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To cite this article: Ahmad Khairut Termizi *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1103** 012027

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Earthquake Threats in Ranau – From The Sources of Mensaban and Mesilou Fault

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Abstract. Unlike the majority of Malaysia's other states, Sabah is characterised by frequent seismological activity; on average, an earthquake of moderate magnitude occurs roughly every 20 years, originating primarily from one of two major sources: either a local source or a regional source. Sabah has seen an upsurge in low to moderate seismic activity in recent years as a result of the fault activities. Between 1900 and lately, magnitudes ranging from MW 2.9 to 6.0 were recorded. While big magnitude earthquakes are relatively uncommon, the area has previously been struck by disastrous earthquakes. Fortunately, the region is demarcated by active Quaternary fault networks. As a result, the area's seismicity is calculated using line sources corresponding to these faults. Two major fault systems are suspected of being the cause of such activity: the Mensaban fault zone and the Mesilou fault zone, as well as several additional nearby faults. This article explains the process for doing a probabilistic seismic hazard analysis (PSHA) while taking into consideration the peak ground acceleration (PGA) on bedrock in the Ranau region for a 10% and 2% chance of exceedance. The PGA estimate values for Ranau are between 0.08g to 0.16g for PGA 10%, while for PGA 2% was between 0.15g to 0.28g. The PGA value is divided into the following five earthquake hazard classes based on a quarterly geostatistical analysis method. These are "very low," "low," "medium," "high," and "very high" classes. In general, this quarterly classification is a good way to see how much local seismic activity there is, based on the PGA value. Which can be seen in 10% probability, 19.88 percent of the study area was in "very low," 20.19 percent was low, 19.98 percent medium, and 19.92 percent high class. 2% probability , it was found that 19.74 percent of the total area was very low class, 20.06 percent low class, 19.79 percent middle class, and 19.82 percent high class. Only 20.6 percent of the area was "very high".

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IOP Conf. Series: Earth and Environmental Science 1103 (2022) 012027 doi:10.1088/1755-1315/1103/1/012027

1. Introduction

Human civilization has demonstrated that earthquakes are natural occurrences with the most catastrophic consequences, the impact of which presents a threat to both human life and property. Earthquakes can strike without warning. An earthquake is a powerful and abrupt tremor in the earth's crust generated by movement between tectonic plates along fault lines. Landslides, liquifaction, cracks, avalanches, fires, and tsunamis are all possible outcomes. The magnitude, time period, geology, kind of construction, and type of risk management used in the region all influence the extent of devastation and damage produced by an earthquake [1].

Fault is a crack or a network of cracks that run down the length of a cracked rock and the active faults are one of the sources of earthquakes on land [2]. Keller and Pinter (1996) define an active fault as one that moved 10.00 years ago. Its existence must be understood in order to reduce the danger of earthquakes caused by the movement of these active faults. Location, distribution, active fault zone, and earthquake source are all things to be aware of. The data is required to study the seismic hazard, either on bedrock or on the ground surface, in order to determine the risk of earthquakes and additional mitigation. Mensaban Fault and Mesilou Fault are the two primary faults in the research region.

The earthquake is a devastating geohazard that has struck the country, particularly the state of Sabah. A magnitude 6 earthquake on the Richter Scale hit Ranau District, Sabah, on June 5, 2015. The quake struck in Kundasang Town at the foot of Mount Kinabalu and was the strongest in Malaysia since the 1976 Lahad Datu earthquake [3]. The shocks from the quake were felt to varied degrees throughout practically all of Sabah, the Federal Territory of Labuan, Miri in Sarawak, and Brunei. The earthquake, which struck at 7.15 a.m. and lasted 30 seconds, has had a significant impact on the afflicted areas' social, economic, and educational systems, particularly in Ranau District.

The Mensaban fault zone and the Crocker fault zone (consists of Mensaban and Mesilou Fault), as well as several other faults in their proximity, are thought to be the cause of such phenomena. Seismic hazard assessments have become an extremely significant and necessary study for the numerous development projects in Sabah, particularly in light of the prevalence of earthquake activity [4].

