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ANALYSIS OF CIANJUR EARTHQUAKE IN 2022 USING OMORI, MOGI-UTSU I, MOGI-UTSU II AND UTSU METHODS

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Abstract. This study looks at how long aftershocks last by looking at how often earthquakes happen and when they occur in days. The earthquake we studied was the Cianjur earthquake, which happened on November 11, 2022. The data used amounted to 384 aftershocks over 14 days. This data was obtained from social media by Dr. Daryono, S. Si, M. Si as the heads of the Earthquake and Tsunami Center-BMKG. To calculate the end time of aftershocks, empirical formulas are used from 4 methods, namely the Omori Method, the Mogi-Utsu I Method, the Mogi-Utsu II Method, and the Utsu Method. Various results with correlation coefficients related to the end of aftershocks were obtained from the results of the calculations using four methods. The best way to figure out when the Cianjur earthquake will stop is by using the Omori method, which is called. that the earthquake will end on the 86th day for n(t) = 1, assumed to end on February 5, 2022, with a coefficient of correlation of 0.761742.

Keywords: *earthquake, mogi, utsu, omori, aftershock*

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INTRODUCTION

Indonesia is one of the countries in the world that experiences a lot of earthquakes. This is because Indonesia is located where three major tectonic plates meet, which are the Eurasian Plate, the Pacific Plate, and the Indo-Australian Plate. The area is prone to frequent seismic activity due to this positioning high level of seismicity and volcanism in Indonesia is a direct result of the tectonic processes in this region (Pusgen, 2017). This makes several regions in Indonesia vulnerable to earthquakes, one of which is earthquake activity on the island of Java. For example, at the end of 2022, there was a Mw 5.6 earthquake in West Java, precisely on November 11, 2022, located in Cianjur Regency, West Java.

Based on data from BMKG, the trigger of the Cianjur earthquake with a magnitude of 5.6 was the Cugenang fault. Mrs. Dwikorita Karnawati as the Head of BMKG said that the Cugenang fault is a newly identified fault with various analyses such as focal mechanism and distribution of aftershock points, analysis of satellite images and aerial photographs, field surveys, distribution of landslide points, morphological alignment and distribution patterns of building damage. Then according to temporary information from BNPB until November 30, 2022, the Cianjur earthquake has caused 328 casualties and 17,864 houses were damaged.

Based on these conditions, the analysis of aftershock decay is important to know the estimated end of the Cianjur aftershock and to analyze the calculation method suitable for that location. The data used in this study are aftershock distribution data from day 1 to day 14 after the main earthquake occurred, obtained from the social media of Dr. Daryono, S.Si, M.Si as Head of the Center for Earthquakes and Tsunamis - BMKG.

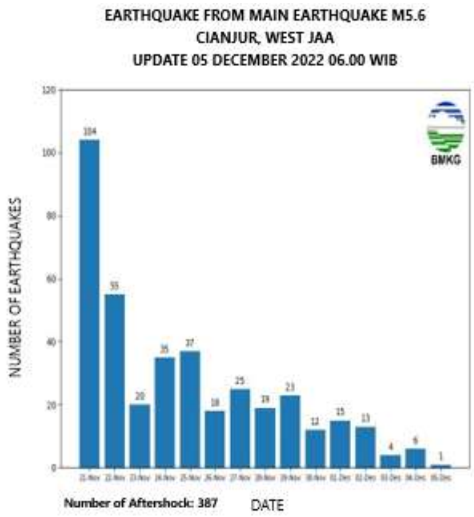

Figure 1. Distribution of Cianjur aftershocks (BMKG, 2022)

METHODS

To figure out when the Cianjur aftershock might end, four different methods were used: Omori, Mogi-Utsu I, Mogi-Utsu II, and Utsu.

