMKG and USGS during 1970 until 2016 [4,5] with criteria of magnitude ≥ 4,

depth ≤ 300 km and distance of no more than 500 km. The object of this study was Lombok Island which is located at 8^{o} $10^{'}$ $00^{"}$ – 9^{o} $05^{'}$ $00^{"}$S and 115^{o} $46^{'}$ $00^{"}$ – 117^{o} $05^{'}$ $00^{"}$E. After the data from USGS and BMKG were selected based on the object of the study, type of magnitude was determined. The type of magnitude was found by determining the value of b by using *likelihood* method. Then, PGA calculation was conducted by applying esteva formulation. However, because esteva formulation was too common, empirical formulation based on the earthquake characteristic in Lombok Island was needed. Before deriving empirical formulation from each earthquake model in Lombok Island, the value of R (hypocenter distance), magnitude surface, and α of PGA were calculated. Next, the constant of *a* and *b* is counted by applying Gauss-Jordan elimination. After those values were derived, empirical model of earthquake characteristic in Lombok Island was found.

The Result and Analysis

The data obtained from USGS and BMKG during 1970 until 2016 showed that there were 908 incidents of earthquake. The data distribution can be seen Figure 1. Next, the data were selected based on the criteria of magnitude ≥ 4, depth ≤ 300 km and distance of no more than 500 km and the result was there were 67 incidents. Data distribution of incidents in Lombok Island can be seen in Figure 2. Data based on the criteria of depth and magnitude were mapped as shown in Figure 3 and 4.

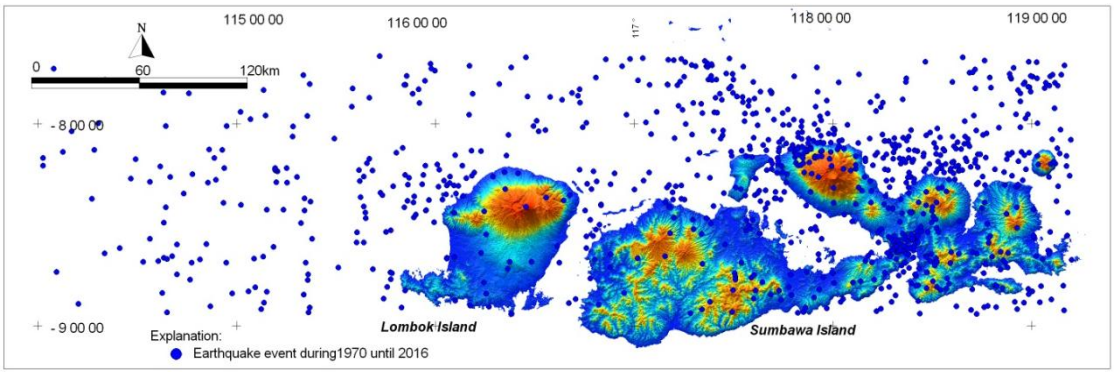

Figure.1. Data distribution of earthquake during1970 until 2016

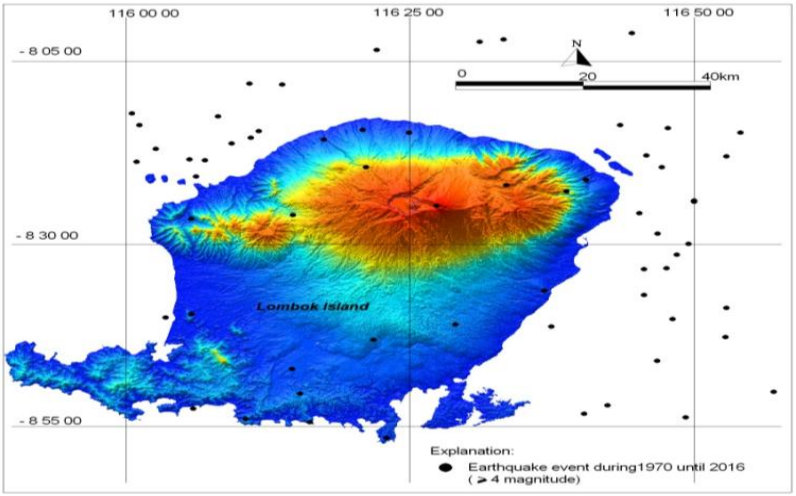

Figure.2. Data distribution of Lombok Island earthquake during 1970 until 2016

There were 908 incidents during 1970 until 2016 based on the data from USGS and BMKG. The earthquake data distribution can be seen in Figure 1. Next, the data were selected based on the criteria of ≥ 4, depth ≤ 300 km and distance of no more than 500 km and the were 62 incidents noted. The earthquake data distribution in Lombok Island is represented in Figure 2.