2. Study Area

According to the current topographic map index provided by the Department of Survey and Mapping Malaysia (JUPEM), the Kundasang-Ranau study area is located on the west coast of Sabah in sections of Sheets 7528, 7529, 7629, and 7628. The research area includes the districts of Tuaran, Kota Belud, and Ranau. The majority of the study area is in Ranau District, with Kota Belud District in the northwestern corner and Tuaran District and a small portion of Tambunan District in the west and southwest. The research region is confined by a latitude line of 05.892 ° N to 06.016 ° N and a longitude line of 116.441 ° E to 116.808 ° E, with a total study area of approximately 920 km^2 (Figure 1).

Local seismicity of Sabah is unusual from other regions of the Malaysian territory. Moderate earthquakes are experienced in three primary areas. These places are near Ranau, Sandakan, and Semporna. The first is the most perilous as it is located near to Kota Kinabalu, the main city of the state. The Ranau activity is most likely an intraplate earthquake activity that stems from movements along local quaternary faults [5].

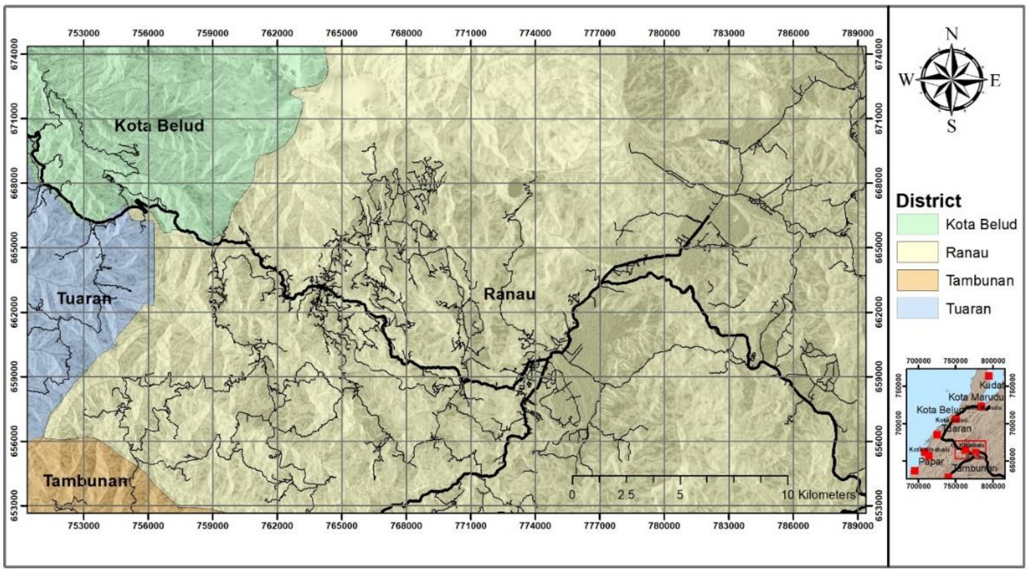

Figure 1. Location of research area consists of 4 districts namely Ranau, Kota Belud, Tuaran, and Tambunan .

Figure 2. Situation in some places of the study area affected by the earthquake.

3. Materials and Methods

Earthquake events are a random component of a natural phenomenon that cannot be predicted with certainty, including the location, time, and magnitude of the occurrence. The occurrence of earthquakes of a particular magnitude and probability can be estimated using the concept of probability [6].

Probabilistic Seismic Hazard Analysis is the term used to describe the application of probability concepts to seismic hazard analysis (PSHA). By utilising the logic tree concept, the PSHA method takes into account uncertainty in determining earthquake parameters such as maximum magnitude, GMPE equation selection, model selection (recurrence model), and recurrence rate [7]. The stages of probabilistic analysis in determining Peak Ground Acceleration (PGA) are presented in Figure 3.

