

# Empirical Attenuation Model for Predicting Peak Ground Acceleration in North Arm Sulawesi, Indonesia

*by Gerald Tamuntuan 17*

---

**Submission date:** 28-Jun-2023 10:56AM (UTC+0700)

**Submission ID:** 2123781650

**File name:** 7\_Pasau\_2021\_IOP\_Conf.\_Ser.\_Mater.\_Sci.\_Eng.\_1115\_012069.pdf (1.42M)

**Word count:** 2586

**Character count:** 12868

PAPER • <sup>5</sup> OPEN ACCESS

## Empirical Attenuation Model for Predicting Peak Ground Acceleration in North Arm Sulawesi, Indonesia

To cite this article: G Pasau *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1115** 012069

View the [article online](#) for updates and enhancements.



**240th ECS Meeting** ORLANDO, FL

Orange County Convention Center Oct 10-14, 2021

Abstract submission deadline extended: April 23rd

SUBMIT NOW

# Empirical Attenuation Model for Predicting Peak Ground Acceleration in North Arm Sulawesi, Indonesia

G Pasau<sup>\*</sup>, G H Tamuntuan, A Tanauma, D P Pandara, F Ferdy, A As'ari and C Maramis

Department of Physics, Sam Ratulangi University, Manado, Indonesia

\*Corresponding author: guntur\_pasau@unsrat.ac.id

**Abstract.** The North Arm of Sulawesi is one of the areas that has very active tectonic conditions. The earthquake source in this area comes from the activity of several tectonic plates such as the North Sulawesi Subduction, the Molluca Sea Collision, the Philippine Sea Plate, the Pacific Plate and several local faults such as the Palu Koro Fault, Gorontalo Fault, Bolmong Fault and Manado Fault. The purpose of this study was to determine the peak ground acceleration value using several empirical attenuation models such as the Fukushima-Tanaka, Donovan, McGuire, Campbell, and Crouse. The peak ground acceleration is the value of the greatest acceleration a place has ever occurred which describes the strength of the tremor or shock of an earthquake. Geographically, this research area is located at 118<sup>o</sup>E to 127<sup>o</sup>E and 0.5<sup>o</sup>S to 4<sup>o</sup>N. The data used are data from the ISC-EHB and USGS catalog during the observation interval 1964-2020. Data processing includes the uniformity of the magnitude scale into the Surface Magnitude (*M<sub>s</sub>*) scale, determining the main shock, sorting earthquake data with a magnitude greater than M6.0 and a depth of less than 100 km, creating a grid measuring 0.05 x 0.05 degree. Next step, determine the peak ground acceleration using an empirical attenuation relationships. The analysis results show that the peak ground acceleration in the North Arm Sulawesi is as follows: McGuire Method 0.4295g, Fukushima-Tanaka 0.3595g method, Crouse method 0.314g, Donovan method 0.3149g, and Campbell method 0.2550g.

## 1. Introduction

Earthquake disasters are geological natural disasters that cause the most casualties to date. Thousands of victims were crushed under the rubble of the building due to the shock of the earthquake. One of the areas in Indonesia that has the potential and is prone to moderate to large earthquakes is North Arm of Sulawesi. The source of the earthquake in this area came from the activity of several tectonic plates such as the North Sulawesi Subduction, the Molluca Sea Collision, the Philippine Sea Plate and the Pacific Plate coupled with local faults [1]. Earthquakes always come suddenly even geologists cannot predict when they will occur. The only way to minimize casualties is through disaster mitigation efforts one of which is by determining or mapping the maximum horizontal acceleration value on the surface or Peak Ground Acceleration (PGA). The peak ground acceleration is the greatest acceleration value in a place that has ever occurred, which describes the strength of an earthquake vibration or shock [2]. The higher the ground acceleration in a place the higher the level of risk in that area. The purpose of this study was to determine the peak ground acceleration (PGA) in the North Arm Sulawesi region through an empirical attenuation relationships model. The attenuation function describes the



relationship between ground motion intensity ( $I$ ) and the magnitude of the earthquake ( $M$ ) and the hypocenter distance ( $R$ ) from a source point.

The empirical attenuation relationships used in modeling the peak ground acceleration are the McGuire, Campbell, Donovan, Crouse-Mc.Guire, and Fukushima-Tanaka Method (see Table 1) [3]-[5]. This method is used if the source of the earthquake is mostly from subduction activity and faults.

