Estimate the Primary Parameters of Extreme Earthquake on Banda Sea, Indonesia

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Abstract. Extreme earthquake events always have an impact on human life, when the intensity of events becomes greater than a certain intensity it will cause disaster. The intensity of a small earthquake occurs at any time without significant side effects. Based on statistical analysis it was revealed that earthquakes with greater intensity occur more difficult than small intensities. In the discussion, earthquake data showed that there were fluctuations in earthquake events which indicated a different maximum earthquake. Thus, major disasters occur because a small portion of major events occurs. The Banda Sea Region is an active earthquake area that contains earthquake events above magnitude 5 Richter scale (Rs) each year with a total average of above 815 major earthquake news during 1970-2018. The results of seismic studies in the Banda Sea region show a return period of 7.5 Rs magnitude earthquake quake is around 48 years and a probability of around 0.020%. Magnitude 7.0 Rs earthquake has a repetition interval of around (12-17) years with a probability of around 0.061%. In this study the analysis of earthquake probabilities and earthquake magnitude in the span of 30 years. An earthquake measuring (5.5-6.5) Rs, for example, has a probability of 100%, but if an earthquake measuring 7.7 Rs is chosen, the probability drops to 46%.

1. Introduction
Earthquakes are one of the most severe and severe natural disasters. earthquake compilation occurs in residential areas, it will cause loss of life, loss of property and severe damage to buildings. Needed to obtain information about specific challenges to build knowledge about tectonic-seismic to be useful for the construction or construction of earthquake-resistant buildings. Statistical surveys allow research on the forecast of future earthquakes. This research is intended to estimate the probability of an earthquake in the future. By better understanding earthquake hazard parameters, we can focus our consideration on these conditions.

The Banda Arc region is one area with a high level of seismicity (Fig. 1). This is due to the meeting of three large tectonic plates, namely the Indo-Australian Plate, the Eurasian Plate, and the Pacific plate. The boundaries of these plates are subduction zones which are earthquake active zones [1,2]. The Banda Arc (Fig. 2), located north-west of Australia, involves subduction along Java, the Timor trench and the Aru trench [3,4,5].
2. Experimentals

2.1 Types of research
This type of research is statistical research, and the data used in this study are secondary data. The data taken is the main parameter of extreme earthquakes in the IRIS Earthquake catalog containing earthquake magnitude \( \geq 5 \) Rs. The time taken for an earthquake and earthquake coordinates during the period 1870-2018 in the Banda Sea with an average total earthquake of 815 events.

2.2 Extreme earthquake analysis
Earthquake predictions can be divided into two parts namely statistical predictions based on previous events and deterministic predictions made from earthquake signs. Most analyzes of extreme earthquake events relate to the distribution of annual or minimum-maximum values for a given earthquake event. This event is given the symbol \( m \), starting with \( m = 1 \) for the highest value, \( m = 2 \) for the next highest and so on in ascending order. Each earthquake magnitude is increased by rank, \( m \), with \( m = 1 \) given to the maximum, more and more, \( m = 2 \) given to the highest, \( m = 3 \) given to the highest, and so on. The magnitude of the earthquake will receive the same rank as the number of years in the earthquake note, \( n \). Thus, a discharge with a rotation value will have \( m = n = 100 \). The US
Geological Survey [7] among others, also uses this formula. According to the Weibull equation [6,7], the return period or the repetition interval \( T \) (in years) is calculated using the following equation:

\[
T \text{ (years)} = (n + 1) m
\]

(1)

where: \( m \) = event ranking (in descending order), and \( n \) = number of events in the period of record. The percentage probability the (annual exceedance probability) for each magnitude is calculated using the inverse of the Weibull equation as follows:

\[
P \text{ (percent)} = 100 \cdot m (n +1)
\]

(2)

From Equations ((1), (2)) it is clear that \( P = 100/T \% \). For example, an earthquake equal to that of a 10-year one would have an annual exceedance probability of 1/10 = 0.1 or 10\%. This would say that in any given year, the probability that an earthquake with a magnitude equal to or greater than that of a 10-year earthquake would be 0.1 or 10\%. Similarly, the probability of an earthquake with a magnitude exceeding the 50 years one in any given year would be 1/50 = 0.02, or 2\%. Note that such probabilities are the same for every year, but in practice, such an earthquake could occur next year, or be exceeded several times in the next 50 years. The probability of an a certain-magnitude earthquake occurring during any period \( t \) can be calculated using the following equation:

\[
P_t = 1 − (1 − P)^t
\]

(3)

where \( P \) is the probability of occurrence over the entire time period, \( t \), and \( P \) is the probability of occurrence in any year.