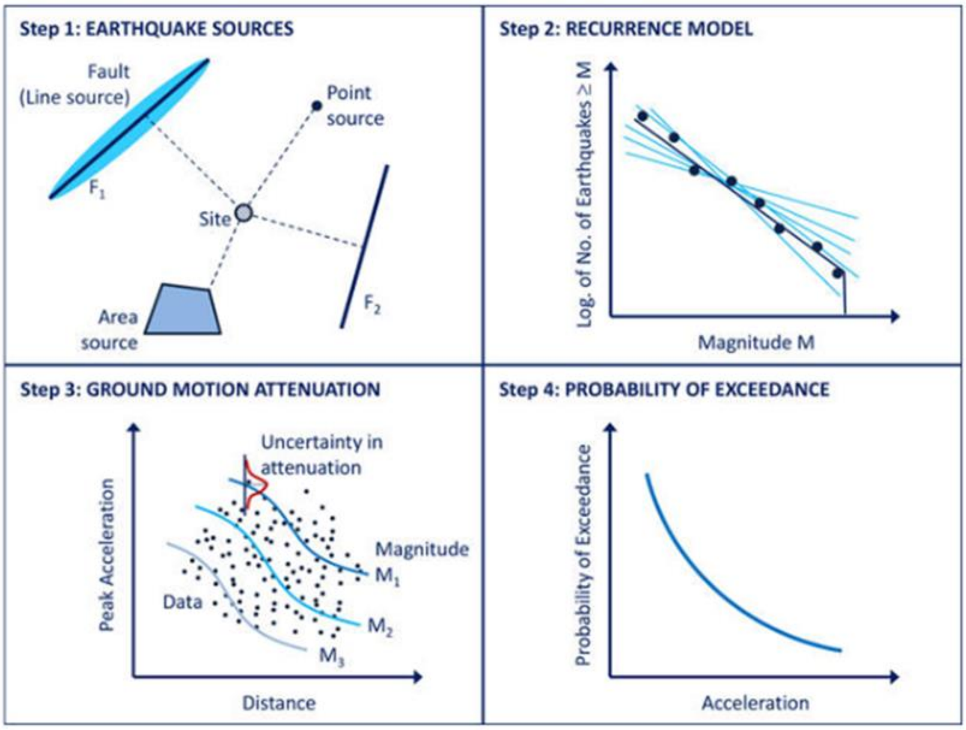

Figure 3. Peak ground acceleration (PGA) analysis using Probabilistic seismic hazard analysis (PSHA) method .

3.1 Source of The Earthquake

Typically, earthquake catalogues do not distinguish between major shock events, subsequent tremors, and prior tremors. These preceding and subsequent earthquakes are dependent on the occurrence of major shock events [8]. Because the Poisson process is used to model the temporal occurrence of earthquakes in this study, it is not valid to obtain recurring statistics from the earthquake catalogue and use them to forecast the occurrence of major shocks. As a result, the catalogue must be separated by excluding all earthquakes other than major ones that can be satisfactorily described by the Poisson model (e.g., Gardner and Knopoff, 1974; Marrow, 1992). Otherwise, we will obtain an incorrect estimate of the probability of a large major earthquake, as the gradient of the frequency magnitude curve will be influenced by the occurrence of numerous minor events. By removing accessory shocks, the magnitude frequency curve becomes less steep. The effect on hazard estimates of excluding prior and subsequent earthquakes is generally considered insignificant or acceptable due to the earthquake being an order of magnitude smaller than the main earthquake.

Three common analyses are performed on the earthquake data catalogue: earthquake size analysis, declustering earthquake events, which involves removing foreshocks and aftershocks from the main earthquake event, and finally, incompleteness analysis. The potential seismic source is then identified, which may include low-frequency seismic activity and regional seismic source zones that are believed to be tectonically active. Because defining earthquake sources is a common practise in seismic hazard analysis, it is necessary to conduct some scientific earthquake studies in order to estimate the seismicity parameters of defined source zones. By estimating the amplitudes of a parameter describing ground motion or the earthquake effect using smoothed-gridded seismicity and a subjectively chosen correlation distance of 50 kilometres covering the entire area of a large city or state, zoning maps can be created by contouring the sub-areas with equal hazard.

The data used in this study is historical data of earthquake events from 1900 to 2020 with the area of extraction. Between 1900 and 2020, about 140 significant earthquakes with a Richter magnitude of 1.0 to 6.0 were reported. The majority of these earthquakes occurred in the western half of the study region, above the Mensaban and Mesilou fault lines. The bulk of earthquakes occur in places with a steep topography.

