Research Paper

International Journal of Research and Review
[Indexed, Peer-Reviewed Journal]
Volume 12; Issue: 4; April 2025
Website: www.ijrrjournal.com
E-ISSN: 2349-9788; P-ISSN: 2454-2237

Microzoning of Landslide Potential Area in MAN Insan Cendekia Area of Central Bengkulu Using Microtremor Method

Endah Lestari[1], Muhammad Farid[2], Henny Johan[3], Yudi Maulana[4]

[1,3,4]Department of Master of Science Education, [2]Department of Physics,
Bengkulu University, Bengkulu, Indonesia

Corresponding Author: Endah

DOI: https://doi.org/10.52403/ijrr.20250404

ABSTRACT

The MAN Insan Cendekia Central Bengkulu region has topographic characteristics and geological conditions that are prone to landslides, so scientific-based mitigation efforts are needed. This research aims to microzone the landslide potential area using microtremor method. Microtremor wave data were recorded at a number of points scattered in the study area and analyzed using the Horizontal-to-Vertical Spectral Ratio (HVSR) method to determine the dominant frequency value (f0) and soil amplification. The analysis results were used to map the landslide vulnerability level into low, medium, high and very high zones. The microzonation map shows a varied distribution of landslide potential, with certain areas having a high level of vulnerability due to topography and soil geotechnical conditions. This research provides mitigation recommendations that can be used as a basis for disaster risk management and development planning in the area. Based on the analysis obtained in the MAN Insan Cendekia Central Bengkulu Region, the lowest dominant frequency value is 1.25 Hz and the highest value is 8.67 Hz, the lowest amplification factor value is 1.61 and the highest is 5.37 and the lowest seismic vulnerability index value is 0.48 and the highest is 17.91. Areas with high landslide potential are located in IC11, IC12, IC13, IC14, IC15.

Keywords: Microzonation, landslide, microtremor, HVSR, disaster mitigation

INTRODUCTION

Indonesia is known as one of the areas with high potential for geological disasters, including landslides. This is due to its complex geographical and geological conditions, such as high rainfall, steep topography, and the presence of unstable soil layers. Landslide is a geological event when there is soil movement, rock collapse or a large decrease in soil mass (Dian, et al., 2021). Indonesia often experiences landslides due to various factors. One of them is its geographical condition, which is dominated by hilly areas with steep slopes. Landslide itself is a geological phenomenon that occurs when large masses of soil and rock move down a slope (Sugianto & Refrizon, 2021). In addition, as a tropical country, Indonesia has high rainfall, which contributes to the high frequency of landslides in various regions (Sunimbar et al., 2022).

Landslides occur due to disturbances in the stability of the soil or rock forming the slope (Amukti, et al., 2021). Fundamentally, landslides can occur due to the driving force on the slope that makes the retaining force on the slope weaken, the factors that affect the driving force itself are generally related to the slope, rock density and water saturation level, while the retaining force is often influenced by the density of the medium that makes up the soil layer on the slope (Dian, et al., 2021).

The Regional Disaster Management Agency (BPBD) of Bengkulu Province has recorded around 122 points prone to landslides spread across all regencies/cities of Bengkulu Province. One area that has the potential for landslides is Central Bengkulu, especially in the MAN Insan Cendekia Central Bengkulu area. This location is characterized by hilly topography and high rainfall, making it prone to land movement. Several landslides have occurred in the area.

Figure 1. Area of MAN Insan Cendekia Bengkulu Tengah

With the increasing need for infrastructure sustainability and safety of the school environment, identification and zoning of landslide potential in this area becomes an urgency that must be done immediately. To reduce the impact caused by landslides, disaster mitigation efforts are needed. One of the mitigation measures is to identify areas at risk of landslides. This identification can be done by utilizing geophysical methods, one of which is the microtremor method. Microtremor surveys also play a role in analyzing the characteristics of soil layer dynamics at the surface. Geophysical methods can be used to identify landslide-prone areas, one of which is the microtremor method. Microtremor method is one of the effective geophysical techniques in mapping subsurface conditions (Prasetyo et al., 2024). This method can be used to identify the intensity of a soil based on the value of the natural/dominant frequency (f0) to determine the potential for landslides (Panjaitan et al., 2023).

