



## Peak Ground Acceleration (PGA) Analysis for Earthquake Risk Mitigation in IKN Area, Sepaku Sub-District, East Kalimantan

Rahmania<sup>1,\*</sup>, Alfania<sup>1</sup>, Febrian Dedi Sastrawan<sup>1</sup>, Meidi Arisalwadi<sup>1</sup>

<sup>1)</sup>Physics Study Program, Institute of Technology Kalimantan  
Jl. Soekarno Hatta Km.15 Balikpapan Utara, Balikpapan, Kalimantan Timur Indonesia

\*E-mail Correspondence: rahmania19@itk.ac.id.

### Article Info:

Sent:  
[December 4, 2024](#)  
Revision:  
[December 7, 2024](#)  
Accepted:  
[December 16, 2024](#)

### Key Words:

PGA, HVSR, Kanai  
Metod, IKN,  
Earthquake

### Abstract

This study examines the distribution of Peak Ground Acceleration (PGA) in the Ibu Kota Nusantara (IKN) development area, Sepaku Sub-District, East Kalimantan, an area with relatively low seismic activity compared to other parts of Indonesia. However, earthquake risks remain a concern due to the planned relocation of Indonesia's capital. Using the Kanai approach and seismic data from microtremor measurements and two significant earthquakes (Paser Regency, 2022, and Palu, 2018), PGA values ranged from 0.69 gal to 34.29 gal. The results show that the 4.5 magnitude Paser earthquake produced PGA values between 0.69 and 3.17 gal (average 1.8 gal), placing most areas in the low-risk zone. In contrast, the distant 7.2 magnitude Palu earthquake generated PGA values between 2.9 and 34.29 gal (average 15.6 gal), placing several areas in the moderate-risk zone. These findings underscore the significant impact of earthquake magnitude on PGA, with larger, more distant earthquakes causing stronger ground shaking. In conclusion, despite East Kalimantan's low local seismic activity, the study highlights the vulnerability of the IKN area to strong ground shaking from distant, high-magnitude earthquakes. This underscores the need for continued monitoring and preparedness, with tailored earthquake risk mitigation strategies, including reinforced construction standards and geotechnical assessments, to ensure the region's resilience to both local and distant seismic events. These insights are crucial for integrating seismic resilience into IKN's urban planning and the sustainable development of Indonesia's new capital city.

© 2024 State Islamic University of Mataram

## INTRODUCTION

The relocation of Indonesia's capital to the new capital city, Nusantara (IKN), in Penajam Paser Utara, East Kalimantan, is a strategic step to ensure more equitable development across the country [1]. Jakarta, the former capital, faces various complex issues such as pollution, flooding, overpopulation, and geographic challenges like land subsidence and its proximity to a subduction zone, making it vulnerable to earthquakes [2]. The history of earthquakes in Jakarta and its surroundings was a key consideration in the relocation decision [3]. Meanwhile, Borneo Island, in general, has a lower seismicity compared to other islands in Indonesia [4][5][3].