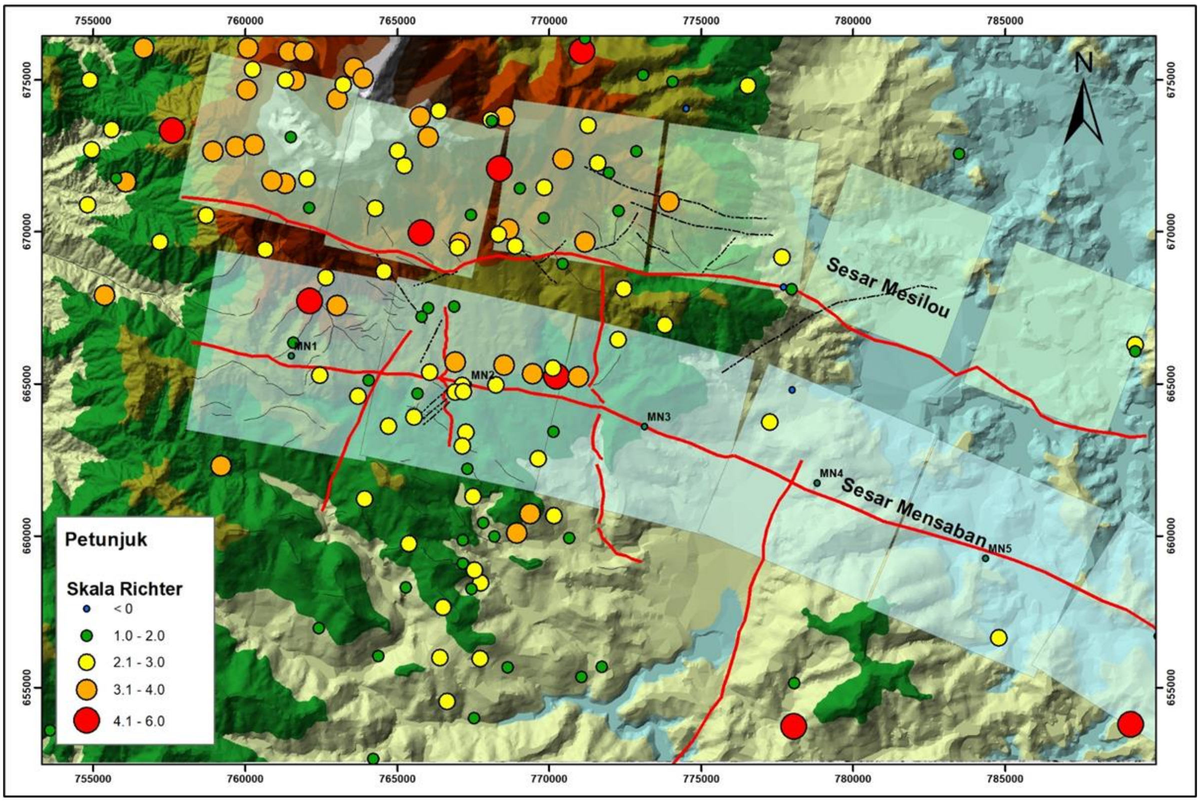

Figure 4. Earthquake models with Mensaban and Mesilou fault sources.

3.2 Data Processing

The magnitude scales of earthquakes received or gathered are vary. Surface wave magnitude (MS), Richter local magnitude (ML), body wave magnitude (Mb), and moment magnitude (MW) are all obtained. To maintain consistency throughout seismic analysis, the same magnitude scale, namely Magnitude moment (MW), is utilised, as it is more consistent than other scales.

After converting the earthquake data to a magnitude scale (Magnitude moment), it is declustring, or separated into dependent and independent earthquakes. Additional dependent earthquake occurrences will result in a modest rise in the seismic hazard analysis results [7]. In this research, dependent and independent earthquake separation methods were developed using empirical models from Gardner and Knopoff (1974).

3.3 Seismic Hazard Analysis

The earthquake origins typically are not clearly characterised in regions of low-to-moderate seismicity, and normally the highest magnitude estimations have rather extended return periods. Based on this, probabilistic seismic hazard analysis (PSHA) is believed to be the best technique of describing the uncertainties and defining the peak ground acceleration for the region. The PSHA is a mathematical technique incorporating a probabilistic analysis to analyse the response for uncertainty regarding seismic location, earthquake magnitude and shaking intensity that could happen in the future. Two of frequent techniques utilised explaining the PSHA approach may be observed in Cornell (1968) and Reiter (1991) investigations. The approach also been revised in Baker (2013) paper which detail the procedure of PSHA fully.

The primary input for the seismic hazard analysis is the source model, stated by the Gutenberg-Richter activity parameters a- and b-value for each of the seismic zones. The a-value indicates the rate of occurrence of events bigger than a specific size (intercept of the curve of the sum of all zones) and b-value gives the relative distribution of small and large events or the slope of the line. The present analysis employed the 12 seismic zones encompassing isolated and local seismic sources. The seismicity may be described using the Gutenberg and Richter (1956) relation using the formula: Log10 $\lambda = a - bM$ where λ is the rate of earthquake with a and b remain constant.