This research aims to microzone the landslide potential area in MAN Insan Cendekia Central Bengkulu using microtremor method. With the result of this microzoning, it is expected to provide accurate information on the level of landslide vulnerability in the area. In addition, this research is also expected to be the basis for decision-making related to disaster mitigation and better environmental management. This approach is not only relevant to the MAN Insan Cendekia Central Bengkulu area but can also be a model applied in other areas with similar characteristics. Thus, the results of this study are expected to make a real contribution to landslide risk mitigation efforts, both at the local and national levels.

MATERIALS & METHODS

This research was conducted with quantitative approach using microtremor method to microzone the landslide potential area in MAN Insan Cendekia Central Bengkulu. The research stages include preparation, field data collection, data analysis, and interpretation of results. This research was conducted in the area of MAN Insan Cendekia Bengkulu Tengah. Microtremor data collection consisted of 20 measurement points around the research area.

At each data collection point, the acquisition process lasted for ± 30 minutes and the sampling frequency used was 200 Hz (SESAME, 2004). Portable Short Period Seismometer namely Seismometer PASI Mod Gemini 2 Sn- 1405 is a tool used during data acquisition to record ambient ground noise. In addition, the equipment used is also a laptop, connecting cable, GPS, compass, camera. Data acquisition recording data in the form of signal data in *SAF format (Pertiwi et al., 2018). Geopsy software was used to process the microtremor data, which was then saved in *.hv format. According to Natasa, et al. (2022), the HVSR curve is said to be good if the resulting peak is clear and the deviation of the curve is close to the average value of the HVSR curve. Based on the dominant frequency (f0) and soil amplification values, the study zone was classified into several landslide vulnerability levels: low, medium, high and very high.

Microtremors are natural vibrations in the environment that can come from various sources, such as wind gusts, ocean waves, vehicle activity, and industrial or factory activities (Maimun et al., 2020). Microtremor analysis for soil response surveys is conducted by applying the HVSR method. This method is recognized as easy to use and the results are also in accordance with soil conditions (A. Fatimah et al., 2022). Supporting parameters generated from microtremor data processed using the HVSR method are dominant frequency, amplification factor. After obtaining the values of the three parameters, spatial distribution mapping can be done by interpolating the data using Surfer software based on the values of the three parameter data. Then interpret based on the distribution of the values of these parameters (Kurniawan et al 2017).

RESULT AND DISCUSSION

Based on the research conducted, the following table shows the results of the 3 parameters in determining landslide potential in the study area.

Table 1. Values f_0, A_0, K_g

Point	f_0	A_0	K_g
1	5.13	3.33	2.161579
2	6.18	3.53	2.016327
3	6.18	3.29	1.751472
4	5.07	4.5	3.994083
5	5.45	3.58	2.351633
6	7.49	2	0.534045
7	7.21	3.14	1.36749
8	8.67	2.6	0.7797
9	4.48	3.92	3.43
10	6.49	2.64	1.073898
11	1.25	1.63	2.12552
12	1.29	3.43	9.120078
13	1.47	3.73	9.464558
14	1.61	5.37	17.91112
15	1.6	4.5	12.65625
16	5.4	3.45	2.204167
17	6.23	3.16	1.602825
18	4.79	2.41	1.212547
19	6.63	2.9	1.268477
20	5.34	1.61	0.485412

Then from the research table, three map results were obtained that can show the potential for landslides in the MAN Insan Cendekia Central Bengkulu area. The map is useful to interpret the microzonation system related to the potential landslide points in the research area consisting of dominant frequency distribution map, amplification factor distribution map and seismic vulnerability index distribution map. The following picture shows the three distribution maps.

Dominant Frequency Distribution Map (f_0)

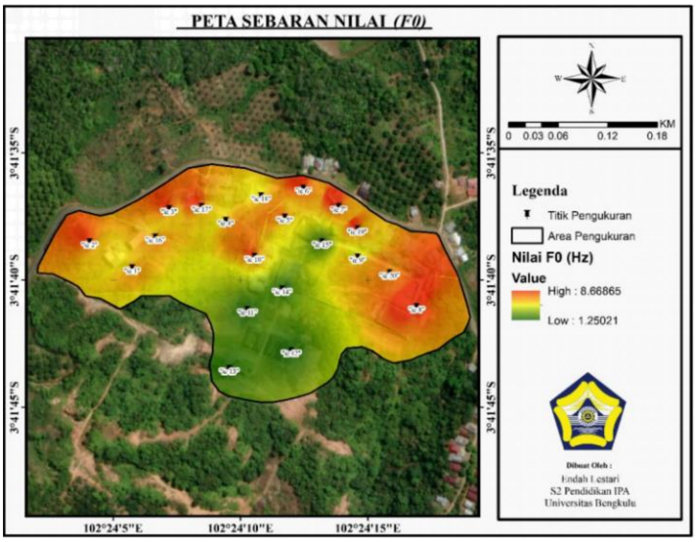

Figure 2 Dominant Frequency Distribution Map (f_0)