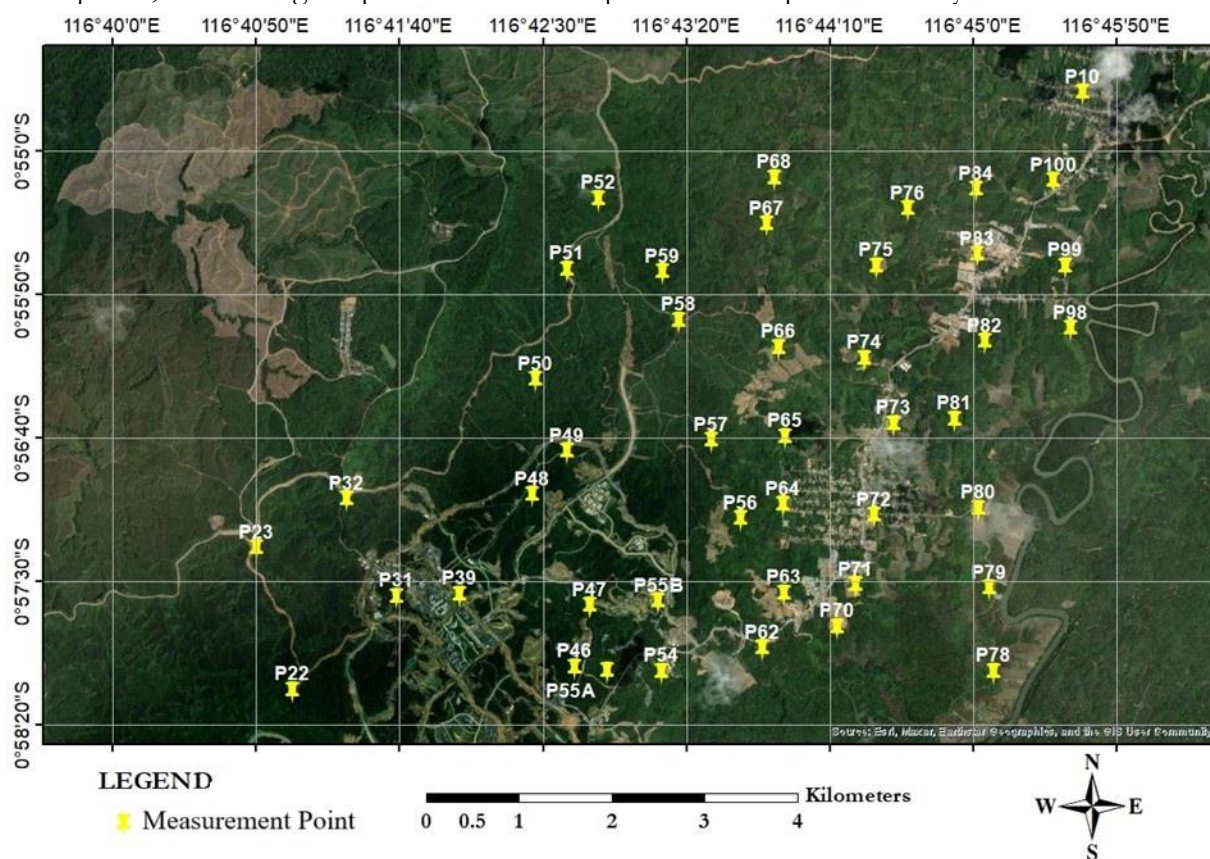
East Kalimantan, where IKN is located, is considered safer from earthquake risks due to its distance from the subduction zone and major active faults [6]. However, East Kalimantan still ranks 26th nationally in terms of seismic activity [7], indicating that the region is not entirely free from earthquake risk. Furthermore, Indonesia's location in the Pacific Ring of Fire makes other islands susceptible to earthquakes and tsunamis [8], which can also affect Kalimantan.

Nowdays, no instruments exist that can accurately predict the location, time, and characteristics of earthquakes. Therefore, to mitigate earthquake risks, studies on relevant physical parameters must be conducted. One important parameter to examine is the mapping of Peak Ground Acceleration (PGA) values. PGA is a key indicator in earthquake risk assessment, measuring the maximum ground acceleration during an earthquake [9][10]. PGA is used to assess the intensity of ground shaking at a specific location during an earthquake, which directly impacts damage to buildings and infrastructure. [11]. The PGA value is crucial in earthquake-resistant building planning because high ground acceleration can cause distribution of force on the building structure, affecting its strength and stability [12]. The higher the PGA value, the stronger the earthquake, accompanied by significant energy capable of causing damage [11]. According to the BMKG earthquake intensity scale, PGA values are categorized into five levels, ranging from the lowest (< 2.9) in category I (earthquake not felt) to the highest (> 564) in category V (severe damage to buildings and infrastructure)[13].

Several studies have previously mapped PGA values in regions of Indonesia with high seismic frequency, such as Java, Sumatra, and Sulawesi [11][14][15]. However, studies on PGA in East Kalimantan, particularly in the IKN area, remain limited. Mapping the PGA in this region is essential for establishing construction standards that align with local geological characteristics, considering the potential earthquake impacts in the future. This research is expected to provide valuable information for safe development planning in Sepaku District, especially in the IKN development area, and support earthquake risk mitigation efforts.

