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# ANALYSIS OF LANDSLIDE POTENTIAL IN GUNUNG OMEH SUB-DISTRICT LIMA PULUH KOTA REGENCY USING HVSR METHOD

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**Abstract.** On BPBD Lima Puluh Kota designated Gunung Omeh Sub-district as a disaster-prone area due to the detected potential of moving soil. This mobile soil causes gaps in the soil with the potential to continue to move at any time and is exacerbated by unstable soil conditions that cause the risk of landslides. Therefore, there is a need for research in Gunung Omeh sub-district on landslide potential. This research aims to analyse the landslide potential in Gunung Omeh sub-district. Data collection is limited to 9 measurement points using a set of Sysmatrack MAE seismograph sensor type S3S. The data generated is in the form of seismic wave signals which are then processed with the HVSR method using Geopsy software to produce H/V curves with parameters $A_0$ and $f_0$. From these two parameters, the values of soil susceptibility index ($K_g$) and ground shear strain ($\gamma_g$) are obtained. The results showed that the susceptibility index ranged from 0.26 x $10^{-6}$ $s^2$/cm to 16.34 x $10^{-6}$ $s^2$/cm and ground shear strain ranged from 1.32 x $10^{-4}$ to 2.15 x $10^{-6}$. Thus, the highest landslide potential is found at point 6 with the highest susceptibility index of 16.34994479 and ground shear strain of 1.32x$10^{-4}$.

**Keywords**: *Landslide, HVSR, Seismic Susceptibility, Ground Shear Strain*
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## INTRODUCTION

Landslides are among the most significant natural damaging events in mountain environments. They are one of the primary causes of property damage, loss of life and injuries of persons [1]. Landslides are one of the most common natural disasters in Indonesia. This is because Indonesia has many hilly areas with steep slopes. In addition, the tropical climate results in high rainfall in most parts of Indonesia which is also one of the factors causing landslides. on September 8, 2021 in Nagari Sarilamak, Harau District, Lima Puluh Kota Regency there was high-intensity rain and unstable soil contours resulting in landslides. Landslides is one of the natural disaster symptoms of mass movement of soil or rock down the slope. Landslides are caused by destabilization of the soil or rocks that make up the slope [2]. Soil characteristic parameters that influence the occurrence of landslides include soil texture, which is related to the movement of water and solutes,air, heat movement, soil volume weight, specific surface area, ease of soil compaction, etc. Lima Puluh Kota districk is an area that has a high level of vulnerability to landslides, although so far there have been no casualties due to natural disasters, especially in the Gunung Omeh District. Gunung Omeh Sub-district has an area of 156.54 km², located at an altitude of 800-1100 meters above sea level, has a topography formed by sedimentary rocks, igneous rocks and volcanic products located in the Barisan range zone. On November 24, 2022 BPBD Lima Puluh Kota designated Gunung Omeh Sub-district as a disaster-prone area due to the detected potential of moving soil. This mobile soil causes gaps in the soil with the potential to continue moving at any time and is exacerbated by unstable soil conditions that cause the risk of landslides so that attention is needed to this area.

Efforts to minimize the impact caused by landslides are through disaster mitigation. One of the ways of disaster mitigation that can be done is by identifying areas that have the potential to experience landslides. The identification is done by using geophysical method, namely HVSR (Horizontal to Vertical Spectral Ratio) method. The HVSR method is one of the measurement methods that can be used to determine the characteristics of the subsurface layer structure without causing damage to the structure[3]. Data processing using the HVSR method produces two parameters, namely the dominant frequency factor ($f_0$) and the dominant amplification factor ($A_0$) where the dominant frequency represents the rock layer[4] These two parameters are used to obtain seismic vulnerability index and ground shear strain values which are useful as parameters for analysis in identifying potential landslide areas. So from the above problems, further research was conducted on the potential of landslides in Gunung Omeh sub-district.