The natural frequency, also known as the dominant frequency, is a physical characteristic of soil that describes the thickness or thinness of the sediment layer in an area. It is closely related to the thickness of the sediment layer (h) (Farid & Mase, 2020). Based on Figure 2, it shows that the dominant frequency value in the study area is different at each point. The dominant frequency value (f_0) has the lowest value of 1.25 Hz and the highest value of 8.67 Hz. So rock types have different dominant frequency values. Based on the soil classification based on the dominant frequency value by Kanai (1983), the research area has soil type 4 which describes the thickness of sediments whose surface is included in the medium category of 5-10 meters which is composed of alluvial rocks (sedimentary rocks), which has a thickness of 5 meters. Consists of sandygravel, sandy hard clay, loam, and others (Kusuma Dewi et al., 2023).

Based on the value of the dominant frequency with a range of values from 5.07 Hz - 8.67 Hz with yellow and red colors on the map shows that the research points have the potential for landslides and are areas where landslides have occurred. The locations of the research points that have the potential for landslides and landslides have occurred are IC1, IC2, IC3, IC4, IC5, IC6, IC7, IC8, IC10, IC16, IC17, IC19, IC20. This is also supported by the slope of the study area which shows that most of the MAN Insan Cendekia Central Bengkulu area has a rather steep to very steep slope marked with yellow, orange and red colors as shown in Figure 3 below.

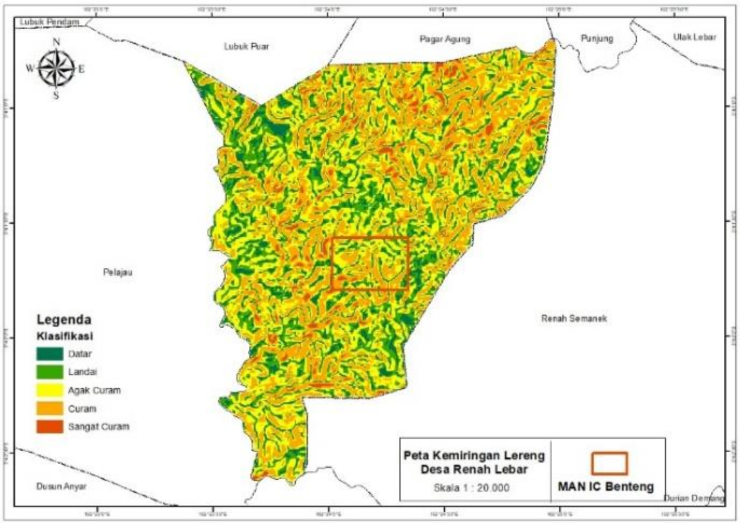

Figure 3 Slope Map of MAN Insan Cendekia Central Bengkulu Area

Areas with low dominant frequency (f_0) values indicate the presence of thick sedimentary layers, while areas with high dominant frequency (f_0) values indicate thin sedimentary layers. In other words, a high dominant frequency (f_0) indicates that the subsurface consists of hard rock, while a low dominant frequency (f_0) indicates the presence of soft rock or sediment (Sunimbar, et.al, 2022). The dominant frequency (f_0) value is influenced by the subsurface wave velocity (vs) and the thickness of the sediment layer (h). Subsurface wave velocities tend to be lower when passing through soft materials, as these materials slow down wave propagation (Yuniarto, 2023).