## RESEARCH METHODS

This study was conducted in Sepaku Subdistrict, located in North Penajam Paser Regency, East Kalimantan, to analyze the distribution of Peak Ground Acceleration (PGA) values and earthquake intensity. This area was selected as it is part of the development zone for Indonesia's new capital city. The study is crucial to support infrastructure planning and disaster risk mitigation for future earthquakes, considering the potential seismic impact on development stability.



**Figure 1.** Research Location Map, Sepaku Subdistrict, North Penajam Paser Regency. The yellow markers on the map indicate the microtremor measurement points.

In this study, geological maps and topographical maps of the research area were used as primary references for determining survey points. The survey design was developed using ArcGIS software, which facilitates efficient visualization and planning of survey points. At each survey point, microtremor data were recorded using a Trillium Compact PH model TC-120 PH2 seismometer, while the location of each survey point was tracked using a Global Positioning System (GPS). The GPS also served as a marker for the survey location. To ensure proper placement of the seismometer, a compass was used to determine true north as a reference for orientation. The collected microtremor data were processed using Geopsy software. Additionally, secondary data, including earthquake history such as magnitude, hypocenter, and epicenter, were obtained from Indonesian Meteorology, Climatology, and Geophysics Agency and USGS (United States Geological Survey) to support the analysis.

Microtremor data were acquired through a survey conducted at 44 strategically selected measurement points to ensure coverage of areas with varying geological conditions and potential seismic amplification zones. Each measurement lasted approximately 30 minutes to ensure sufficient signal capture and reliability. Data were collected using calibrated seismometers, GPS devices for precise location recording, and compasses for orientation, ensuring consistency and accuracy across all points. The microtremor data, automatically recorded by the instruments, consisted of time series functions for three components: vertical (up and down), horizontal north-south, and horizontal east-west. To obtain meaningful results, the focus was on capturing stationary signals (signals with constant amplitude and stable characteristics over time), while minimizing environmental noise and other interferences. This approach ensures the data are robust and representative for further analysis of ground motion and seismic vulnerability in the study area.

The raw microtremor data were processed using Geopsy software through several stages: (1) performing data corrections; (2) applying a band-pass filter in the frequency range of 0.5–20 Hz to filter the data; and (3) conducting signal windowing and using the H/V tool in Geopsy as the final step in the HVSR analysis. The Horizontal-to-Vertical Spectral Ratio (HVSR) method is an effective approach for studying ground motion amplification. This method compares the spectral ratio of the horizontal components of microtremor signals to their vertical component [5]. Mathematically, it is expressed through Equation (1) as follows.

$$HVSR = \frac{\sqrt{(S_{NS})^2 + (S_{EW})^2}}{(S_V)^2} \dots\dots\dots(1)$$

$S_{NS}$ ,  $S_{EW}$ , and  $S_V$  represent the spectral amplitudes of the north-south, east-west, and vertical components, respectively. Generally, HVSR analysis yields a spectral peak at the natural frequency ( $f_0$ ) and an amplification factor ( $A_0$ ) to describe the dynamic characteristics of the soil [6]. The natural frequency or dominant frequency indicates the number of wave cycles occurring per unit of time. It represents the frequency most commonly observed in the study area and is derived from the horizontal axis of the H/V curve's peak [7]. Amplification refers to the increase in seismic wave amplitude caused by significant differences between rock or soil layers. The amplification factor value can increase when soil or rock layers undergo deformation, such as weathering, folding, or faulting, which alters the rock's properties. The amplification value for the same type of rock can vary depending on the degree of deformation caused by weathering [8].

The  $f_0$  value is used to calculate the dominant period ( $T_g$ ), which is an input parameter for determining the PGA value. Ground acceleration, the rate of change in velocity during seismic wave propagation, is a primary factor in earthquake damage. Higher PGA values indicate a greater risk of earthquake damage at a specific location [9]. The higher the PGA value of an area, the greater the risk of damage caused by an earthquake in that area. The PGA value can be calculated using several empirical formulas, one of which is the Kanai (1966) empirical formula [2]. The calculation of the PGA value at the measurement point is performed using Equation (2).

$$a_g = \frac{5}{\sqrt{T_g}} 10^{[(0,61M) - (1,66 + \frac{3,6}{R}) \log R + (0,167 \frac{1,83}{R})]} \dots\dots\dots(2)$$

where  $a_g$  is the PGA in gal,  $T_g$  is the dominant period of the soil at the research location in seconds ( $T_g = \frac{1}{f_0}$ ),  $M$  is the earthquake magnitude on the Richter scale, and  $R$  is the hypocentral distance in km.