Due to the short dataset accessible in background sources, the determination of b for different zones are calculated as well as the maximum magnitude for each zone by means of the earthquake catalogue [9]. In each zone a maximum magnitude that has ever been recorded may be found. For the choice of minimal magnitude, one would assume that it does not greatly alter the hazard estimate, since tiny magnitudes do not cause harm. The identification of the maximum and lowest magnitude (Mmax and Mmin) in each seismic source is supposed to be varied and it is determined by reference to the earthquake catalog. The a- and b-value were transformed to α and β where $\alpha = 2.303a$ and $\beta = 2.303b$ which suggest that the earthquake magnitudes are exponentially distributed. The input parameters that were considered for the final seismic hazard, such as α, β, recurrence rate, λ and maximum size of future earthquakes for each source.

4. Result and Discussion

PSHA were performed for the reutrn periods of 500 (probability 10%) and 2500 (probability 5%) years. Ground motion levels were found to be highest for Ranau, which is where this study is taking place. This is how things are supposed to work out, and it should be this way.

PSHA analyses two types of earthquake hazards, namely those with 10% and 2% probabilities, i.e. with 50 years of ground movement activity, which corresponds to 500 and 2500 years of earthquake recurrence period, respectively. The PSHA method is used to peak ground acceleration values (PGA) at bedrock. Horizontal and vertical PGA reaction spectra on bedrock are estimates of the wave motion characteristics of rocks with a given period. This spectrum is required to generate synthetic soil acceleration and to serve as a reference for designing bedrock structures [10].

From the macrozonation earthquake hazard modeling, it was found that the range of PGA values obtained was between 0.08g to 0.16g for PGA 10%, while for PGA 2% was between 0.15g to 0.28g. From the PGA value, it is divided into five earthquake hazard classes by quarterly geostatistical analysis method[11,12], namely "very low", "low", "medium", "high", and "very high" classes. In general, this quarterly classification is representative of the state of local seismicity activity with the PGA value obtained. The 10% macro -zoning earthquake hazard showed (Figure 5) that 19.88% of the total area of the study area was in “very low”, 20.19% “low”, 19.98% “medium” , 19.92% “high”, and 20.03% were very high class. As for the 2% macro zoning earthquake hazard (Figure 6) it was found that 19.74% of the total area was in very low class, 20.06% low class, 19.79% middle class, 19.82% high class, and 20.6% were “very high”.

In macrozonation earthquake risks, it is assumed that waves propagate through a homogenous medium and that bedrock has the same qualities . As a result, wave propagation from the earthquake source remains unchanged and is only altered by the area's relative distance to the earthquake source. There is a different level of vulnerability in the Ranau area, where people need to take extra care because of the high risk of being harmed [13].

IOP Conf. Series: Earth and Environmental Science 1103 (2022) 012027 doi:10.1088/1755-1315/1103/1/012027