## RESEARCH METHOD

The research method began by taking measurements at 9 points in the Gunung Omeh sub-district with 55 minutes of insurance. Then, the results of microtremor measurements are processed based on the HVSR method. The HVSR method is used to identify local subsurface structures seen from physical parameters in the form of frequency and amplification which are used to estimate the seismic vulnerability index[5]. Then, it is analyzed using geopsy software to obtain an H/V graph to obtain frequency ($f_0$) and amplification ($A_0$) values[6].The dominant frequency is the frequency value of the rock layer in the area to show the type and characteristics of the rock. Based on the frequency of the soil, it is formulated with the following equation (1):

$$f_0 = \frac{v_b}{4AH} \qquad (1)$$

Where $v_b$ is the wave velocity below the ground surface, A is the amplification factor and H is the sediment thickness[7].
The following soil classification based on the dominant frequency according to Kanai can be seen in table 1 below:

**Table 1.** Classification of Seismic Vulnerability Values [8]

| No | Dominant frequency (Hz) | Description | Categories |
|---|---|---|---|
| 1 | 6,667 – 20 | The thickness of the surface sediments is very thin, dominated by hard rocks. | Hard |
| 2 | 10 – 4 | The thickness of the surface sediments falls into the medium category of 5 - 10 meters. | Medium |
| 3 | 2,5 – 4 | Surface sediment thickness falls into the thick category of about 10 - 30 meters | Soft |
| 4 | < 2,5 | The thickness of the surface sediments is very thick. | extremely soft |

Amplification gives an idea of the change (magnification) of ground motion acceleration of the surface bedrock. The amplification equation can be seen in equation (2) below:

$$A_0 = \frac{\rho_b . v_b}{\rho_s . v_s} \qquad (2)$$

Where $\rho_b$ is the density of bedrock (gr/ml), $\rho_s$ is the density of soft rock (gr/ml), $v_b$ is the speed of wave propagation in bedrock (m/s) and $v_s$ is the speed of wave propagation in soft rock (m/s)[9].
The following amplification classification can be seen in Table 2 below:

**Table 2.** Classification of Dominant Amplification [10]

| Zone | Classification | Amplification Factor Value | Colors in the mapping |
|---|---|---|---|
| 1 | Low | < 3 | Green |
| 2 | Medium | 3 – 6 | Blue |
| 3 | High | 6 – 9 | Yellow |
| 4 | Extremely High | ≥ 9 | Red |

Based on the frequency and amplification, the vulnerability index value is obtained using the following equation (3):

$$K_g = \frac{A^2}{f_0} \qquad (3)$$

where $K_g$ is seismic susceptibility, $A_0$ is amplification and $f_o$ is frequency
The classification of seismic vulnerability index values can be seen in table 3 below:

**Table 3**. Classification of seismic vulnerability index values[11]

| Zone | Value Kg |
|---|---|
| Low | <3 |
| Medium | 3-6 |
| High | >6 |

The value of ground shear strain in an area estimates the potential for soil layers to shift and move due to earthquake impacts. Ground Shear Strain is applied to impacts caused by earthquakes including landslides, liquefaction, subsidence and ground shaking[12]. The ground shear strain value can be seen in equation 4 below:

$$\gamma_g = K_g \times 10^{-6} \times \alpha \qquad (4)$$

Where $\gamma_g$ is strain seismic, $K_g$ is seismic susceptibility $\alpha$ adalah PGA

Another input parameter used is Peak Ground Acceleration (PGA), PGA is the value of ground acceleration at a place of earthquake vibration in a certain period of time[13]. The parameters used to obtain the PGA value are the strength of the earthquake and the distance of the earthquake hypocenter to the measurement location. The PGA equation can be seen in equation (5) below:

$$\alpha = 427e^{0,278Mw}(R + 25)^{-1.301} \qquad (5)$$

Where $\alpha$ is PGA, $M_w$ is earthquake strength and R is hypocenter distance to the measurement site
With

$$R = \sqrt{\Delta^2 + h^2} \qquad (6)$$

$$\Delta = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2} \qquad (7)$$

Where $X_1$ is latitude of epicenter, $X_2$ latitude of the measurement point (°), $Y_1$ is longitude of epicenter (°), $Y_2$ is longitude of the measurement point (°), Δ is distance episenter (1° = 111,1 km) and h is the depth of the earthquake.

## RESULTS AND DISCUSSIONS

Data collection in the research in Gunung Omeh District, Lima Puluh Kota Regency using the HVSR method was carried out at nine points with different coordinates. The distance between measurement points is around 500-700 meters and 55 minutes of recording time. After obtaining the recorded data, the data was processed using Geopsy software to convert the time form to frequency using the FFT process to obtain the H/V curve[14]. The H/V curve shows the analysis of seismic wave data to obtain the dominant amplification value and dominant frequency. The amplification and dominant frequency are related to the type and character of the soil and sediment layer by using equations (1) and (2), then the analysis of frequency and amplification can be seen in table 4 below:

**Table 4.**Frequency and amplification analysis

| Points | Longitude (m) | Latitude (m) | Dominant Amplification | Classification | Dominant Frequency (Hz) | Soil Character Classification |
|---|---|---|---|---|---|---|
| 1 | 100.412538 | -0.093735 | 4.29631 | Medium | 3.05425 | Soft |
| 2 | 100.4 14253 | -0.094846 | 2.94077 | Low | 8.25293 | Hard |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | 100.412178 | -0.090658 | 3.64844 | Medium | 2.96886 | Soft |
| 4 | 100.413076 | -0.088669 | 4.26677 | Medium | 7.53724 | Hard |
| 5 | 100.414812 | -0.090216 | 2.845 | Low | 4.57499 | Medium |
| 6 | 100.416951 | -0.090026 | 6.6508 | High | 2.7054 | Soft |
| 7 | 100.41535 | -0.09373 | 3.67754 | Medium | 5.92698 | Medium |
| 8 | 100.411231 | -0.092512 | 1.79365 | Low | 12.0908 | Hard |
| 9 | 100.413712 | -0.091405 | 3.12717 | Medium | 6.81838 | Hard |

Based on Table 4, the results of the dominant frequency analysis can be concluded that Points 1, 3 and 6 have soft soil characteristics, points 5 and 7 have medium soil characteristics and points 2, 4, 8 and 9 have hard soil characteristics. Frequency is related to the type and character of the soil and the thickness of the sediment layer. The smaller the dominant frequency value ($f_0$), the thicker the sediment layer and the deeper the base layer. And for theoretical amplification if the dominant amplification value ($A_0$) is greater then the sediment in the area is softer and vice versa. Based on table 4, it can be concluded that the classification is low to high. With the highest peak at point 9 and has a soft sedimentary soil condition. Then, from the frequency and amplification values, the seismic vulnerability index value is obtained [15]. using equation (3). The following are the results of the seismic vulnerability analysis and its classification based on Table 5:

**Table 5.** Soil Vulnerability Analysis

| **Points** | **Longitude (m)** | **Latitude (m)** | **Seismic Vulnerability Index ($K_g$)** | **Classification** |
|---|---|---|---|---|
| 1 | 100.412538 | -0.093735 | 6.043473722 | High |
| 2 | 100.414253 | -0.094846 | 1.047885805 | Low |
| 3 | 100.412178 | -0090658 | 4.483577681 | Medium |
| 4 | 100.413076 | -0.088669 | 2.415383646 | Low |
| 5 | 100.414812 | -0.090216 | 1.769189659 | Low |
| 6 | 100.416951 | -0.090026 | 16.34994479 | High |
| 7 | 100.41535 | -0.09373 | 2.281819823 | Low |
| 8 | 100.411231 | -0.092512 | 0.266084984 | Low |
| 9 | 100.413712 | -0.091405 | 1.434239835 | Low |

Based on Table 5, it explains the vulnerability index values data at 9 research points. Analyzed the vulnerability index values of frequency and amplification values in the Gunung Omeh sub-district area. The seismic vulnerability index value obtained ranges from 0.266084984 to 16.34994479 with a classification in the low to high category. It can be seen that the highest value is at point 6 with a high classification and the lowest at point 8 with a low classification. The following contour map of the seismic vulnerability index analysis results based on table 5 is shown in figure 1:

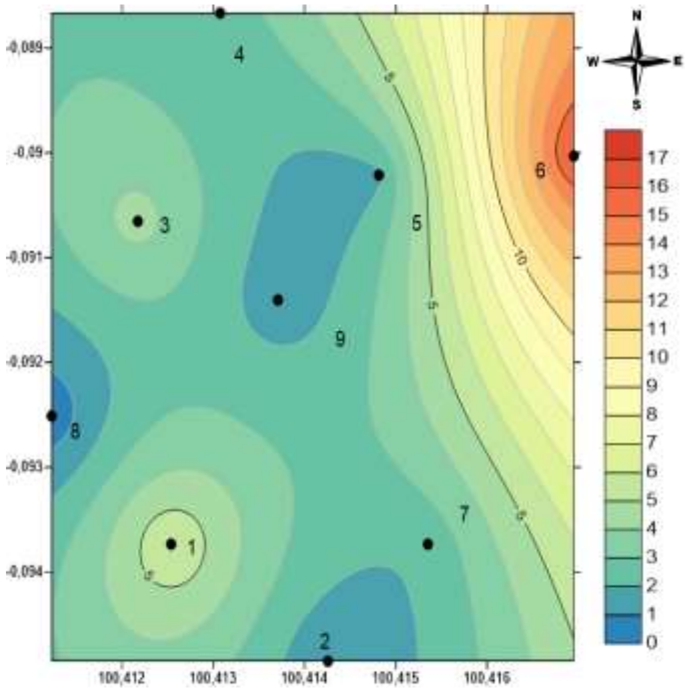


**Figure 1**. Seismic Vulnerability Index Distribution Map

Figure 1 shows a contour map with soil susceptibility index value of Gunung Omeh Sub-district ranges from 0 to 17 by connecting the susceptibility index value in table 5, then obtained soil susceptibility index of Gunung Omeh Sub-district especially aisle Pandam Gadang is included in the low to high landslide potential zone. Points 2, 5, 8 and 9 are dominated by blue color so they have low landslide potential, points 1, 3, 4 and 7 are dominated by green to yellow color so they have medium landslide potential and point 6 is dominated by red so it has high landslide potential. This is in line with the opinion of Rendi W.K and Wahyudi N.P which states that if the value of seismic vulnerability is greater, the level of risk of damage caused will be greater[16].

The level of risk of damage is also related to the geological conditions in the Gunung Omeh sub-district, especially the Pandam Gadang area, which has constituent materials consisting of pumice and andesite, Miocene sandstone and early tertiary andesite. According to the rock constituent material, the density characteristics of this type of rock are relatively small because this rock constituent material is classified as having low to medium water permeability[17]. The characteristics of these materials in the rainy season have the ability to absorb water and have the potential for landslides. The ground shear strain value is influenced by the seismic vulnerability index and peak ground acceleration (PGA) [18]. Next, to analyze the strain value ($\gamma_g$) obtained based on equation (4) shown in table 6:

**Table 6.** Analysis of soil shear strain values

| Point | Longitude (m) | Latitude (m) | Ground Shear Strain ($\gamma_g$) |
|---|---|---|---|
| 1 | 100.412538 | -0.093735 | 4.87x10$^{-5}$ |
| 2 | 100.414253 | -0.094846 | 8.42x10$^{-6}$ |
| 3 | 100.412178 | -0.090658 | 3.63x10$^{-5}$ |
| 4 | 100.413076 | -0.088669 | 1.96x10$^{-5}$ |
| 5 | 100.414812 | -0.090216 | 1.43x10$^{-5}$ |
| 6 | 100.416951 | -0.090026 | 1.32x10$^{-4}$ |
| 7 | 100.41535 | -0.09373 | 1.83x10$^{-5}$ |
| 8 | 100.411231 | -0.092512 | 2.15x10$^{-6}$ |
| 9 | 100.413712 | -0.091405 | 1.16x10$^{-5}$ |

Table 6 shows the shear strain data obtained from 9 test points. The shear strain values obtained ranged from 2.15x10$^{-6}$ to 1.32x10$^{-4}$ . The higher the shear strain value of an area, the higher the landslide potential of the area. It can be seen that the highest value is found at point 6 with a value of 2.15x10$^{-6}$ and the lowest value is found at point 8 with a value of 1.32x10$^{-4}$ . According to Table 6, the soil shear strain distribution map is shown in Figure 2:

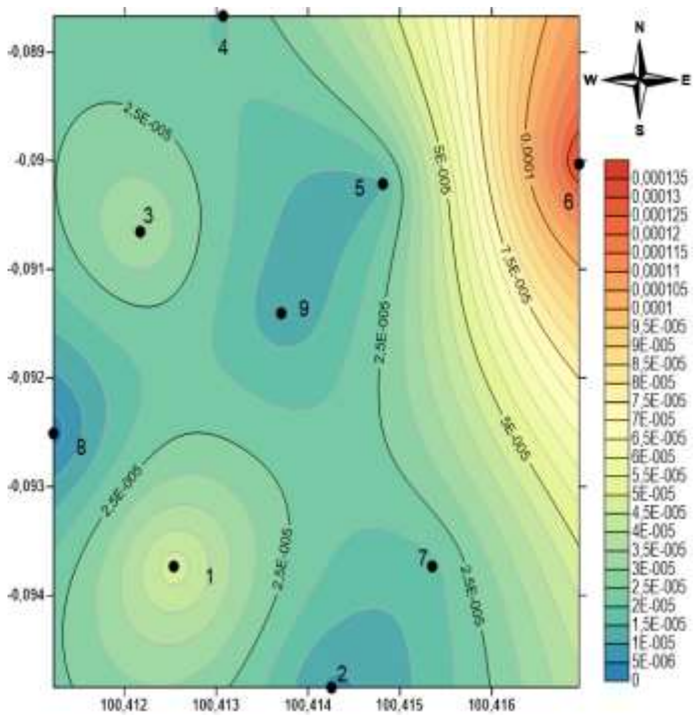

**Figure 2.** Strain distribution map in Gunung Omeh Sub-district

Figure 2 is a contour map of the ground shear strain value in Gunung Omeh Subdistrict specifically Jorong Pandam Gadang by connecting with table 3, It is obtained that the ground shear strain is included in the low to high landslide potential zone. Points 2, 5, 8 and 9 are dominated by blue color so they have low landslide potential, points 1, 3, 4 and 7 are dominated by green to yellow color so they have moderate landslide potential and point 6 is dominated by red color so it has high landslide potential. The soil layer will experience static conditions if the shear strain value is around 100 x $10^{-6}$ and for shear strain values >10,000 x $10^{-6}$ soil conditions are prone to fractures, landslides, and liquefaction in the event of an earthquake[19]. Some plate boundaries glide past each other smoothly, while others are punctuated by catastrophic failures. Some earthquakes stop after only a few hundred metres while others continue rupturing for a thousand kilometres. Earthquakes are sometimes triggered by other large earthquakes thousands of kilometres away [20]. The strain value obtained in the Gunung Omeh sub-district of Lima Puluh Kota regency is about 0.266084984 and the soil strain is 2.15x10-6. From the value of soil shear strain obtained from the research site, several points have the potential to experience the phenomenon of landslides, soil compaction and liquefaction. According to the research of Ayu Shaleha et al, who also studied the identification of soil layer structure in landslide prone areas in Banyubiru Subdistrict, Semarang Regency using HVSR method. Based this research, the strain results obtained were 10.5 x 10-1- 191.8 x 10-1, thus showing the potential for landslides.

It can be concluded that the analysis of potential landslides uses the HVSR method with parameters of seismic vulnerability index and soil shear strain: Potential landslides in Gunung Omeh District are divided into 3 categories. The 3 categories are low, medium and high. The highest value is shown at point 6 with susceptibility index value of 16.34994479 and soil strain of 1.32 x $10^{-4}$. The lowest value at point 8 with susceptibility index value of 0.266084984 and soil strain of 2.15x$10^{-6}$. The analysis is also validated by the soil characteristics, strain, and geology of Gunung Omeh Sub-district.

## CONCLUSIONS

Based on the result of the research, it can be concluded that the landslide potential using HVSR method with seismic susceptibility parameter ($K_g$) has a value range of 0.266084984-16.34994479 and ground shear strain with a value range of 2.15 x $10^{-6}$-1.32 x $10^{-4}$. Landslide potential in Gunung Omeh sub-district has low to high potential where the highest landslide potential is shown at point 6 (northeastern part of the study area) with a vulnerability index value of 16.34994479 and ground shear strain of 1.32 x $10^{-4}$. The research results also refer to the soil characteristics, strain and geology of Gunung Omeh District.

## REFERENCE

[1] Jan Blahut, Cees J. van Westen, Simone Sterlacchini. (2010). "Analysis of landslide inventories for accurate prediction of debris-flow source areas". Geomorphology, Volume 119 (Issues 1-2), Pages 36-51

[2] R. Amukti, "Identifikasi Kerentanan Longsor Daerah Pangalengan Dengan Metode Slope Morphology," 2017. [Online]. Available: http://journal2.um.ac.id/index.php/jpse

[3] C Damayanti and Sismanto, 2021," Analysis of potential soil fracture based on ground shear strain values in Solok, West Sumatra," IOP Conf. Ser.: Earth Environ. Sci. 789 012058

[4] I. N. Risa, M. Maison, and I. K. Dewi, "Analisis Kerentanan Tanah Berdasarkan Pengukuran Mikrotremo di Desa Jati Mulyo, Tanjung Jabung Timur," *JGE (Jurnal Geofisika Eksplorasi)*, vol. 9, no. 1, pp. 18–31, Mar. 2023, doi: 10.23960/jge.v9i1.236.