Validation of microtremor data is carried out to ensure that the data obtained from field measurements is reliable and meets analysis standards. The first step involves an initial inspection of the data, including the quality of recordings on horizontal and vertical components to ensure there is no significant noise interference, such as human activity, vehicles, or wind [21]. The recording duration should comply with standards, typically 20–60 minutes, with a sufficient sampling frequency (generally 100 Hz or higher) [22]. Next, data consistency is checked, such as ensuring a reasonable energy distribution across frequencies and balanced amplitude among the three components. The main analysis is performed using the H/V (Horizontal-to-Vertical Spectral Ratio) method with software [23]. The H/V ratio is calculated to obtain a stable curve with a clear peak at the soil's dominant frequency ( $f_0$ ). If the curve exhibits anomalies such as double peaks, insignificant peaks, or extreme fluctuations, the data is considered invalid [24]. The ( $f_0$ ) results are then validated by comparing them to the local geological characteristics or prior seismic data and ensuring consistency through repeated measurements at the same location.

The validation process also involves noise filtering, either by segmenting the data to exclude disturbed sections or by applying a bandpass filter to isolate relevant frequencies without removing important signals. The measurement location should be far from sources of interference, such as highways or heavy machinery [25]. All these steps should be thoroughly documented, including recording duration, measurement time, environmental conditions, equipment used, and results such as H/V curves, frequency spectra, and measurement site maps. International guidelines such as the *SESAME Guideline* can be used as a reference to ensure data validity. If the data is deemed invalid, re-measurement should be conducted while addressing the previously identified disturbances [26]. And We validated the results of the Peak Ground Acceleration (PGA) analysis using the Kanai method by comparing the estimated results with observed earthquake data. The Kanai method uses an empirical formula [10]. This process of validation should include data from several earthquake events of varying magnitudes and epicentral distances to ensure the Kanai method is generally applicable. All results, including graphs, parameter adjustments, are clearly documented. This validation ensures that the PGA analysis results match the physical conditions of the field and are reliable for seismic risk evaluation.

## RESULTS AND DISCUSSION

The analysis of PGA is an important parameter used to predict the level of damage in an area due to an earthquake. The PGA value in the research area was calculated using an empirical formula based on the Kanai method (Equation 2). This study used earthquake data from March 1<sup>st</sup>, 2022, in Paser Regency, with a hypocenter depth of 10 km and a magnitude of 4.5 (earthquake data 1). This earthquake reflects the local seismic conditions around the IKN area, making it relevant for modeling the potential PGA generated by small to medium-magnitude earthquakes in the region. This data is also crucial for understanding the response of the soil and structures around IKN to frequent earthquakes in the area. The second earthquake data comes from the large earthquake that occurred in Palu City on September 28<sup>th</sup>, 2018, with a hypocenter depth of 10 km and a magnitude of 7.2. Although the location is relatively far from IKN, this data was selected to represent a scenario of a large earthquake with significant energy, providing insight into the potential maximum PGA that could occur. The results of the PGA analysis at the research location are shown in Table 1.1, which varies from <2.9 gal to 2.9-34.29 gal.