1. Omori method

According to Omori (1894), the level of aftershock activity in the relationship between aftershock frequency [n (t)] and time [t] is:

Number of Aftershock: 387 DATE

$n(t) \quad t+c \quad [-]$

Description:

n(t) = Number of aftershocks over time

t = time (days)

k, c = constants, k=intercept and c=gradient/slope

To obtain the values of k and c, the linear regression method is used, where the Omori equation is as follows.

$$\frac{1}{n(t)} = \frac{c}{k} + \frac{1}{k}.t \sim Y = A + BX$$

where :

$Y = \frac{1}{n(t)}$ ~ earthquake frequency

$A = \frac{c}{k}$ ~ constant

$B = \frac{1}{k}$ ~ constant

X = *t* ~ time

2. Mogi-Utsu Method I

According to Mogi (1962) and Utsu (1957), this shows the level of aftershock activity lasting at least 100 days, in the relationship between earthquake frequency and time.

$$n(t) = a.t^{-b} \quad [2]$$

Description:

n(t) = Number of aftershocks over time

t = time (days)

a,b = constants, a=intercept and b=gradient slop

To obtain the values of a and b, the linear regression method is used, where the Omori equation is as follows.

$$log\, n(t) = log\, a - b.log\, t \sim Y = A + BX$$

where :

Y=log n(t) ~ earthquake frequency

A=log a ~ constant

B=-b ~ constant

X=log t ~ time

3. Mogi-Utsu II Method

Based on the work of Mogi (1962) and Utsu (1957), the level of aftershock activity within the first 100 days shows how earthquake frequency changes over time.

$$n(t) = a.e^{-t.b} \quad [3]$$

Description:

n(t) = Number of aftershocks over time

t = time (days)

a, b = constants, a=intercept and b=gradient/slope

To obtain the values of a and b, the linear regression method is used, where the Omori equation is as follows.

$$ln\, n(t) = ln\, a - b.t \sim Y = A + BX$$

where :

Y=ln n(t) ~ earthquake frequency

A=ln a ~ constant

B=-b ~ constant

X=t ~ time

4. Utsu method

The Utsu method is a modification of the Omori equation by Tokuji Utsu that is used to analyze the decay of aftershocks in a region. The frequency of aftershocks per unit time interval (1 day, 1 month, etc.) is well represented by the modified Omori formula as follows:

$$n(t) = k(t + c)^{-p} \quad [4]$$

Description:

n(t) = Number of aftershocks over time

t = time (days)

k, c, p = constants, *k*=intercept, *p*= gradient/slope, and *c*=0.01

To obtain the values of a and b, the linear regression method was used, where Utsu's equation is as follows.

$$log\, n(t) = log\, k - p.log\,(t + c) \sim Y = A + BX$$

where :

Y=log n(t) ~ earthquake frequency

A=log k ~ constant

B=-p ~ constant

X=log (t+c) ~ time

By inputting aftershock frequency data (X) and time (Y) into the equations of each method, the coefficients A and B are obtained with the following formulas.

$$B = \frac{n(\Sigma XY) - \Sigma X.\Sigma Y}{n(\Sigma X^2) - (\Sigma X)^2} \quad [5]$$

$$A = \frac{\Sigma Y - B.\Sigma X}{n} \quad [6]$$

The next step is to find the value of the correlation coefficient (r) to determine how strong the relationship is between variables X (earthquake frequency) and Y (time) with the following formula.

$$r = \frac{n(\Sigma XY) - \Sigma X.\Sigma Y}{\sqrt{(n(\Sigma X^2) - (\Sigma X)^2)(n(\Sigma Y^2) - (\Sigma Y)^2)}} \quad [7]$$

Then the values of A and B are re-entered into the linear equation of each method with n(t) equal to 1 so that a value of t can be obtained, which will be assumed to be the cessation time of the aftershocks.

RESULTS AND DISCUSSION

Based on statistical calculations of earthquake decay in Cianjur, these four methods get varying results. The earthquake decay that occurs decreases in space and time, because the broken rock immediately finds its equilibrium point (Sasabil, 2019). The table below shows the results from the calculation of when the aftershocks in Cianjur ended on November 11, 2022.