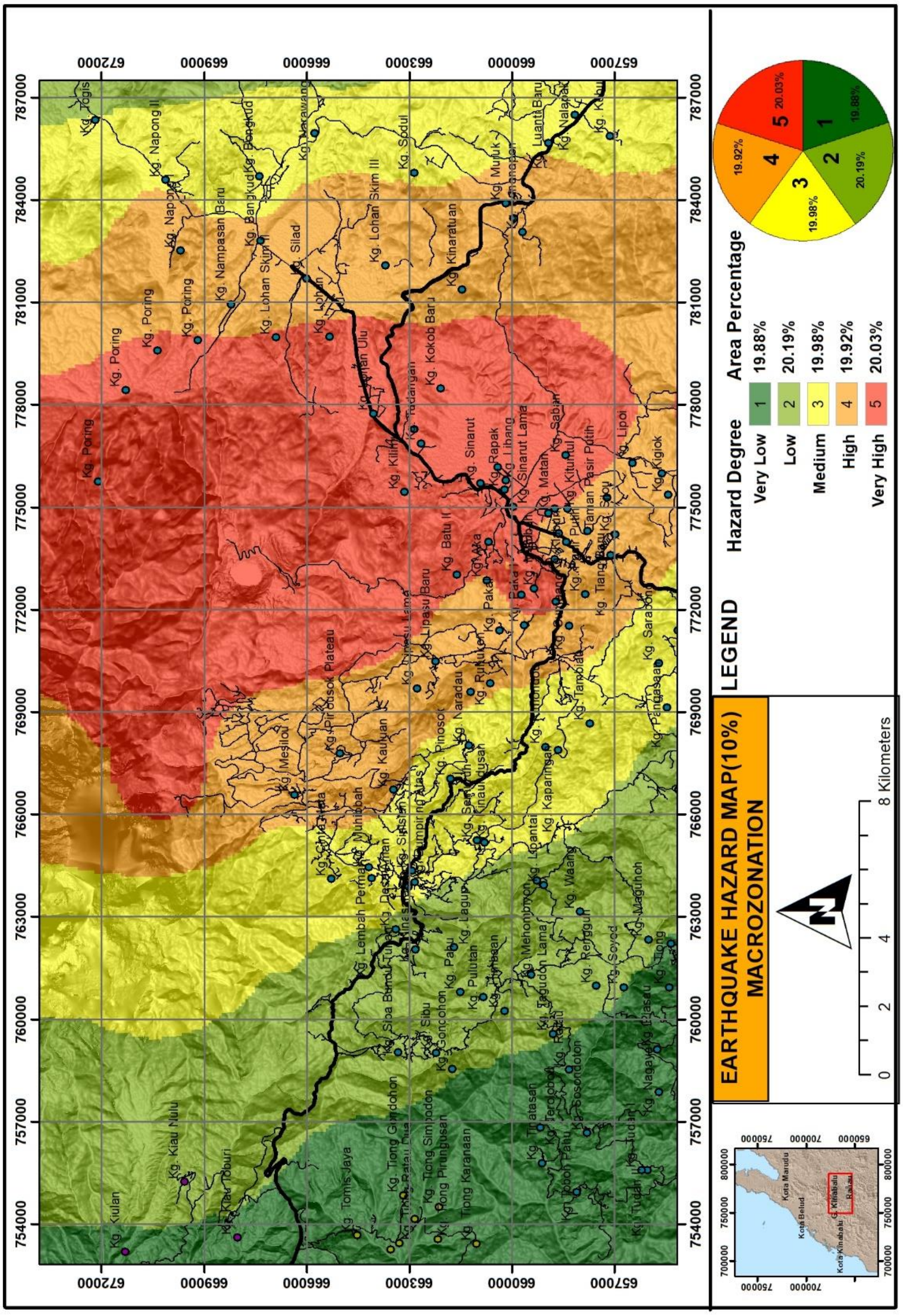

Figure 5. Earthquake Hazard Map 10% for Macrozonation.

