

Correlation Equation of Fault Size, Moment Magnitude, and Height of Tsunami Case Study: Historical Tsunami Database in Sulawesi

Admiral Musa Julius^{a)} Sugeng Pribadi^{b)} Muzli Muzli^{c)}

Agency for Meteorology Climatology and Geophysics (BMKG)
Jl. Angkasa 1 No. 2, Kemayoran, Jakarta, Indonesia 10720

^{a)}*admiralmusajulius@gmail.com*

^{b)}*sugengpribadimsc@gmail.com*

^{c)}*muzli@bmkg.go.id*

Abstract. Sulawesi, one of the biggest island in Indonesia, located on the convergence of two macro plate that is Eurasia and Pacific. NOAA and Novosibirsk Tsunami Laboratory show more than 20 tsunami data recorded in Sulawesi since 1820. Based on this data, determination of correlation between tsunami and earthquake parameter need to be done to proved all event in the past. Complete data of magnitudes, fault sizes and tsunami heights on this study sourced from NOAA and Novosibirsk Tsunami database, completed with Pacific Tsunami Warning Center (PTWC) catalog. This study aims to find correlation between moment magnitude, fault size and tsunami height by simple regression. The step of this research are data collecting, processing, and regression analysis. Result shows moment magnitude, fault size and tsunami heights strongly correlated. This analysis is enough to proved the accuracy of historical tsunami database in Sulawesi on NOAA, Novosibirsk Tsunami Laboratory and PTWC.

Keywords: tsunami, magnitude, fault, height

1. Introduction

Sulawesi, one of the biggest island in Indonesia, located on the convergence of two macro plate that is Eurasia and Pacific. They are not only great plate, but also micro plate Philippine. Repercussions by this convergence, Sulawesi divided into two subduction zone that is Sulawesi sea and Molucca sea. They are not only subduction zone, Sulawesi also has more active tectonic fault such as Walanae, Palukoro, Gorontalo, Matano, Lawanopo, and Kolaka.

Tsunami happened because vertical deformation located on the sea floor suddenly. The deformation such as earthquake, landslide, volcano and fall of rock space. It make a movement of water column on the very long wavelength from the sea to the coastal point. Based on earthquake event, there are some parameter controlled tsunami problem such as magnitude. Magnitude strongly involved on the rupture size of fault that determine the tsunami size. Not only magnitude, tsunami strength also influenced by depth and slope between intra-plate. Study the correlation of moment magnitude, fault size and tsunami height has been done by Utsu (1954), Tocher (1958), Kanamori (1975), Bonilla (1984), Wesnousky (1986), Ambraseys (1988), Wells (1994), Wang (1998), Papazachos (2004) and Muzli (2015). This correlation use to predict the fault size and height of tsunami in Sulawesi by moment magnitude of earthquake. However, this study aims to determine the correlation between them.



2. Data and Method

This study using moment magnitude of earthquake and tsunami height data in Sulawesi region, sourced from Pacific Tsunami Warning Center catalogue. This catalogue found only 16 tsunami events that have height data. Based on this small number, we use empirical equation to determine tsunami height. We calculate tsunami Height using Supassri [1] equation:

$$H = 3E-5M_w^{6.2344} \quad (1)$$

H = tsunami height

M_w = moment magnitude

Step we used are collecting, processing and assessing the correlation. Firstly, we converting surface magnitude (M_s) to moment magnitude (M_w) because there is only available M_s on the catalogue. We used Asrurifak [7] equation to convert this magnitude.

$$M_w = 0.143 M_s^2 - 1.051 M_s + 7.285 \quad (2)$$

Meanwhile, we used Papazachos [4] equation to determine length (L), wide (W), Area (S) and Slip (U). There are some categories for each magnitude:

$$\text{LogS} = 0.86M - 2.82, \sigma = 0.25, 6.7 \leq M \leq 9.2 \quad (3)$$

$$\text{LogL} = 0.55M - 2.19, \sigma = 0.18, 6.7 \leq M \leq 9.3 \quad (4)$$

$$\text{LogW} = 0.31M - 0.63, 6.7 \leq M \leq 9.2 \quad (5)$$

$$\text{LogU} = 0.64M - 2.78, 6.7 \leq M \leq 9.2 \quad (6)$$

L = fault length; W = fault width; U = fault slip; M = moment magnitude

After fault size has been done, we will found the correlation between moment magnitude, fault size and tsunami height using simple regression. We make correlation by linear and logarithm regression between moment magnitude – fault size, moment magnitude – tsunami height, and fault size-tsunami height.