**Table 1.** The empirical attenuation relationship use

ID	Source	Empirical Attenuation
1	Fukushima-Tanaka	$\log A = 0.41Ms - \log(R + 0.032 \times 100.41Ms) - 0.0034R + 1.30$
2	Crouse & Mc.Guire	$\ln Y = 2.4846 + 0.7334M - 0.0151M^2 - 0.5056 \ln(R + 1) - 0.0094R$
3	Mc.Guire	$\alpha = \frac{47238 \times 10^{0.278M}}{(R + 25)^{1.301}}$
4	Donovan	$\alpha = \frac{1080 \times 10^{0.5M}}{(R + 25)^{1.32}}$
5	Campbell	$\ln Y = -2.501 + 0.623M - \ln(R + 7.28)$

where:  $A, Y, \alpha$ : acceleration (PGA value) in  $g$   
 $Ms$ : Magnitude Surface ( $Ms$ )  
 $R$ :  $(r^2 + h^2)^{1/2}$   
 $r$ : hypocenter distance  
 $h$ : focal depth

In this study we used data of good quality / high resolution. The data we have used are mostly from the ISC-EHB earthquake catalog (72%) where the data have been relocated. We also tried to use the shock data from each events earthquake.

The purpose of this study was to determine the peak ground acceleration (PGA) value in the North Arm of Sulawesi using the empirical attenuation relationship model. The distribution of PGA values is then plotted on a map that produces a peak ground acceleration map to find out which areas have tectonic conditions that are particularly vulnerable.

10  
**2. Materials and methods**

**2.1. Data Collection**

The data used in this study is earthquake data that has been recorded occurs around the North Arm of Sulawesi. Recorded earthquakes were collected from the USGS (United States Geological Survey) and ISC-EHB (International Seismological Centre - Engdahl, van der Hilst & Buland) Bulletin during the observation period from 1964 - 2020 (see Figure 1)

From a number of earthquake data that have been collected, namely earthquakes with a magnitude greater than  $M5.0$  and a depth of less than  $100$  km, then carried out the magnitude scale uniformity. Uniformity or conversion of various magnitude scales into Surface Magnitude ( $Ms$ ) using the empirical model proposed by Scordilis:

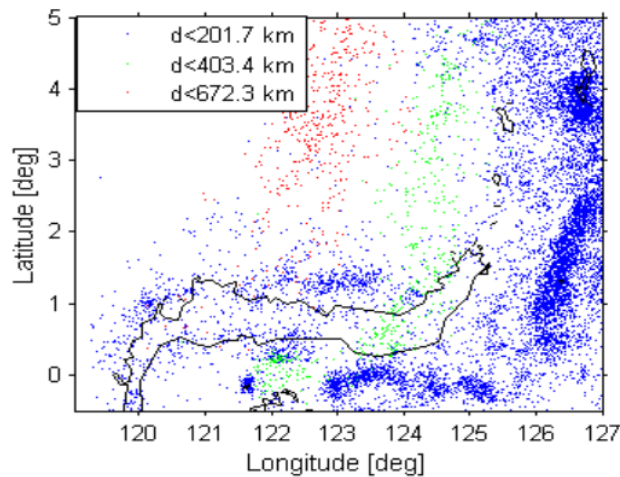
7  $M_s = 0.85M_b + 1.02 \quad 2.6 \leq m_b \leq 5.3 \dots\dots\dots(1)$

$M_w = 0.65M_s + 2.20 \quad 3.0 \leq M_s \leq 6.1 \dots\dots\dots(2)$

$M_w = 1.00M_s - 0.02 \quad 6.2 \leq M_s \leq 8.0 \dots\dots\dots(3)$

The magnitude scale  $M_b > 6.3$  is considered to be equivalent to the moment magnitude  $M_w$  [6].

Data processed with a magnitude greater than  $M5.0$  with maximum depth of  $100$  km. Earthquake data which has been collected from various catalogs have a different scale of magnitude therefore this is the first step to take what to do is conversion scale into the surface magnitude scale ( $Ms$ ).



**Figure 1.** Plot earthquakes data period of 1964 - 2020.

Uniformity results later sorted or declustering catalogues using Gardner and Knopoff to determine mainshock apart from the foreshock and aftershock [7]. This uniformity process done based on the time window criteria and window spacing using empirical methods proposed by Gardner and Knopoff (1974), with the zmap software rocks. From the main earthquake the selected socks are then counted. Data at depths greater than 300 km do not contribute to ground acceleration on the surface. The results of the uniformity of earthquake data and earthquake data were selected as many as 11 data that caused the biggest shock impact in the North Arm of Sulawesi ( see Table 2).