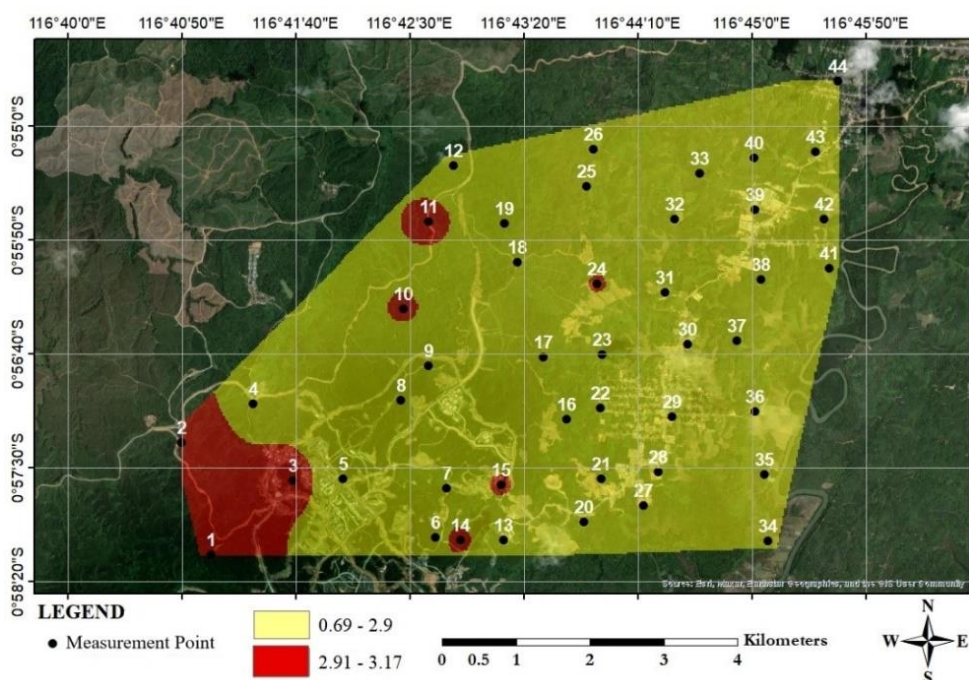
**Table 1.** PGA Values at Each Microtremor Measurement Point.

Measurement Point	$F_0$ (Hz)	$T_g$ (s)	PGA (gal) (Earthquake Data 1)	PGA (gal) (Earthquake Data 2)
1	13.77	0.07	3.17	33.41
2	13.51	0.07	3.11	33.09

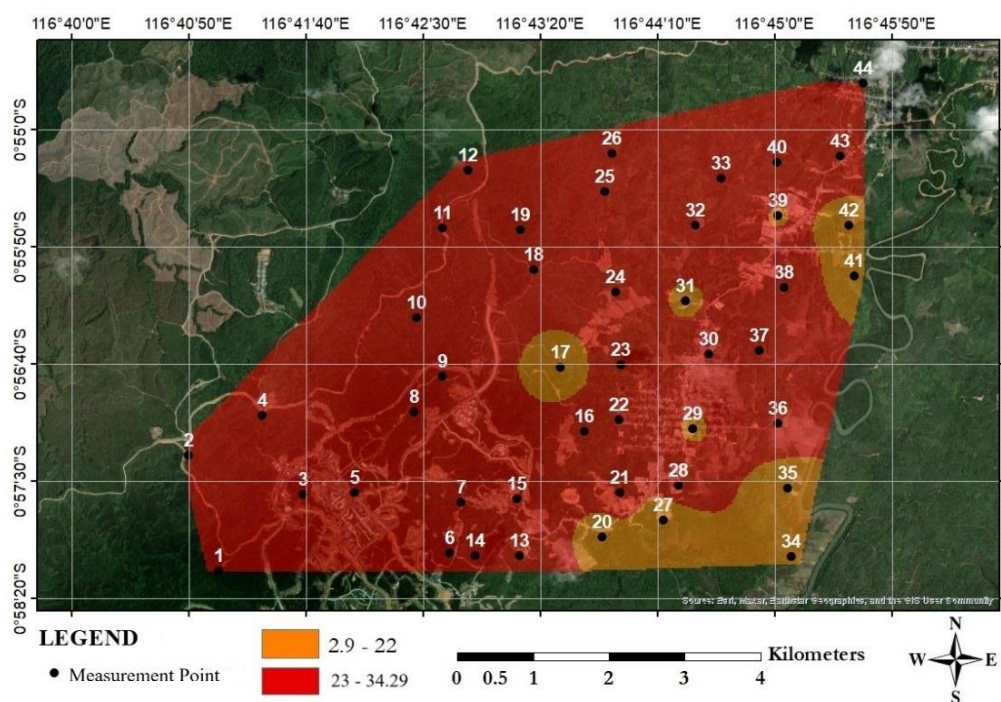
Measurement Point	F <sub>0</sub> (Hz)	T <sub>g</sub> (s)	PGA (gal) (Earthquake Data 1)	PGA (gal) (Earthquake Data 2)
3	13.62	0.07	3.10	33.42
4	11.38	0.09	2.83	30.51
5	8.33	0.12	2.42	26.22
6	11.69	0.09	2.85	31.20
7	11.35	0.09	2.79	30.78
8	9.04	0.11	2.48	27.43
9	8.48	0.12	2.39	26.63
10	13.18	0.08	2.97	33.17
11	14.01	0.07	3.03	34.29
12	11.60	0.09	2.73	31.27
13	8.01	0.12	2.34	24.81
14	12.88	0.08	2.99	32.80
15	13.01	0.08	2.97	33.07
16	9.76	0.10	2.54	28.78
17	0.74	1.35	0.70	7.92
18	9.73	0.10	2.51	28.71
19	11.60	0.09	2.74	31.34
20	2.62	0.38	1.33	14.90
21	10.95	0.09	2.70	30.52
22	11.76	0.09	2.78	31.66
23	12.54	0.08	2.86	32.72
24	13.58	0.07	2.95	34.07
25	10.97	0.09	2.63	30.64
26	13.15	0.08	2.87	33.58
27	0.81	1.23	0.73	8.32
28	11.23	0.09	2.72	31.01
29	4.92	0.20	1.79	20.56
30	11.64	0.09	2.73	31.69
31	4.02	0.25	1.60	18.61
32	11.13	0.09	2.64	31.01
33	6.98	0.14	2.07	24.61
34	3.81	0.26	1.58	18.17
35	2.49	0.40	1.27	14.70
36	10.08	0.10	2.54	29.58
37	12.75	0.08	2.84	33.26
38	13.49	0.07	2.90	34.29
39	5.20	0.19	1.79	21.30
40	11.02	0.09	2.59	31.03
41	1.80	0.56	1.05	12.58
42	2.40	0.42	1.21	14.53
43	11.31	0.09	2.61	31.55
44	12.30	0.08	2.69	32.98