3. Results and Discussion

Table 1 shows the calculation of rank \( m \), probability \( P \) and returns period \( T \) for annual data from the maximum magnitude according to the seismicity map of Figure 1 which shows the location of the research data. The probability with the largest magnitude occurred in 2001 with a magnitude of 7.5 Rs while the return period was 49 years. The table also obtained the largest probability of 100\% in 2017 for a magnitude of 5.5 Rs with a return period of 1 year.

| Rank (\( m \)) | Years | Maximum Magnitude | Probability (\( P \)) % | Return Period (\( T \)) |
|----------------|-------|-------------------|-------------------------|-------------------------|
| 1              | 2001  | 7.5               | 2.04082                 | 49.00000                |
| 2              | 2012  | 7.1               | 4.08163                 | 24.50000                |
| 3              | 1995  | 7                 | 6.12245                 | 16.33333                |
| 4              | 1998  | 7                 | 8.16327                 | 12.25000                |
| 5              | 2011  | 6.9               | 10.20408                | 9.80000                 |
| 6              | 2015  | 6.9               | 12.24490                | 8.16667                 |
| 7              | 1983  | 6.7               | 14.28571                | 7.00000                 |
| 8              | 1993  | 6.6               | 16.32653                | 6.12500                 |
| 9              | 1974  | 6.5               | 18.36735                | 5.44444                 |
| 10             | 1988  | 6.5               | 20.40816                | 4.90000                 |
| 11             | 2013  | 6.5               | 22.48989                | 4.45455                 |
| 12             | 2000  | 6.4               | 24.48980                | 4.08333                 |
| 13             | 2018  | 6.4               | 26.53061                | 3.76923                 |
| 14             | 2007  | 6.4               | 28.57143                | 3.50000                 |
| 15             | 1971  | 6.3               | 30.61224                | 3.26667                 |
3.1 The probability of an annual earthquake occurring and the period returning

The return period or the return interval of the magnitude size with the same or at least once. 100-year earthquakes are earthquakes that are expected to occur, on average every 100 years, or have a one percent chance of happening every year. Based on the graph in Fig. 3(a) shows that the relationship of earthquake magnitude and probability is exceeded annually (linear scale) with an annual maximum magnitude per year on the Y-axis versus the annual exceedance probability on the X-axis. The X and Y axes both use linear scales. On the X-axis for a 10-year repetition interval. An earthquake with a magnitude 7.5 Rs has an annual exceedance probability of 2.04%, 7.1 Rs has annual exceedance probability 4.08%, 7.0 has annual exceedance probability 6.12% and (5.5 - 6.2) Rs has annual > 50% annual exceedance probability. Fig. 3(b) represents the earthquake magnitude and the annual exceedance probability (log scale) relationship. Percentage probability is determined by dividing one by the recurrence interval and multiplying by 100.
Figure 3. (a) Earthquake magnitude and probability relationship (linear scales) and (b) Earthquake magnitude and annual exceedance probability (log scale) relationship

Figure 4. Earthquake magnitude and return period relationship (linear scales)

Fig. 4 shows the magnitude of the earthquake and the return period relationship on a linear scale. From the picture shown, the return period of an earthquake of magnitude 7.5 Rs is around 49 years, and a magnitude 7.0 Rs has a repetition interval of around (12-17) years.
Figure 5. Earthquake magnitude, probability and return period relationship

Based on Fig. 5 shows the relationship between the earthquake magnitude on the X-axis and the annual exceedance probability on the first Y-axis and the return period on the second Y-axis. The two Y axes use a log scale so that the relationship appears as a semi-parallel line, this will allow for easier findings.

Figure 6. Earthquake probability for some earthquake magnitudes in a time span period

Based on equation (3) for earthquakes with the highest magnitude representing the most dangerous event on-site. This equation is applied to earthquakes measuring 7.0 Rs, 7.1 Rs and 7.5 Rs the probabilities are 0.061%, 0.040%, and 0.020% respectively. The results are illustrated in Fig. 6 for earthquakes on the Banda Sea. magnitude: 7.0 Rs (P = 46.12%) with a period of 16 years, Richter
scale 7.1 Rs ($P = 71.35\%$) with a period of 24 years and 7.5 Rs ($P = 84.97\%$) for the span of the next 49 years.

![Figure 7. Earthquake probability and earthquake magnitudes in a time span of 30 years.](image)

Fig. 7 shows the earthquake probability and earthquake magnitudes in a time span of 30 years. An earthquake of a magnitude of (5.5-6.5) Rs, for example, has a 100% probability of occurrence but, if the earthquake of magnitude 7.5 Rs is chosen, the probability drops to 46%.

4. Conclusions

Estimates The primary parameters of earthquakes in the Banda Sea consist of earthquake magnitude, earthquake frequency, return period, the probability of an earthquake occurring annually, and the likelihood of an earthquake occurring for magnitude given over a t-year time span with a 49-year period pressure. The Weibull equation is applied to estimate the return period, while the inverse of the Weibull equation is used to calculate the probability of occurrence. The Banda Sea Region is an active earthquake area that contains earthquake events above magnitude 5 each year with a total average of above 815 major earthquake news during 1970-2018. The results of seismic studies in the Banda Sea region show a return period of 7.5 Rs magnitude earthquake quake is around 48 years and probability around 0.020%. Magnitude 7.0 Rs earthquake has a repetition interval of around (12-17) years with a probability of around 0.061%. In this study the analysis of earthquake probabilities and earthquake magnitude in the span of 30 years. An earthquake measuring (5.5-6.5) on the Richter scale, for example, has a probability of 100%, but if an earthquake measuring 7.7 Rs is chosen, the probability drops to 46%. Therefore, the record of past earthquakes in the Banda Sea is important for predicting earthquake conditions in the future such as annual periods, return periods, probability percentages, and the probability of earthquakes occurring in the region for any period.

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