**Table 2.** Earthquake data used in this study

Lon ( $^{\circ}$ E)	Lat ( $^{\circ}$ N)	Origin Time (UTC)		$M_s$	Depth (km)
126.244	1.441	8/10/1968	02:07:4.15	7.6	20.9
119.685	0.091	8/14/1968	22:14:20.15	7.2	16.8
126.475	1.799	8/14/1986	19:39:14.65	7.1	32.3
122.811	1.196	4/18/1990	13:39:22.45	7.3	39.8
122.748	1.184	6/20/1991	05:18:53.12	7.0	26.3
119.908	0.698	1/1/1996	08:05:12.2	7.5	24
126.359	1.106	1/21/2007	11:27:44.48	7.3	22.2
122.098	1.308	11/16/2008	17:02:32.97	7.0	31
119.8462	-0.2559	9/28/2018	10:02:45	7.5	20
126.1892	0.5126	7/7/2019	15:08:40	7.2	35
126.4156	1.6213	11/14/2019	16:17:40	7.1	33

## 2.2. Methods

Earthquake data collected from various catalogs usually have different magnitude scales. Therefore, the first step that must be done is to uniform the magnitude scale into the Surface Magnitude (*M<sub>s</sub>*) scale. The results of uniformity are then sorted to determine the mainshock by applying the time window and distance window criteria using ZMAP software [8]-[10]. The uniformity results were then selected for large earthquakes with magnitudes greater than M6.0 and depths less than 100 km. The next step is to determine the amount of peak ground acceleration using the empirical attenuation relationships such as Fukushima, Tanaka, Campbell, Crouse, Donovan, and McGuire. Then map the spatial acceleration value by first creating a grid measuring 0.05 x 0.05 degree to determine which area has a significant value (greatest acceleration).

## 3. Result and Discussion

The results of calculations using the empirical attenuation relationships model show that the peak ground acceleration values in the North Arm of Sulawesi range from 0.001 g to 0.429590 g. The largest value is obtained from the Mc.Guire attenuation, which is 0.002244 g - 0.429590 g while the smallest value is obtained from the Crouse-Mc.Guire attenuation with a value of around 0.00022 g - 0.2254655 g (see Table 3).

**Table 3.** PGA value from several attenuation model

No	Methods	Peak Ground Acceleration (g)		
		Min	Average	Max
1	Fukhusima-Tanaka	0.0000082	0.010041	0.359595
2	Mc.Guire	0.002244	0.027128	0.429590
3	Donovan	0.0021811	0.021102	0.3149190
4	Crouse & McGuire	0.00022	0.01068	0.2254655
5	Campbell	0.001002	0.015608	0.2550339

The minimum value is generated at a place far from the epicenter earthquake while the maximum value is generated at the epicenter. This is the result of attenuation as a function of the distance, magnitude, and depth of the earthquake. Table 3 shows that the reasonable value is the value of the Mc.Guire method, the Donovan method and the Fukushima-Tanaka method. Meanwhile, the value generated by Crouse and Campbell attenuation is considered too small by considering the existing tectonic conditions.

The relationship between distance (km) versus PGA (g) for the M7.0 and M7.6 magnitudes is shown in Figure 2.

From Figure 2, we can see that the magnitude M7.0 shows that the graph of the acceleration value generated by the Crouse-Mc.Guire and Campbell method is almost the same (coincide). Meanwhile, the graph with magnitude M7.6 shows that the graphs produced by the two methods have separate values. The interesting thing about the two graphs above is that for the magnitude  $M \leq 7.0$  value of the ground acceleration generated by the two methods is almost the same while for  $M > 7.0$  the value of the ground acceleration is different.

The distribution of the peak ground acceleration values uses several attenuation relationship formulas as shown in Figure 3. In general, the North Arm of Sulawesi region has a high PGA value, this is due to its proximity to the earthquake source. The distribution of PGA values for each method shows the same pattern as the maximum values found in the western and northern regions. The distribution of PGA values for each method shows the same pattern as the maximum values found in the western region, namely Donggala and Tolitoli. Meanwhile, in the north, they are in the Buol, North Gorontalo and Boroko regions.