3. Result and Discussion

The relationship between the magnitude of moments (M_w) with the parameters of fault extent such as fault length (L), fault area (S), fault width (W) and slip or displacement (U) can be expressed using equations from Papazachos et al. in the data and methods below.

3.1. Regression of Moment Magnitude – Fault Size

3.1.1. Moment Magnitude-Length

The graph of regression result below shows the linear relationship between the two parameters ie logarithmic fault length and moment magnitude (**FIGURE 1**).

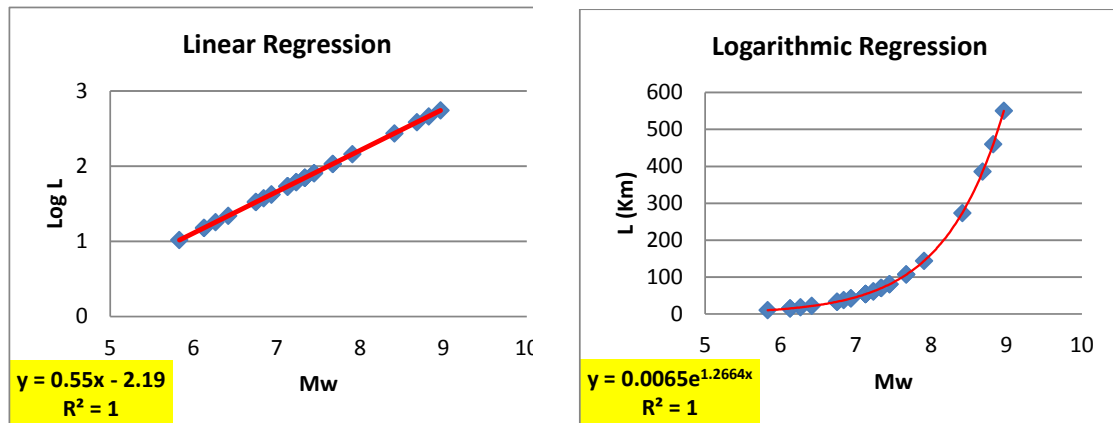


FIGURE 1. linear (left) and logarithmic (right) curve of moment magnitude – length regression

3.1.2. Moment Magnitude-Width

The graph of regression result below shows the linear relationship between the two parameters ie logarithmic fault width and moment magnitude (**FIGURE 2**).

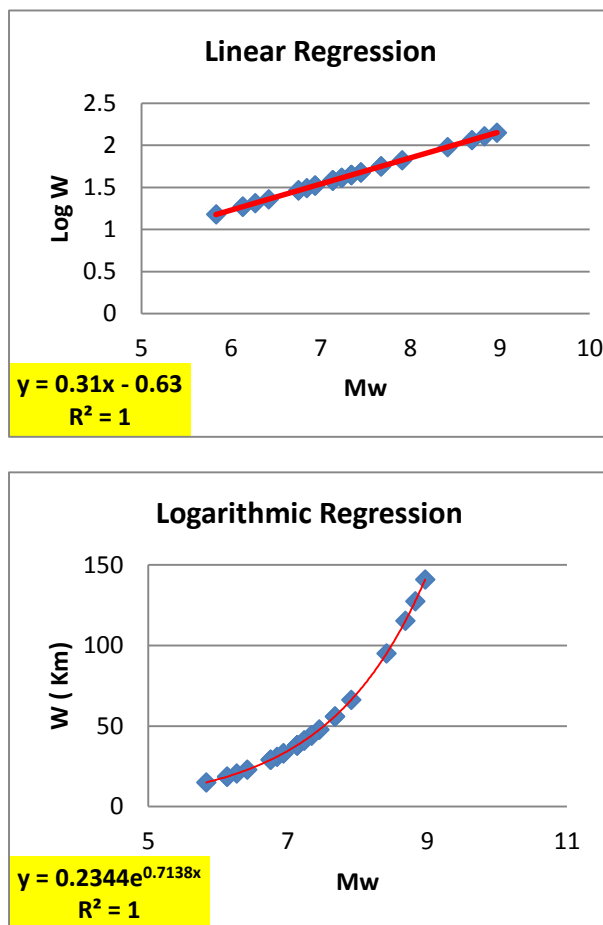


FIGURE 2. linear (left) and logarithmic (right) curve of moment magnitude – width regression