Tabel 1. Calculation results of the end time of the aftershock in Cianjur on November 11, 2023

Methods	Correlation Coefficient	Time of Expiration (Days)	Date
Omori	0.761742	86	5 February 2023
Mogi 1	-0.870884	146	6 April 2023
Mogi 2	-0.889656	24	5 December 2022
Utsu	-0.861822	202	1 June 2023

The Omori method resulted in the calculation that on the 86th day the Cianjur aftershock ended. It is estimated that the aftershocks will end on February 5, 2023. The correlation coefficient obtained in the Omori method is 0.761742. The Mogi-Utsu I method produced calculations on the 169th day the Cianjur aftershock ended. It is estimated that the aftershocks are expected to stop on April 6, 2023. The correlation coefficient obtained in the Mogi-Utsu I method is 0.870884. Although this method is theoretically suitable for the time when aftershocks end (t≥100 days), it is considered inaccurate in describing the conditions of the Cianjur aftershock because, as of January 6, the frequency of aftershocks had stabilized with aftershock frequencies ranging from 0 to 3 per day and magnitudes ranging from 1 to 2.5.

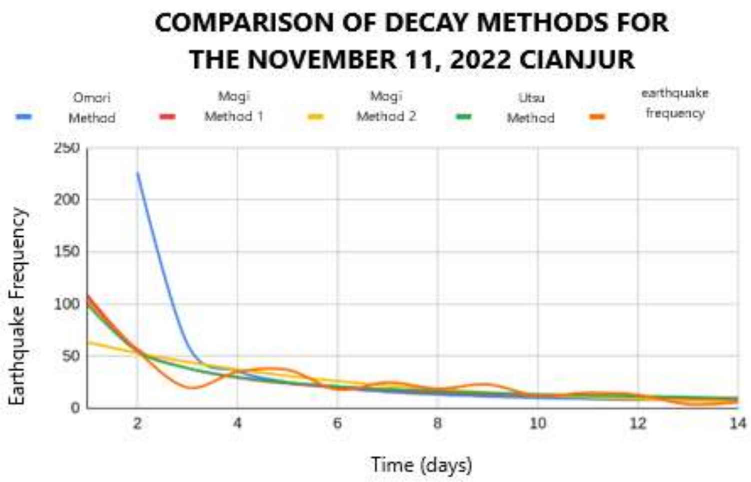

Figure 2: Comparison graph of true earthquake frequency against the four decay methodsV

The Mogi-Utsu II method produced calculations on the 24th day of the Cianjur aftershock. It is estimated that The aftershocks will stop on December 5, 2022. The correlation coefficient from the Mogi-Utsu II method is -0. 889656. This method is considered inappropriate because the Cianjur aftershock is still ongoing. A similar trend was reported by Nurfitriani and Hadi [8], who found that the West Java subduction zone often exhibits aftershock behavior that diminishes rapidly within the first 30 days, consistent with the Omori model rather than Mogi-Utsu or Utsu. The Utsu method produces a calculation on the 202nd day that the Cianjur aftershock will end. It is estimated that the aftershocks will end on June 1, 2023. The correlation coefficient obtained in the Utsu method is -0.861822. Similar to the Mogi-Utsu I method, the Utsu method is considered less precise because the real aftershock data is stable and the magnitude ranges from 1 to 2.5 M. Ardiansyah and Mulyana [9] confirmed that in Java, the Omori law consistently produced the closest approximation to actual aftershock sequences, unlike in Eastern Indonesia where Mogi or Utsu performed better.