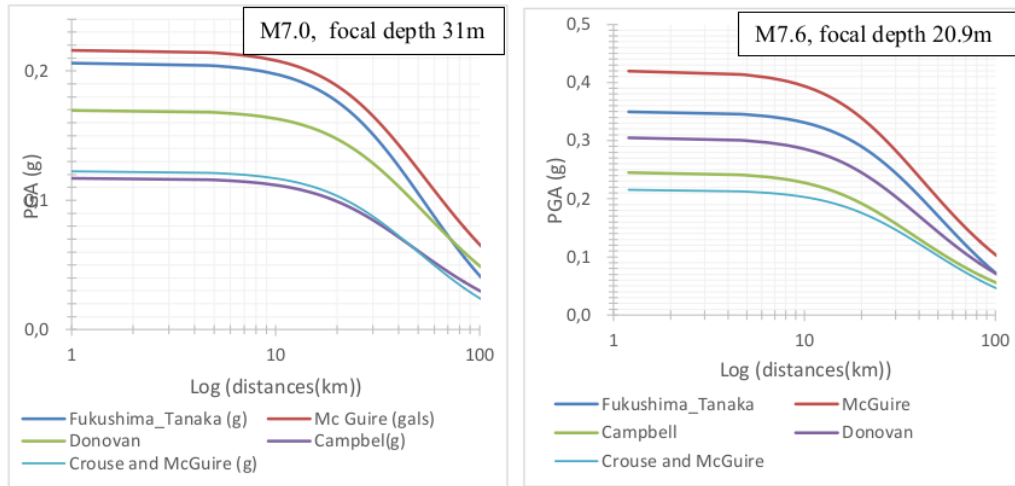


Figure 2. The PGA Attenuation Model Curve for Magnitude 7.0 Ms and 7.6 Ms

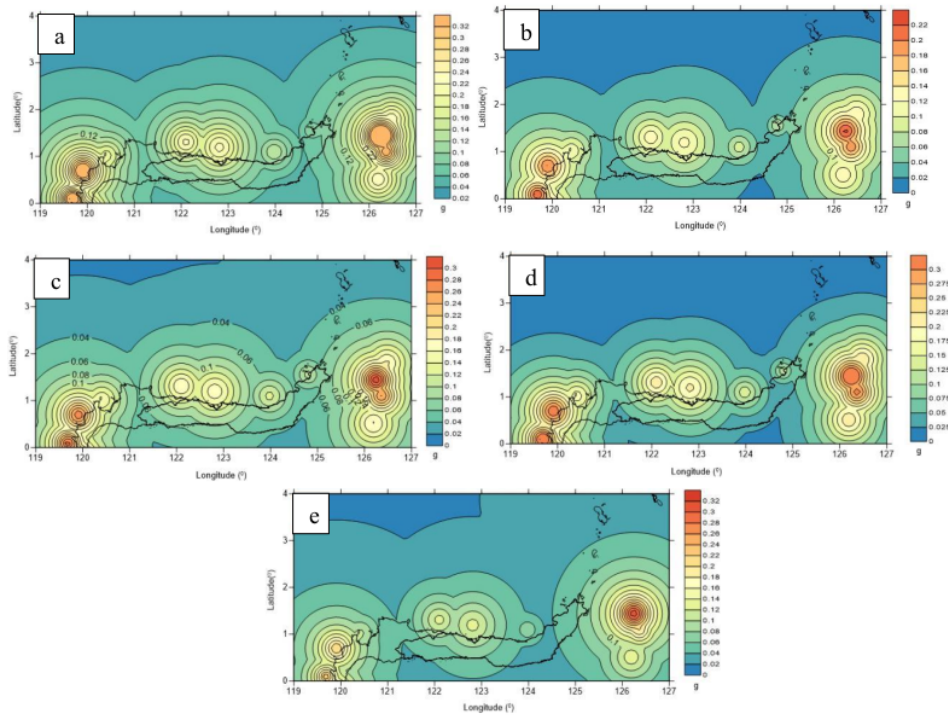


Figure 3. Distribution PGA value by using attenuation: (a) Mc.Guire (b) Crouse-McGuire (c) Donovan (d) Fukushima-Tanaka (e) Campbell

#### 4. Conclusion

Prediction of peak ground acceleration using the attenuation relationship model has been carried out for the North Arm of Sulawesi. The analysis results show that the peak ground acceleration in this region ranges from 0.0000082 g - 0.429590 g. The greatest peak ground acceleration is obtained from the Mc.Guire attenuation relationship, while the smallest is obtained from the Crouse attenuation relationship. Generally, the greatest ground acceleration results from large magnitude earthquakes originating from subduction zones. The seismic vulnerability of a point depends on the proximity of an earthquake source such as the North Sulawesi Subduction and the Molluca Sea double collision.