3.1.3. Moment Magnitude-Area

The graph of regression result below shows the linear relationship between the two parameters ie logarithmic fault area and moment magnitude (**FIGURE 3**).

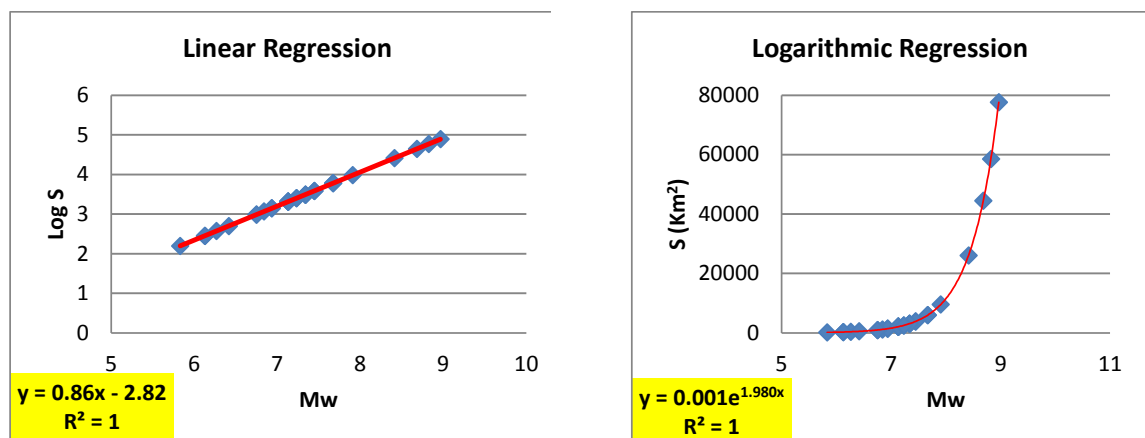


FIGURE 3. linear (left) and logarithmic (right) curve of moment magnitude – area regression

3.1.4. Moment Magnitude-Slip

The graph of regression result below shows the linear relationship between the two parameters ie logarithmic fault area and moment magnitude (**FIGURE 4**).

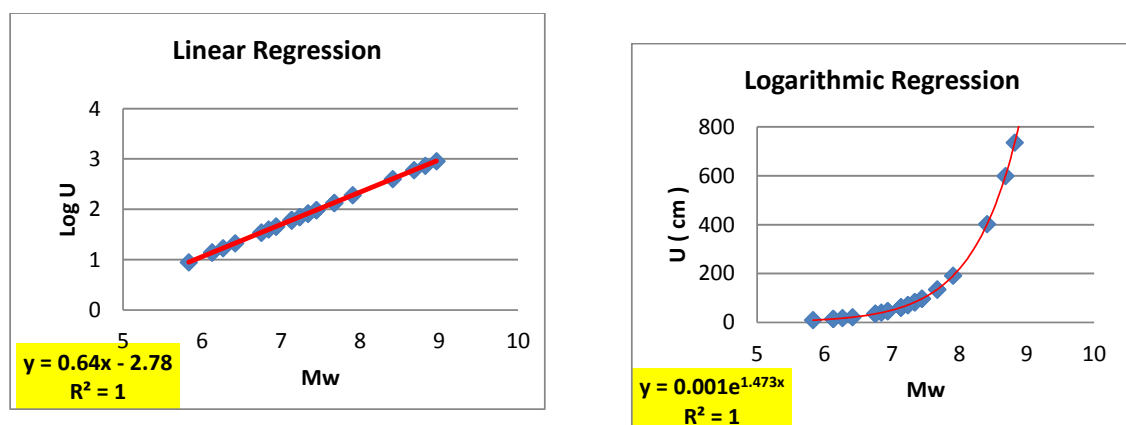


FIGURE 4. linear (left) and logarithmic (right) curve of moment magnitude – slip regression