The calculation results were then visualized on a map to show the distribution of PGA values, as seen in Figures 2 and 3, allowing the PGA distribution pattern in the study area to be identified.



**Figure 2.** PGA Distribution Map Using the March 10, 2022 Earthquake Database in Paser Regency with a hypocenter depth of 10 km and a magnitude of 4.5.



**Figure 3.** PGA Distribution Map Using the September 28, 2018 Earthquake Database around Palu City with a hypocenter depth of 10 km and a magnitude of 7.2.

Figure 2 displays the distribution map of low dominant PGA values, ranging from 0.69 gal to 2.9 gal. Several points show slightly higher values, within the moderate category, ranging from 2.91 gal to 3.17 gal, localized in small red-colored areas on the map. Meanwhile, Figure 3 shows the distribution of PGA values, which also fall within the moderate range, from 2.9 gal to 34.29 gal, indicated by orange to red colors. The orange areas represent PGA values between 2.9 and 22 gal, while the red areas indicate higher values, ranging from 23 to 34.29 gal.

PGA values are influenced by several factors, such as earthquake magnitude, hypocenter depth, epicenter distance, and the physical properties of rocks [4]. Earthquakes with smaller magnitudes and distant epicenters tend to produce lower PGA values, while large earthquakes at shorter distances produce higher PGA values [10]. In line with these findings, this study reveals that the 7.2 magnitude earthquake, despite being farther from the study location, produced higher PGA values compared to the 4.5 magnitude earthquake, which was closer. This is due to the significant energy generated by the larger earthquake, which results in noticeable impacts even after attenuation due to distance.

Based on the Samarinda Geological Map, the study area lies within the Pamaluan Formation and Alluvial Deposits. The Pamaluan Formation, formed during the Tertiary period, is dominated by quartz sandstone with intercalations of claystone, shale, limestone, and siltstone. On the other hand, the Alluvial Deposits consist of gravel, sand, and silt formed in river, swamp, delta, and coastal environments. These geological characteristics affect the behavior of seismic waves, which ultimately influence the PGA values in the area.