[5] Arif Ismul Hadi, Refrizon, M. Farid, Budi Harlianto, and Julia Inti Sari, "Landslide Potential Investigation for Disaster Risk Reduction in Central Bengkulu Regency, Bengkulu Province, Indonesia," Indonesian Journal on Geoscience, Vol. 8 No. 3 December 2021

[6] G. Dal Moro, "On the Identification of Industrial Components in the Horizontal-to-Vertical Spectral Ratio (HVSR) from Microtremors," *Pure Appl Geophys*, vol. 177, no. 8, pp. 3831–3849, Aug. 2020, doi: 10.1007/s00024-020-02424-0.

[7] M. Mucciarelli and M. R. Gallipoli, "A critical review of 10 years of microtremor HVSR technique Project INSIEME (Induced Seismicity in Italy: Estimation, Monitoring, and sEismic risk mitigation)," 2015. [Online]. Available: https://www.researchgate.net/publication/279895512

[8] M. I. Nurwidyanto, M. Zainuri, A. Wirasatrya, and G. Yuliyanto, "Struktur Bawah Permukaan Pantai Semarang berdasarkan Metode HVSR," *Indonesian Journal Of Applied Physics*, vol. 13, no. 1, pp. 117–127, Apr. 2023, doi: 10.13057/ijap.v13i1.66864.

[9] A. S. Zuhri, G. Yuliyanto, and U. Harmoko, "Modeling of 3D Aquifer Layers using Poisson's Ratio Analysis HVSR Method in Tembelang Village, Candimulyo District, Magelang Regency," 2020. [Online]. Available: https://ejournal2.undip.ac.id/index.php/jpa/index

[10] A. Kansa Maimun *et al.*, "Analisis Indeks Kerentanan Seismik, Periode Dominan, Dan Faktor Amplifikasi Menggunakan Metode HVSR di Stage Of Tangerang," 2020.

[11] D. Ikhlas Fadli *et al.*, "Identifikasi Daerah Rawan Longsor Secara Mikrozonasi di Jalan Alternatif Provinsi Menggunakan Metode Simple Additive Weighting (SAW)," *Indonesian Journal of Applied Physics (IJAP)*, vol. 13, no. 1, p. 37, 2023, doi: 10.13057/ijap.v13i1.62110.

[12] Y. Nakamura, "Clear identification of fundamental idea of Nakamura's technique and its applications," 2000. [Online]. Available: https://www.researchgate.net/publication/228603691

[13] Teguh Hariyanto, Filsa Bioresita, Cherie Bhekti Pribadi, Chomia Nilam Safitri "Determination Of Earthquake Intensity Based On PGA (Peak Ground Acceleration) Using Multi-Event Earthquake Data", IOP Conference Series: Earth and Environmental Science, 2021.

[14] W. S. Yuliawati, S. Rasimeng, and K. Karyanto, "Pengolahan Data Mikrotremor Berdasarkan Metode HVSR Dengan Menggunakan Matlab," *JGE (Jurnal Geofisika Eksplorasi)*, vol. 5, no. 1, pp. 45–59, Jan. 2020, doi: 10.23960/jge.v5i1.22.

[15] I. Saraswati Siregar, "Analisis Mikrotremor Dengan Metode HVSR Untuk Mengetahui Zona Penguatan Gempa Bumi di Wilayah Stasiun Seismik Jawa Timur," *Jurnal Inovasi Fisika Indonesia (IFI)*, vol. 06, pp. 33–38, 2017, [Online]. Available: http://202.90.198.100/webdc3/

[16] Wijaya Rendi K dan Nasrul Wahyudi P, "Analisa Potensi Longsor Menggunakan Data Mikrotremor dan Kemiringan di Jalan Raya Puncak Kabupaten Bogor," *Jurnal Widya Climago*, vol. 2, pp. 38–46, May 2020.

[17] A. Widiastari, "Analisa Datamining dengan Metode Klasifikasi C4.5 Sebagai Faktor Penyebab Tanah Longsor," *Journal of Computer System and Informatics (JoSYC)*, vol. 2, no. 3, 2021.

[18] N. Sugianto and M. Farid, "Kondisi Geologi Lokal Kota Bengkulu Berdasarkan Ground Shear Strain (GSS)," *Jurnal Fisika dan Aplikasinya* , vol. 2, pp. 29–36, 2017, doi: 10.21009/SPEKTRA.

[19] Dyah Gofur AGP dan Budi Nugroho Wibowo, "Identifikasi Daerah Longsor Kecamatan Bagelen MenggunakanMetode Mikrotremor," *Wahana Fisika*, vol. 3(2), pp. 102–110, 2018.

[20] Hiroo Kanamori and Emily E Brodsky,(2004) "The physics of earthquakes". *Iop science*, Volume 67, Number 8.