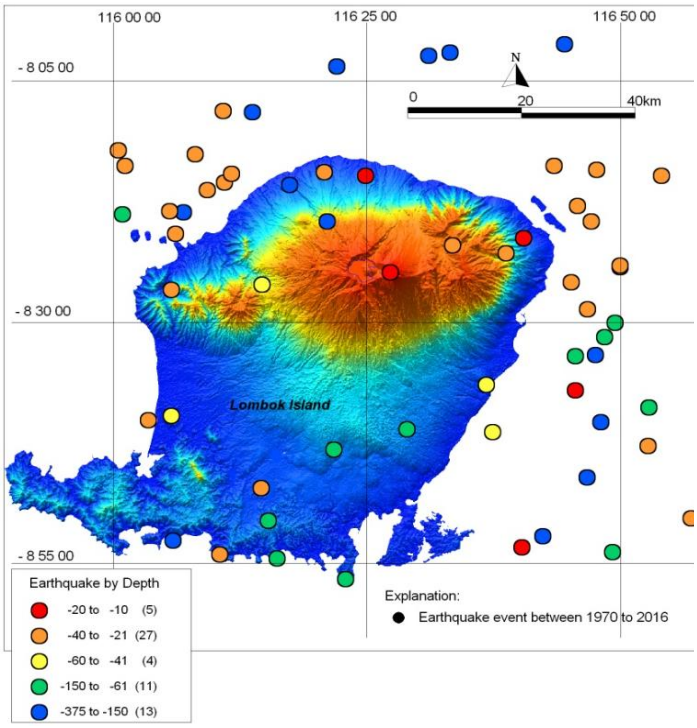

Figure.3. The data distribution based on the criteria of earthquake depth in Lombok Island during 1970 until 2016

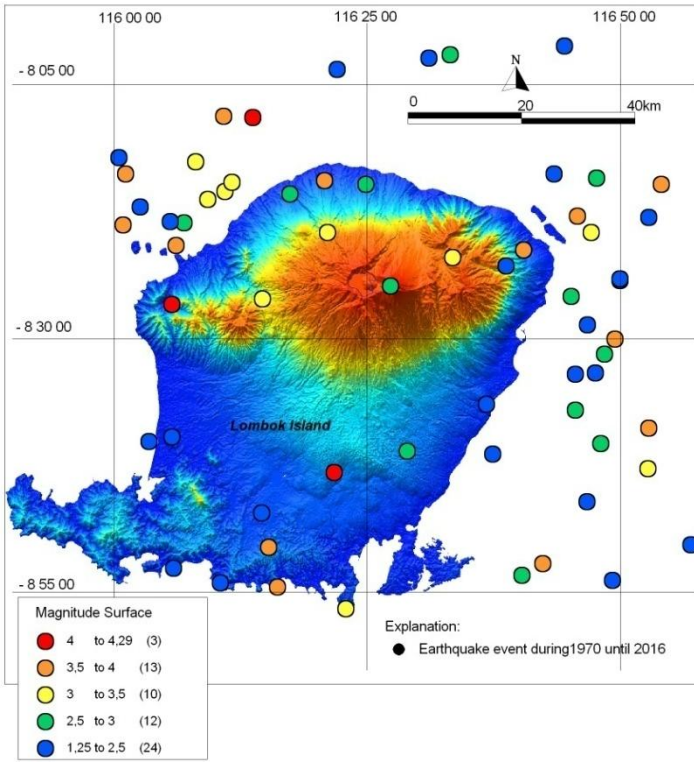

Figure.4. The data distribution based on earthquake magnitude (magnitude surface) in Lombok Island during 1970 until 2016

Next, the value of *b* and the other earthquake parameters which are R, Ms, and α were determined. After the earthquake parameter and esteva formulation were obtained, the constant values of *a* and *b* were determined to find the value of empirical PGA.

Based on the parameter of earth quake, the constant values of *a* and *b* were obtained by applying elimination method of Gauss-Jordan. It was found that the value of *a* was 8.63 and the value of *b* was 0.502. Thus, the equation of empirical PGA based on the earthquake incidents in Lombok Island was 1.