According to the BMKG Earthquake Intensity Scale (SIG) classification [11], the study location falls within Intensity Categories I (< 2.9 gal) and II (2.9–88 gal). Category I indicates that the earthquake is generally not felt or only felt by a few people, although it is recorded by instruments. Category II shows that the earthquake is felt by many people but does not cause damage. In this category, light hanging objects may sway, and window glass may vibrate. This suggests that the study area is relatively safe from earthquake risks. However, attention should still be given to areas with moderate PGA values to ensure risk mitigation measures, such as strengthening building structures and implementing earthquake risk-based planning, to reduce the impact of future earthquakes."

dominant frequency and an increase in dominant period at greater distances. In contrast, larger magnitude earthquakes release more energy, particularly at lower frequencies, which increases the wavelength of seismic waves. These low-frequency waves tend to dominate soil response, leading to a lower  $F_0$  and longer  $T_0$  for higher-magnitude earthquakes. The interaction between distance and magnitude demonstrates that large-magnitude earthquakes occurring far from the measurement site typically produce longer dominant periods, while nearby small-magnitude earthquakes tend to produce shorter dominant periods. Therefore, both distance and magnitude must be considered simultaneously when analyzing dominant frequency and period as key parameters for determining Peak Ground Acceleration (PGA), ensuring more accurate seismic risk assessments.

Although the Kanai approach used in this research has broad applications in analyzing soil response, especially in linking dominant frequency and period to ground acceleration, it has several limitations. These include the neglect of factors such as soil heterogeneity, soil-structure interaction, and the non-linearity of soil response. While the Kanai model provides a solid foundation for understanding soil behavior, more advanced and realistic approaches are necessary for more accurate analysis, particularly in seismic risk assessment and infrastructure design.

## **CONCLUSION**

In conclusion, this study highlights the significant influence of earthquake magnitude, distance, and local geology on ground shaking intensity (PGA). While the 4.5 magnitude local earthquake produced low PGA values (0.69–3.17 gal), the 7.2 magnitude distant earthquake generated significantly higher values (2.9–34.29 gal) due to its greater energy, demonstrating the potential impact of large earthquakes outside Kalimantan.

The Pamaluan Formation and Alluvial Deposits further amplify seismic wave behavior, increasing regional vulnerability. These findings emphasize the importance of considering high-magnitude earthquakes from distant sources in earthquake risk mitigation strategies for the IKN area. Moderate-risk zones require reinforced construction standards and geotechnical assessments, while low-risk zones must adopt baseline measures to address long-term risks. Integrating these insights into urban planning and infrastructure design is crucial to ensuring the resilience and sustainable

development of Indonesia's new capital city against both local and distant seismic hazards.

## ACKNOWLEDGMENT

The author would like to express gratitude to the Kalimantan Institute of Technology through the Institute for Research and Community Service (LPPM) for funding this research. The author also extends thanks to all the faculty members of the Physics Department at ITK, the students, and the BMKG Geophysical Station in Balikpapan for their cooperation in the microtremor data acquisition activities.