3.1.5. Moment Magnitude-Fault Size

When combined, the relationship between moment magnitude and fault parameters is (**FIGURE 5**):

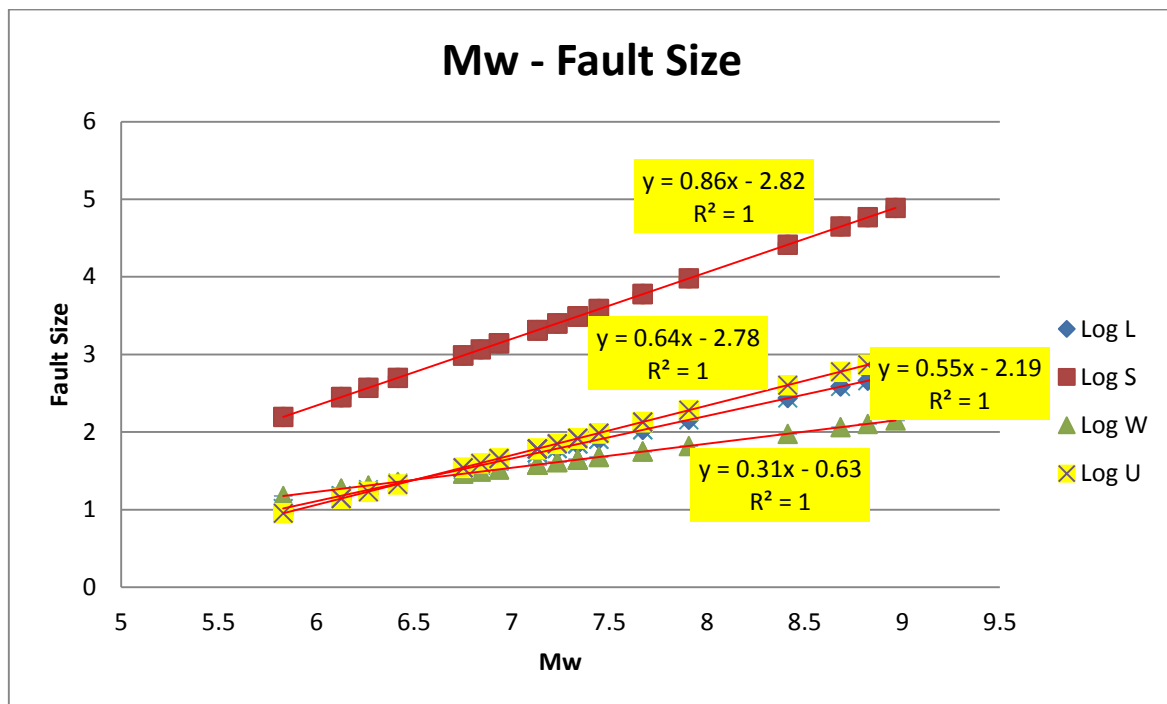


FIGURE 5. linear (left) and logarithmic (right) curve of moment magnitude – fault size regression