Amplification Factor Distribution Map (A_0)

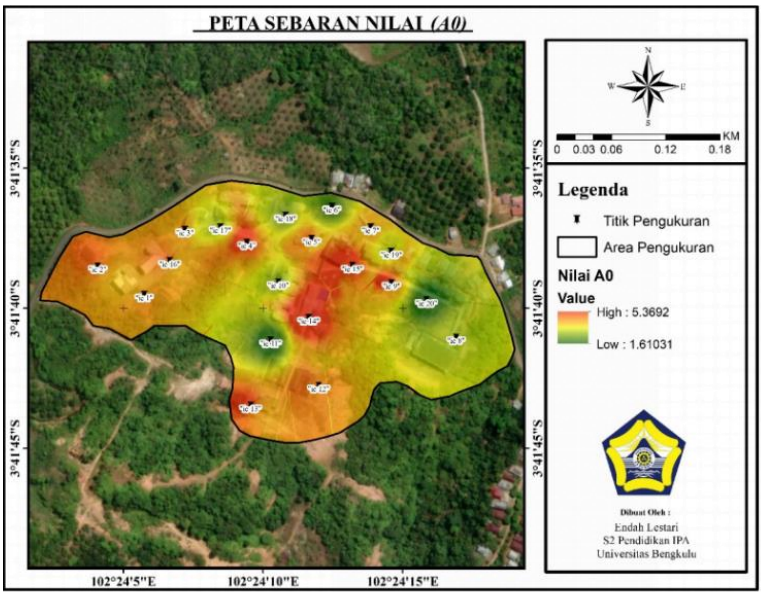

Figure 4 Amplification Factor Distribution Map (A_0)

Figure 4 shows the distribution map of the amplification factor in the MAN Insan Cendekia Central Bengkulu research area. Based on the figure, the value of the amplification factor at the research points is shown in green, yellow and red. The range of A_0 values with the lowest 1.61 and the highest 5.37. The A_0 value will describe the soil density in an area. The smaller the A_0 value, the denser the soil in the area and for areas that have the potential for landslides or have experienced landslides will have less soil density than areas that do not have the potential for landslides.

The level of rock density is related to the amplification factor, the speed of waves propagating in a medium is a factor influencing the amplification value, when the waves have a small speed, the amplification will be greater and vice versa (Syahputri & Sismanto, 2020). Because soft sediments will prolong the time of waves traveling in the area. The amplification value distribution map illustrates the research location that most of the amplification values are small which can be seen in green and yellow colors with values of 1.61 - 3.92, which are shown at points IC1, IC2, IC3, IC5, IC6, IC7, IC8, IC9, IC10, IC11, IC12, IC, IC13, IC16, IC17, IC18, IC19, IC20. The red color on the map indicates moderate to high amplification values with values from 4.5 - 5.37, which are shown in the IC4, IC14, and IC15 areas.

The amplification factor is the maximum amplitude value obtained through microseismic data processing. The magnitude of this factor is influenced by wave speed, where the slower the wave speed, the higher the amplification factor. This indicates that the amplification factor has a relationship with the level of rock density (Misliniyati et al., 2023). Amplification (A_0) is affected by wave speed. The smaller the wave speed, the greater the amplification value. Conversely, if the wave speed increases as it passes through a medium, the amplification value will decrease. This shows that amplification is related to the level of rock density. When the rock density decreases, the amplification value increases, while if the rock density increases, the amplification value becomes smaller. In addition, amplification is also related to the intensity of the shock and the level of risk due to vibration. The higher the amplification value, the stronger the shaking and the greater the risk. Conversely, if the amplification value is low, the shaking and the risk are also smaller (Mustika, et al., 2022).

Soil Vulnerability Index Distribution Map (Kg)

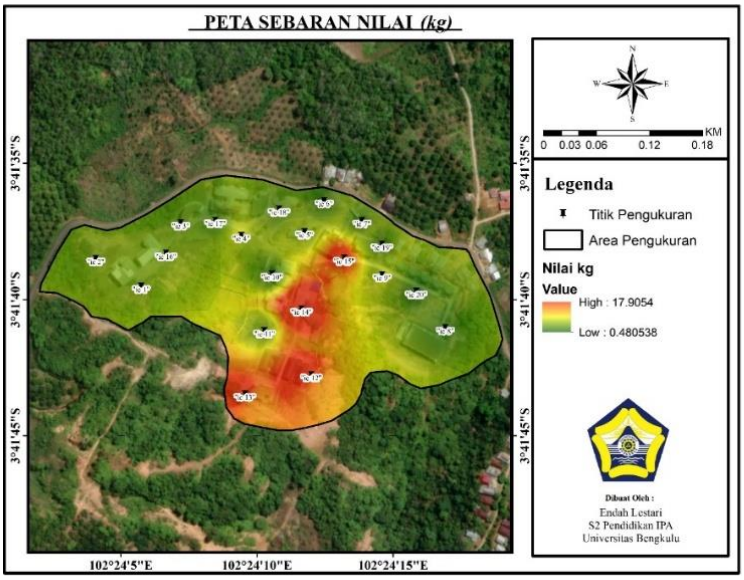

Figure 5 Soil Vulnerability Index Distribution Map (Kg)