#### Acknowledgments

We express our sincere thanks to the Institute for Research and Community Service (LPPM) Unsrat for funding this research .

#### References

- [1] Pasau G, Tamuntuan G H, Tanauma A 2019 Numerical Modeling For Tsunami Wave Propagation (Case Study: Manado Bays) *IOP Conference Series: Material Science and Engineering* **567** 012005
- [2] Pradhan B, Moneir A A A and Jena R 2018 Sand dune risk assessment in Sabha region, Libya using Landsat 8, MODIS, and Google Earth Engine images *Geomatics, Natural Hazards and Risk* **9** (1) 1280-1305
- [3] Fukushima Y and Tanaka T 1990 A new attenuation relation for peak horizontal acceleration of strong earthquake ground motion in Japan *Bulletin of the seismological Society of America* **80** (4) 757-783
- [4] Campbell K W 1997 Empirical near-source attenuation relationships for horizontal and vertical components of peak ground acceleration, peak ground velocity, and pseudo-absolute acceleration response spectra *Seismological research letters* **68** (1) 154-179
- [5] Crouse C B, Vyas Y K and Schell B A 1988 Ground motions from subduction-zone earthquakes *Bulletin of the Seismological Society of America* **78** (1) 1-25
- [6] Scordilis E M 2006 Empirical global relations converting MS and mb to moment magnitude *Journal of seismology* **10** (2) 225-236
- [7] Gardner J K and Knopoff L 1974 Is the sequence of earthquakes in Southern California, with aftershocks removed, Poissonian? *Bulletin of the Seismological Society of America* **64** (5) 1363-1367
- [8] Wiemar S 2001 A software package to analyze seismicity ZMAP *Seismological Research Letters* **72** (2) 373-382
- [9] Öztürk S 2011 Characteristics of seismic activity in the Western, Central and Eastern parts of the North Anatolian Fault Zone, Turkey: Temporal and spatial analysis *Acta Geophysica* **59** (2) 209-238
- [10] Zarifi Z., Nilfouroushan F and Raeesi M 2014 Crustal stress map of Iran: insight from seismic and geodetic computations *Pure and Applied Geophysics* **171** (7) 1219-1236



# Empirical Attenuation Model for Predicting Peak Ground Acceleration in North Arm Sulawesi, Indonesia

## ORIGINALITY REPORT

24%

SIMILARITY INDEX

23%

INTERNET SOURCES

15%

PUBLICATIONS

9%

STUDENT PAPERS

## PRIMARY SOURCES

1 [www.researchgate.net](http://www.researchgate.net) 10%  
Internet Source

2 [repository.unmuhjember.ac.id](http://repository.unmuhjember.ac.id) 4%  
Internet Source

3 [inspirehep.net](http://inspirehep.net) 2%  
Internet Source

4 [repository.untar.ac.id](http://repository.untar.ac.id) 1%  
Internet Source

5 [iopscience.iop.org](http://iopscience.iop.org) 1%  
Internet Source

6 [repo-dosen.ulm.ac.id](http://repo-dosen.ulm.ac.id) 1%  
Internet Source

7 Submitted to National & Kapodistrian University of Athens 1%  
Student Paper

8 [repository.usd.ac.id](http://repository.usd.ac.id) 1%  
Internet Source

Submitted to King Saud University

9

Student Paper

1 %

10

[www.mdpi.com](http://www.mdpi.com)

Internet Source

1 %

11

Mahmoud Y. Al-Qaryouti. "Attenuation relations of peak ground acceleration and velocity in the Southern Dead Sea Transform region", Arabian Journal of Geosciences, 10/2008

Publication

&lt;1 %

12

Ratiranjan Jena, Biswajeet Pradhan, Abdullah M. Alamri. "Geo-structural stability assessment of surrounding hills of Kuala Lumpur City based on rock surface discontinuity from geological survey data", Arabian Journal of Geosciences, 2020

Publication

&lt;1 %

13

[ejournal.upi.edu](http://ejournal.upi.edu)

Internet Source

&lt;1 %

14

[pt.scribd.com](http://pt.scribd.com)

Internet Source

&lt;1 %

15

[www.gmpe.org.uk](http://www.gmpe.org.uk)

Internet Source

&lt;1 %

Exclude bibliography  On