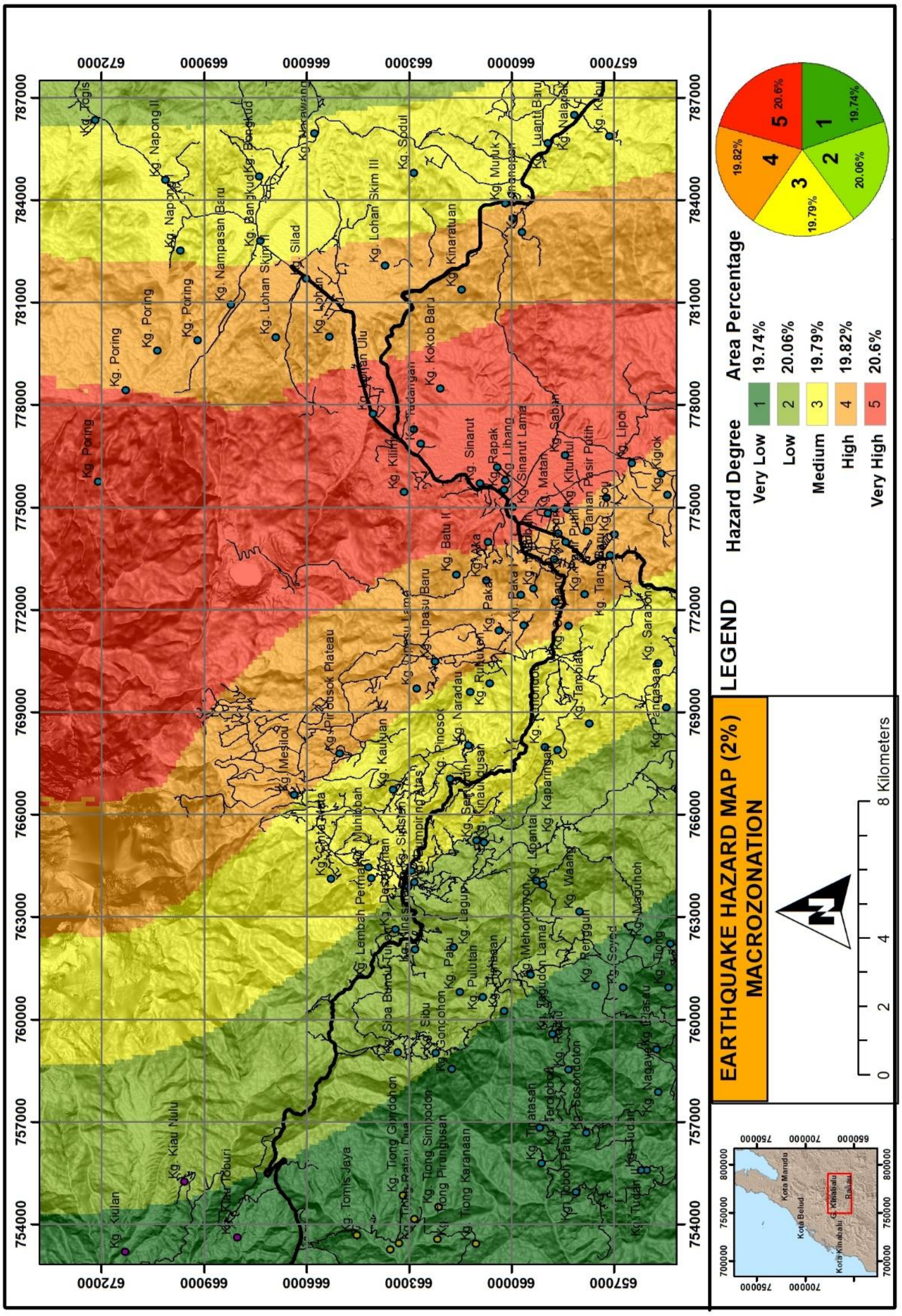

Figure 6. Earthquake Hazard Map 2% for Macrozonation.

5. Conclusion

Earthquake hazard analysis determines the research area's degree of earthquake hazard using the Probabilistic Seismic Hazard Assessment (PSHA) approach. PSHA is a suitable strategy for meeting the earthquake management target of giving catastrophe information over the next 50 years with a probability of 10% and 2%. The hazard assessment findings are very beneficial for land use planning and community social activities in the research region. PSHA is also a reference for designing buildings that are compatible with Earthquake Hazard Map. Adnan (2015) and Khalil (2017) studied on seismic risks in the Ranau area also indicates that the Ranau area is one of the places with active seismic activity in Malaysia when the causes of earthquakes are considered. This research takes a more detailed look at earthquake origins by simulating the Mensaban and Mesilou faults. These two faults are the most susceptible to earthquakes, as are the nearby active towns.

The degree of hazard is classified into two categories: macrozonation 10% and 2% probability. Categories of danger degree analysis depending on the research area's development demands. Consider a 500-year recurrence time for 10%, and utilise this 10% to design low and medium impact development such as medium density housing, agricultural and forestry projects, tourist sector development with value-added natural features, and so on. All projects that are neither large-scale or high-risk may use 10% of the Earthquake Hazard Map as a reference point for their planning strategy. For 2%, the recurrence time is 2500 years, and 2%'s job is to aid in land use planning and the creation of high-risk and large-scale structures. The construction of public infrastructure such as bridges, schools, administrative buildings, police stations, fire stations, and hospitals needs a more extensive evaluation with increased danger assumptions using an Earthquake Hazard Map 2% probability. The longer the recurrence time of an earthquake, the greater the degree of hazard caused, but the lower the risk of danger. This strategy is critical in development planning in order to decrease earthquake risk as much as feasible.

6. Acknowledgments

Sincere gratitude to Universiti Malaysia Sabah (UMS) for providing easy access to laboratories and research equipment. Highest appreciations also to the research grant award (SDN0026 and GUG0246-1/2018) to finance all the costs of this research.

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