In addition to the distribution map of dominant frequency and amplification factor values, a distribution map of seismic vulnerability index values was also obtained. The higher value of the soil vulnerability index at a research point compared to other points, makes the risk of danger to earthquakes and landslides greater, this is associated with the dominant frequency and amplification factor. The seismic vulnerability index (Kg) is used to determine the level of vulnerability and potential damage from ground movement. According to Akkaya (2020), seismic susceptibility (Kg) is a parameter that depends on the dynamic characteristics of the soil. This parameter allows the evaluation of the level of susceptibility of a site to shaking due to strong ground movements. The value of this index is influenced by the dominant frequency and amplification. In addition, the seismic susceptibility index (Kg) has a direct relationship with the thickness of the sediment layer (h). The higher the seismic susceptibility index (Kg) value in an area, the thicker the sediment layer in the region. Conversely, if the index value is low, the sediment layer in the area tends to be thinner (Fadli, D. I., et al. (2021). In the MAN Insan Cendekia Central Bengkulu area, the soil susceptibility index (Kg) shows a value range of 0.48 - 17.91 which is marked with green to red colors.

Referring to the classification of Daryono (2009), the overall value of the soil vulnerability index in this study is included in the low group, but among all measurement points there are several points with higher values than other points that can be alerted to the greater danger of landslides, namely at points IC12, IC13, IC14, IC15 with the highest seismic vulnerability index value at point 14 with a value of 17.91 cm⁄s^2. The seismic vulnerability index can also be used to identify the level of vulnerability of an area to the effects of shaking or movement of rock layers. The higher the seismic susceptibility index value, which is usually marked in red, the greater the risk of the area to shaking. Areas that have a high level of susceptibility to shaking or rock movement are known as weak zones (Zaenudin et al., 2022).

CONCLUSION

Based on the analysis and calculation of three parameters in the research area of MAN Insan Cendekia Bengkulu Tengah, the lowest dominant frequency value is 1.25 Hz and the highest value is 8.67 Hz, the lowest amplification factor value is 1.61 and the highest is 5.37 and the lowest seismic vulnerability index value is 0.48 and the highest is 17.91. From the analysis of microtremor data for the dominant frequency value, amplification factor, and seismic vulnerability index, areas that have high landslide potential are located in IC11, IC12, IC13, IC14, IC15. Meanwhile, other areas have low landslide potential and landslides have already occurred.

Declaration by Authors

Acknowledgement: None
Source of Funding: None
Conflict of Interest: No conflicts of interest declared.

REFERENCES

1. Akkaya, İ. (2020). Availability of seismic vulnerability index (Kg) in the assessment of building damage in Van, Eastern Turkey, Earthquake Engineering and Engineering Vibration, 19(1): 189-204. http://dx.doi.org/10.1007/s11803-020-0556-z
2. Amukti, R., Damayanti, C., Yamko, K. A. & Lekalette, J. D. (2021) Aplikasi Metode Geolistrik Konfigurasi Dipole-Dipole untuk Identifikasi Daerah Rawan Longsor (Studi Kasus di Desa Poka, Ambon). Teknik, 42(1), pp. 79-86. https://doi.org/10.14710/teknik.v42i1.29035
3. Dian, P. M., Muh, S. L. & Ayusari. (2021) Penentuan nilai indeks kerentanan seismik daerah rawan longsor metode mikrotremor di kecamatan tombolopao kabupatengowa. Tolis Ilmiah, 3(1), pp. 14-23. https://doi.org/10.56630/jti.v3i1.159
4. Fadli, D. I., et al. (2021). Identifikasi Daerah Rawan Longsor Secara Mikrozonasi Di Jalan Alternatif Provinsi Menggunakan Metode Simple Additive Weighting (SAW). Indonesian Journal of Applied Physics, 13(1), pp. 37-52. https://doi.org/10.13057/ijap.v13i1.62110
5. Farid, M. & Mase, L. Z. (2020). Implementation of seismic hazard mitigation on the basis of ground shear strain indicator for spatial plan of Bengkulu City, Indonesia, International Journal of