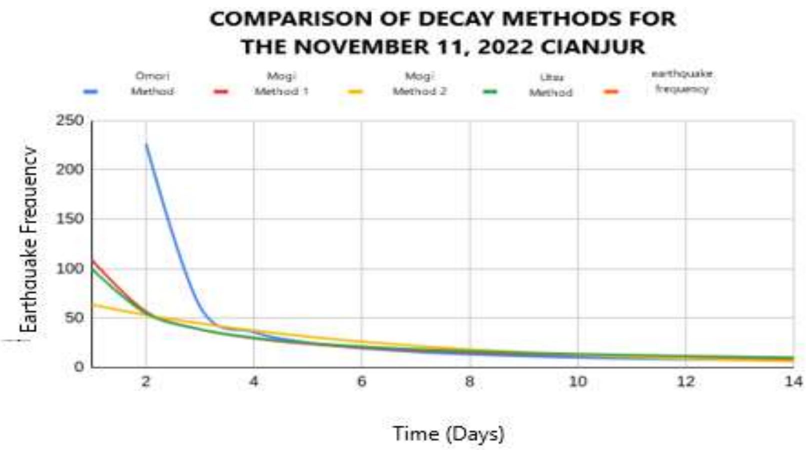

Figure 3. Comparison stage of the 4 decay methods

Some studies also explain that the most appropriate method to use in describing aftershock activity that occurs on the island of Java is the Omori method. This is also supported by fault mapping studies in Cianjur, which revealed that the geometry of the Cugenang Fault may contribute to the aftershock pattern [10]. This is because the results obtained through statistical calculations are close to the real results in the field. According to Rohmawati Tita (2018), because the results from data processing and analysis show that the time when aftershocks stop in each area is different, the Sumatra, Java, and Sulawesi regions work best with the Omori method. This is because the results from this method are very close to what is actually seen in the field. Data from BMKG in early January 2023 showed that aftershock activity in these areas dropped to fewer than 3 events per day, which supports this finding [11]. The Papua region is best described using the Mogi II method, the Maluku region uses the Utsu method, and the Kalimantan region also fits best with the Mogi II method.

The correlation coefficient in the Omori method is positive, meaning the X and Y variables, which have been made straight using equation [7], have a direct or one-way relationship. The closer the coefficient is to +1, the stronger and more positive the connection is. On the other hand, the correlation coefficients in the Mogi-Utsu I, Mogi-Utsu II, and Utsu methods are negative, showing that the X and Y variables have an opposite or reverse relationship. A coefficient near -1 shows a strong negative link. The decrease in the number of earthquake frequencies indicates that the residual energy released after the main earthquake also decreased over time as the movement of shifting rocks began to find its equilibrium point. This is also reflected in BNPB's emergency report which noted that most disaster recovery efforts were completed within two months after the quake [12]. Daryono [13] also reported no significant energy release beyond early January, validating the Omori model's reliability in this case. These findings are in line with prior Indonesian case studies using statistical approaches [8], [9].

CONCLUSION

Based on the research that was done, the best way to figure out when the aftershocks in Cianjur ended on November 11, 2022, is by using the Omori Method. This method shows that the earthquake's aftershocks stopped on the 86th day. for n(t) = 1, assumed to end on February 5, 2022 with a correlation coefficient of 0.761742. This calculation is in accordance with the BMKG earthquake repository website data as of January 6, 2023, the Cianjur aftershocks have stabilized with earthquake frequencies of 0 to 3 per day and magnitudes ranging from 1 to 2.5 M.

REFERENCES

[1] Putratama, R. (2022, December 10). Gempa Cianjur Disebabkan Sesar Cugenang, BMKG Dorong Pemkab Cianjur Relokasi 9 Desa. BMKG. Retrieved January 19, 2023, from https://www.bmkg.go.id/berita/?p=gempa-cianjur-disebabkan-sesar-cugenang-bmkg-dorong-pemkab-cianjur-relokasi-9-desa&lang=ID

[2] Harna, Arsyad, M., & Tiwow, V. A. (2020). Analisis Seismisitas dan Peluruhan Gempa Bumi (Studi kasus Gempa Bumi Banggai 12 April 2019). Seminar Nasional Fisika 2020 Program Pascasarjana Universitas Negeri Makassar, Hal 44-47.