From the amount of data obtained from Agency for Meteorology, Climatology, and Geophysics (*Badan Meterologi, Klimatologidan Geofisik),* there were found 908 incidents of earthquake with the magnitude ≥3SR, depth h ≤ 100 km. In the calculation, the researcher divided the area into 62 regions. It was done in order to make the research more thorough, the process of the research easier, and data to be representative for the concern of community. The value *b* was found by applying the method of *likelihood* and the result was 0.52 which has been explained in sub chapter 3.3. This indicated that mostly the area of research has high seismicity activeness and it is in line with B. *Guttenberg* and C.F. Ritcher calculation. Some experts state that the value of *b* is stable and it is around 1 (one). The value difference is caused by different data difference and the method being used. However, most experts say that the value of *b* varies depending on the area and the depth of earthquake source and it also depends on the heterogeneity and distribution of stress space of the rocks volume of the earthquake source (Sunardidkk, 2013).

The area with the low value of *b* correlates with the high level of stress while the high level of *b* value correlates with the low level of stress. The area with low value of *b* is relatively potential for big earthquake compared to area with high level of *b* value. This can be understood because the area with low value of *b* undergoes stress accumulation which has not been released yet. Besides, the area with high heterogeneity correlates with high value of *b* (Sunardidkk, 2013). The value of *b* also presents ratio of small

to big earthquake (Asrirufak, 2010). Besides that, an area with high heterogeneity correlates with high value of *b* (Mogi, 1962). The value of *b* which is 0.52 indicates earthquake with medium activeness level.

$$\alpha = \frac{8.63 * Exp(0.5Ms)}{(R+40)^2} \quad (1)$$

Actually, there is inconsistency in the result of Gauss –Jordan elimination method. This appears because each earthquake has its own characteristic and the inconsistency may appear because of determination of the amount of numbers after comma. However, constant value of *a*and*b* still can be derived.

Determining and mapping of seismotectonic parameter with the method of Gutenberg-Richter were done by applying *software of* MAP INFO 10 and DISCOVER version 10 [5.6]. Based on the value of constant, empirical PGA can be found. Thus, based on the empirical PGA, the distribution of incidents can be obtained such as shown in Figure 5.

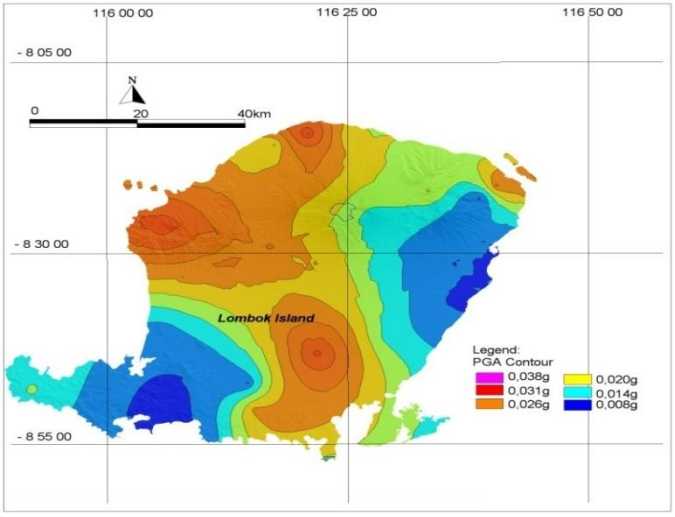

Figure.5 Spectrum of empirical PGA of Lombok Island

Figure 5 presents data distribution based on empirical PGA showing the same thing with Figure 4 which shows PGA value based on esteva formulation. Northern region of Lombok Island has higher earthquake activeness compared to the southern region. The empirical PGA in northern region averagely is around 0.0364 while in southern region is around 0.0008. This enables earthquake in northern region harmsmore than the earthquake in southern region. There are two generators of earthquake in northern region and its surrounding. At the western region, there is subduction zone of Java segment mega thrust[7]. At the eastern region, there is Bimasubduction zone [8] At southern region, there is only one generator which is subduction zone of southern region of Lombok Island [8]. The constant of value of *a* for Lombok Island is 8.63 such as shown in Figure 4.5. The value of *a* is seismic parameter where the value depends on the amount of earthquake incident. The Lombok Island region has value of a which is relatively high which is 8.63. The bigger the value of *a* in a region, the higher the seismic activity in the region. Conversely, the smaller the value of *a* in a region, the lower the seismic activity in the region[8].

Conclusion

Based on the method of maximum *likelihood*, the value of *b* is around 0.502 and if it is closer to 1, there is a tendency of earthquake. Based on the calculation, the value of α is around 0.08 to 0.38. The value of α on this PGA will represent the value of surface ground acceleration in earthquake mitigation.

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