Geomate, 18(69): 199-207. http://dx.doi.org/10.21660/2020.69.24759

6. Fatimah, R., Ardianto, T., & Qomariyah, N. (2019). Mikrozonasi Gempabumi Di Desa Medana Dan Jenggala Kecamatan Tanjung Kabupaten Lombok Utara Menggunakan Metode Mikroseismik. Indonesian Physical Review, 2(1), 18. https://doi.org/10.29303/ipr.v2i1.19
7. Kurniawan, R., Eva, M. N., Tinggi, S., Adisutjipto, T., Fisika, J., Geologi, P. S., Geologi, B., Seismik, K., & Strain, G. S. (2017). Pemetaan Daerah Rawan Resiko Gempa Bumi Menggunakan Metode Hvsr di Kotamadya Denpasar Dan Sekitarnya, Bali. Kurvatek, 2(1), 21–30. https://doi.org/10.33579/krvtk.v2i1.415
8. Kusuma Dewi, I., Lucya Resta, I., Sucitra Amin, S., Situmorang, S., & Fitri Ramadhani, A. (2023). Analisis Kerentanan Tanah Fakultas Sains Dan Teknologi Universitas Jambi Dengan Menggunakan Data Mikrotremor. JoP, 9(1), 109–115. https://doi.org/10.22437/jop.v9i1.28788
9. Akkaya, İ. (2020). Availability of seismic vulnerability index (Kg) in the assessment of building damage in Van, Eastern Turkey, Earthquake Engineering and Engineering Vibration, 19(1): 189-204. http://dx.doi.org/10.1007/s11803-020-0556-z
10. Amukti, R., Damayanti, C., Yamko, K. A. & Lekalette, J. D. (2021) Aplikasi Metode Geolistrik Konfigurasi Dipole-Dipole untuk Identifikasi Daerah Rawan Longsor (Studi Kasus di Desa Poka, Ambon). Teknik, 42(1), pp. 79-86. https://doi.org/10.14710/teknik.v42i1.29035
11. Dian, P. M., Muh, S. L. & Ayusari. (2021) Penentuan nilai indeks kerentanan seismik daerah rawan longsor metode mikrotremor di kecamatan tombolopao kabupatengowa. Tolis Ilmiah, 3(1), pp. 14-23. https://doi.org/10.56630/jti.v3i1.159
12. Fadli, D. I., et al. (2021). Identifikasi Daerah Rawan Longsor Secara Mikrozonasi Di Jalan Alternatif Provinsi Menggunakan Metode Simple Additive Weighting (SAW). Indonesian Journal of Applied Physics, 13(1), pp. 37-52. https://doi.org/10.13057/ijap.v13i1.62110
13. Farid, M. & Mase, L. Z. (2020). Implementation of seismic hazard mitigation on the basis of ground shear strain indicator for spatial plan of Bengkulu City, Indonesia, International Journal of Geomate, 18(69): 199-207. http://dx.doi.org/10.21660/2020.69.24759
14. Fatimah, R., Ardianto, T., & Qomariyah, N. (2019). Mikrozonasi Gempabumi Di Desa Medana Dan Jenggala Kecamatan Tanjung Kabupaten Lombok Utara Menggunakan Metode Mikroseismik. Indonesian Physical Review, 2(1), 18. https://doi.org/10.29303/ipr.v2i1.19
15. Kurniawan, R., Eva, M. N., Tinggi, S., Adisutjipto, T., Fisika, J., Geologi, P. S., Geologi, B., Seismik, K., & Strain, G. S. (2017). Pemetaan Daerah Rawan Resiko Gempa Bumi Menggunakan Metode Hvsr di Kotamadya Denpasar Dan Sekitarnya, Bali. Kurvatek, 2(1), 21–30. https://doi.org/10.33579/krvtk.v2i1.415
16. Kusuma Dewi, I., Lucya Resta, I., Sucitra Amin, S., Situmorang, S., & Fitri Ramadhani, A. (2023). Analisis Kerentanan Tanah Fakultas Sains Dan Teknologi Universitas Jambi Dengan Menggunakan Data Mikrotremor. JoP, 9(1), 109–115. https://doi.org/10.22437/jop.v9i1.28788
17. Maimun, A. K., Silvia, U. N., & Ariyanto, P. (2020). Analisis Indeks Kerentanan Seismik, Periode Dominan, Dan Faktor Amplifikasi Menggunakan Metode Hvsr Di Stageof Tangerang. Jurnal Meteorologi Klimatologi dan Geofisika, 7(2), 24–30.https://jurnal.stmkg.ac.id/index.php/jmkg/article/view/194
18. Misliniyati, R., Mase, L. Z. & Refrizon. (2023). Upaya Peningkatan budaya sadar bencana gempa melalui analiis statistik parameter geofisika di kota bengkulu, indonesia. Jurnal pegabdian masyarakat, 8(1): 67-77. https://orcid.org/0000-0002-7951-640X
19. Mustika, R., Putra, R. R. & Fitria, R. (2022). Analisis Periode Getar Alami Bangunan Menggunakan Mikrotremor. Jurnal Teknik Sipil, 18(2). https://doi.org/10.28932/jts.v18i2.5027
20. Natasya, I. D., Larang, M. P., Putri, E. G. G., & Refrizon, (2022). Upaya Mitigsi Bencana Longsor Jalan Lintas Bengkulu-Kepayang Berdasarkan Kecepatan Gelombang Geser (Vs). Jurnal of Physics, 3(1). https://doi.org/10.33369/nmj.v3i1.21243
21. Panjaitan, A., Saragih, R., & Hutahuruk, A. (2023). Mikrozonasi Kawasan Potensi Longsor Menggunakan Metode