3.2. Regression of Moment Magnitude – Tsunami Height

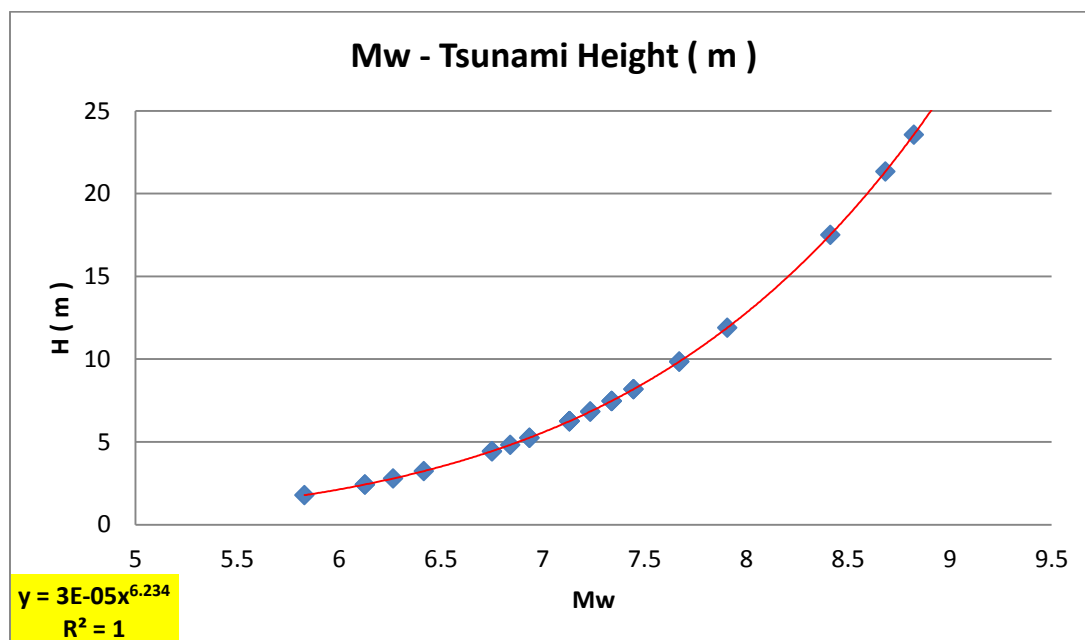


FIGURE 6. linear (left) and logarithmic (right) curve of moment magnitude – tsunami height regression

Based on the graphic images of the above regression results (**FIGURE 6**) it is known that the correlation value indicates a value of 1, which means there is a very strong relationship between the moment magnitude to the tsunami generated.