[3] Salsabil A. K., Ginting, R. A., A, Qadri., & A, Kamal. M. (2019). Analisis Peluruhan Gempa Bumi Menggunakan Metode Omori,Mogi-Utsu I Dan Mogi-Utsu II (Studi Kasus Gempa Bumi Banten 23 Januari 2018). Prosiding Seminar Nasional Fisika (E-journal), Vol. VIII, SNF2019-PA-7–14.

[4] Irsyam M, Widiyantoro S, Natawidjaja DH, Meilano I, Rudyanto A, Hidayati S, Triyoso W, Hanifa NR, Djarwadi D, Faizal L, Sunarjito (eds) (2017). Peta sumber dan bahaya gempa Indonesia tahun 2017, Cetakan pertama. Pusat Penelitian dan Pengembangan Perumahan dan Permukiman, Badan Penelitian dan Pengembangan, Kementerian Pekerjaan Umum, Bandung

[5] Vellicia, Audrey, Komang N. Suarbawa, and Rudy Darsono. 2019. “Penentuan Asumsi Waktu Berakhirnya Gempa Susulan Studi Kasus Gempabumi Lombok 5 Agustus 2018.” *Kappa Journal Program Studi Pendidikan Fisika FMIPA Universitas Hamzanwadi* 3, no. 2 (Desember): 99-104.

[6] T. Rohmawati, Analisis Waktu Berakhirnya Gempa Bumi Susulan dengan Menggunakan Metode Omori, Mogi I, Mogi II, dan Utsu untuk Kejadian Gempa Bumi di Indonesia Tahun 2009-2017, Bandung: UIN Sunan Gunung Djati, 2018.

[7] Faradilla, A. (2022, November 29). [UPDATE] 327 Orang Meninggal Dunia Pasca Gempa Cianjur. BNPB. Retrieved January 19, 2023, from https://bnpb.go.id/berita/-update-327-orang-meninggal-dunia-pasca-gempa-cianjur-

[8] M. Sari and N. T. Puspito, “Statistical Analysis of Aftershock Sequences in Indonesia Using Modified Omori Law,” *Indonesian Journal of Geophysics*, vol. 15, no. 2, pp. 112–121, 2021.

[9] F. Ardiansyah and A. Mulyana, “Comparative Analysis of Aftershock Decay Using

Omori and Utsu Models in Eastern Indonesia," *Jurnal Sains Atmosfer dan Bumi*, vol. 4, no. 1, pp. 45–53, 2023.

[10] B. Kurniawan and D. Prabowo, "Identifikasi Sesar Aktif Menggunakan Citra Satelit di Sekitar Cianjur Jawa Barat," *Majalah Geologi Indonesia*, vol. 35, no. 2, pp. 78–85, 2020.

[11] BMKG, "Katalog Gempa Bumi Indonesia Tahun 2022," Badan Meteorologi Klimatologi dan Geofisika, 2022. [Online]. Available: https://www.bmkg.go.id/

[12] H. Sutopo, "Penanganan Bencana Cianjur 2022 dan Pembelajaran Tanggap Darurat," BNPB, 2022.

[13] S. Daryono, "Fenomena Gempa Cianjur: Analisis Awal dan Rekomendasi Mitigasi," Pusat Gempa dan Tsunami BMKG, 2023.

[14] M. Sari and N. T. Puspito, "Statistical Analysis of Aftershock Sequences in Indonesia Using Modified Omori Law," *Indonesian Journal of Geophysics*, vol. 15, no. 2, pp. 112–121, 2021.

[15] R. Wulandari and A. D. Nugraha, "Seismicity Pattern and Aftershock Decay in West Java Region," *Jurnal Geofisika Eksplorasi,* vol. 23, no. 1, pp. 33–40, 2020.