Mikrotremor di Kabupaten Bengkulu Utara-Lebong. Jurnal Ilmiah Fisika FMIPA Universitas Lambung Mangkurat, 20(2), 2541–1713. https://doi.org/10.20527/14957

22. Pertiwi, G., Wibowo, N., & Darmawan, D. (2018). Identifikasi Daerah Longsor Kecamatan Bagelan menggunakan Metode Mikrotremor. Wahana Fisika, 3(2), 102–110. https://doi.org/10.17509/wafi.v3i2.12740
23. Prasetyo, R. D., Harlianto, B., & Hadi, A. I. (2024). Identification of Landslide-prone Areas on the Road Connecting Kaur Regency, Bengkulu Province to South Oku Regency, South Sumatra Province Using the Microtremor Method. Journal of Aceh Physics Society, 12(4), 1–5. https://doi.org/10.24815/jacps.v12i4.35665
24. SESAME. (2004). Guidlines For The Implementation Of The H/V Spectral Ratio Technique On Ambient Vibrations Measurments, Processing And Interpretation. Interpretation A Journal Of Bible And Theology, D23.12(December), 169.
25. Syahputri, A., & Sismanto, S. (2020). Identifikasi Potensi Tanah Longsor Menggunakan Metode Mikrotremor Di Dusun Tegalsari Desa Ngargosari Kecamatan Samigaluh Kabupaten Kulon Progo. Jurnal Fisika Indonesia, 24(2), 66–71. https://doi.org/10.22146/jfi.v24i2.53636
26. Sunimbar, Ignasius Suban Angin, E. I. G. (2022). Analisis Geologi Kejadian Longsor di Desa Wolotolo Kecamatan Detusoku Kabupaten Ende. 9(2), 10–24. https://doi.org/10.20527/jpg.v9i2.13471
27. Yuniarto, Abdul Hakim Prima. (2023). Mikrozonasi Seismik Di Kawasan Itsnu Pekalongan Dengan Menggunakan Metode Hvsr. Jurnal Kumparan Fisika, Vol. 6 No. 1, April 2023, Hal. 47-54. https://doi.org/10.33369/jkf.6.1.47-54
28. Zaenudin, A., Darmawan, I.G.B., Farduwin, A. & Wibowo, R.C. (2022). Shear wave velocity estimation based on the particle swarm aplitimization method of HVSR curve inversion in Bakauheni district, Indonesia. Journal of Earth Sciences, 31(5). http://dx.doi.org/10.55730/1300-0985.1815

How to cite this article: Endah Lestari, Muhammad Farid, Henny Johan, Yudi Maulana. Microzoning of landslide potential area in MAN Insan Cendekia area of central Bengkulu using microtremor method. *International Journal of Research and Review*. 2025; 12(4): 21-29. DOI: *https://doi.org/10.52403/ijrr.20250404*

******