3.3. Regression of Fault Size – Tsunami Height

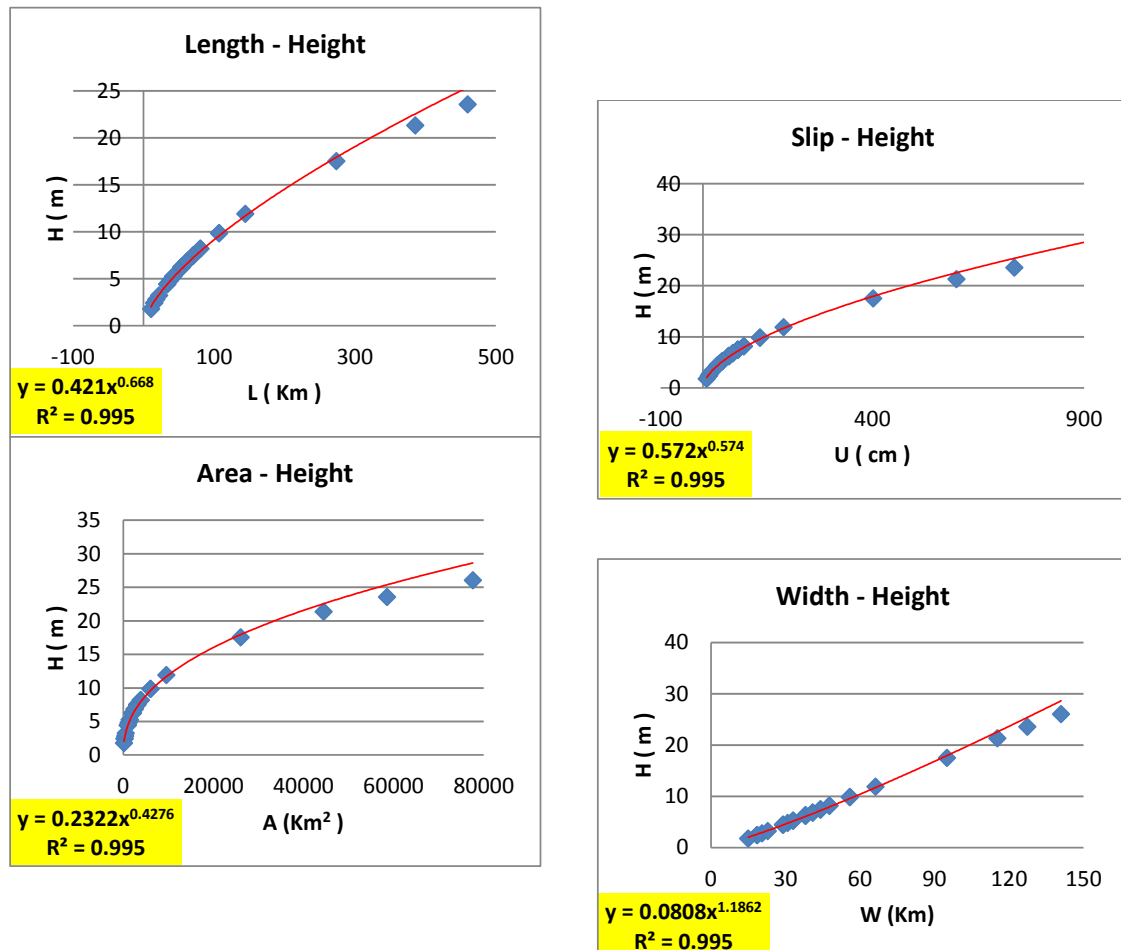


FIGURE 7. linear (left) and logarithmic (right) curve of fault size – tsunami height regression

Based on the graphic images of the above regression results (**FIGURE 7**), it is known that the correlation value indicates a value of 1, which means there is a very strong relationship between the fault sizes to the tsunami height.

Based on theory of statistics regression assessment, variable strongly correlated shown on the alignment model (r^2) near to 1. According to simple regression result, it known that moment magnitude, fault size (length, width, area, and slip) and tsunami height strongly correlated [6]. It showed on the value of r^2 near to 1. Due to the fact that, with increasing the value of moment magnitude, value of fault size and tsunami height are also increase. This strong correlation means, all historical tsunami database in Sulawesi on NOAA, Novosibirsk Tsunami Laboratory and PTWC are correct.

This methods can be effectively used to predict tsunami height in order to tsunami risk reduction by land use planning such as plantation and constructing emergency building such as break water, emergency shelter, and water purification. In the other hand, tsunami risk reduction also strongly

prevented by mitigation such as tsunami early warning system, community awareness, and education [5].

4. Conclusion

The result show that moment magnitude, fault size and tsunami height strongly correlated. Due to the fact that, with increasing the value of moment magnitude, value of fault size and tsunami height are also increase. This strong correlation means, all historical tsunami database in Sulawesi on NOAA, Novosibirsk Tsunami Laboratory and PTWC are correct.

References

- [1] A. Supassri, et al., "Relationship Between Earthquake Magnitude and Tsunami Height Along the Tohoku Coast Based On Historical Tsunami Trace Database and the 2011 Great East Japan Tsunami", Report of Tsunami Engineering Vol. 30, 37-49 (2013).
- [2] B. Priadi, "Geochimie du magmatisme de l'Oustet du Nord de Sulawesi, Indonesia: Tracage des sources et implications geodynamique," Ph.D. thesis, Universite Paul Sabatier, Toulouse, France 1993.
- [3] B. Sunardi (private communication).
- [4] C. Papazachos, et al., "Global Relations Between Seismic Fault Parameters and Moment Magnitude of Earthquakes", Bulletin of The Geological Society of Greece Vol. **36**, 1482–1489 (2004).
- [5] K. Satake, "Earthquakes and Tsunamis," in *Tsunami Lecture*, edited by S. Pribadi (International Institute of Seismology and Earthquake Engineering, Tokyo, 2008), pp. 4.
- [6] Muzli, et al., "Rapid Moment Magnitude Estimation using Strong Motion Derived Static Displacements" (Elsevier, Procedia Earth and Planetary Science, 2015), pp. 11–19.
- [7] M. Asrurifak, et al., "Development of Spectral Hazard Map for Indonesia with a Return Period of 2500 Years using probabilistic Method", Civil Engineering Dimension Vol. **12 No. 1**, 52-62 (2010).
- [8] NGDC/WDS Global Historical Tsunami Database available at https://www.ngdc.noaa.gov/hazard/tsu_db.shtml , accessed May 2015
- [9] Novosivirsk Russia Tsunami Laboratory Catalogue available at http://tsun.sccc.ru/On_line_Cat.htm, accessed May 2015.