## REFERENCES

- [1] Desfiandri Rahmadani Amri and Zulkipli Lessy, "Analisis Diskursus Pemerataan Ekonomi dalam Pembangunan Nasional Ibu Kota Nusantara," *Al-Kharaj J. Ekon. Keuang. Bisnis Syariah*, vol. 6, no. 5, pp. 2655–2672, 2024, doi: 10.47467/alkharaj.v6i5.2642.
- [2] A. H. Salsabila and N. Nurwati, "Deforestasi Dan Migrasi Penduduk Ke Ibu Kota Baru Kalimantan Timur: Peran Sinergis Pemerintah Dan Masyarakat," *Pros. Penelit. dan Pengabd. Kpd. Mayi.*, vol. 7, no. 1, p. 27, 2020, doi: 10.24198/jppm.v7i1.28259.
- [3] A. Kurniadi, "JMB : Jurnal Manajemen Bencana," *JMB J. Manaj. Bencana*, vol. 5, no. 2, pp. 1–12, 2019.
- [4] W. L. Hutasoit, "Analisa Pemindahan Ibukota Negara," *Dedik. J. Ilm. Sos. Hukum, Budaya*, vol. 19, no. 2, pp. 108–128, 2018.
- [5] F. N. Ramadhani and S. Cahyadini, "Pendekatan Resiliensi Terhadap Bencana dalam Pengembangan Kawasan Permukiman Atas Air Balikpapan," *J. Sains dan Seni ITS*, vol. 11, no. 5, pp. 165–170, 2023, doi: 10.12962/j23373520.v11i5.99570.
- [6] M. I. Tawakal, "Identifikasi Bahaya Gempabumi Kalimantan Timur Menggunakan Metode Probabilistic Seismic Hazard Analysis (PSHA) untuk Probabilitas Terlampaui 10% dalam 50 Tahun (500 Tahun)," *Bul. Meteorol. Klimatologi, dan Geofis.*, vol. 2, no. 2, pp. 18–25, 2022.
- [7] A. Sabtaji, "Statistik Kejadian Gempa Bumi Tektonik Tiap Provinsi Di Wilayah Indonesia Selama 11 Tahun Pengamatan (2009-2019) Statistics of Tectonic Earthquake Events Each Province in Indonesia Territory for 11 Years of Observation," *Bul. Meteorol. Klimatologi, Dan Geofis.*, vol. 1, no. 7, pp. 31–46, 2020.
- [8] S. W. Dyah and E. Prasojo, "Tata Kelola Kolaboratif Dalam Upaya Penanggulangan Pasca Gempa di Wilayah Jawa Bagian Barat," *J. Ilmu Adm. Publik*, vol. 8, no. September, pp. 1–19, 2020.
- [9] U. Azmiyati, "Analisis Percepatan Getaran Tanah Maksimum Akibat Gempabumi Di Wilayah Nusa Tenggara Dengan Metode Probabilistic Seismic Hazard Analysis (PSHA)," *JISIP (Jurnal Ilmu Sos. dan Pendidikan)*, vol. 5, no. 1, pp. 331–339, 2021, doi: 10.58258/jisip.v5i1.1709.
- [10] N. B. Wibowo and J. N. Sembri, "Analisis Peak Ground Acceleration (PGA) dan Intensitas Gempabumi berdasarkan Data Gempabumi Terasa Tahun 1981 - 2014 di Kabupaten Bantul Yogyakarta," *Indones. J. Appl. Phys.*, vol. 6, no. 01, p. 65, 2016, doi: 10.13057/ijap.v6i01.1804.
- [11] M. C. Irawan, "ANALISIS PGA (PEAK GROUND ACCELERATION) BERDASARKAN DATA GEMPA UNTUK WILAYAH JAKARTA TIMUR MENGGUNAKAN SOFTWARE PSHA," vol. 11, no. 4, pp. 379–384, 2018.
- [12] C. Maramis, G. Pasau, and G. H. Tamuntuan, "Analisis Percepatan Tanah Maksimum Akibat Adanya Gempa Bumi di Lengan Utara Pulau Sulawesi Menggunakan Metode Fukushima Tanaka," *J. MIPA*, vol. 9, no. 2, p. 97, 2020, doi: 10.35799/jmuo.9.2.2020.29029.
- [13] Badan Meteorologi Klimatologi dan Geofisika, "Skala intensitas gempabumi (SIG) BMKG," *Badan Meteorologi Klimatologi dan Geofisika*. 2019. [Online]. Available: <https://www.bmkg.go.id/gempabumi/skala-intensitas-gempabumi.bmkg>
- [14] M. Rajif, "HAZARD SEISMIC ZONATION ANALYSIS OF WEST SUMATRA REGION USING PROBABILISTIC HAZARD SEISMIC ANALYSIS (PHSA) METHOD," vol. 14, no. 1, pp. 8–17, 2021.



- [15] L. Kainde, C. Poluakan, A. M. Rampengan, and M. Zulkifli, "Pemodelan Percepatan Tanah sebagai Parameter Hazard Gempabumi menggunakan Metode Deterministic Seismic Hazard Analysis di Kota Manado," *J. FisTa Fis. dan Ter.*, vol. 4, no. 2, pp. 84–94, 2023, doi: 10.53682/fista.v4i2.286.
- [16] N. A. F. Tanjung, H. P. Yuniarto, and D. Widyawarman, "Analisis Amplifikasi Dan Indeks Kerentanan Seismik Di Kawasan Fmipa Ugm Menggunakan Metode HVSR," *J. Geosaintek*, vol. 5, no. 2, p. 60, 2019, doi: 10.12962/j25023659.v5i2.5726.
- [17] Y. Nakamura, "Clear identification of fundamental idea of Nakamura's technique and its applications," *Proc. 12th world Conf. ...*, p. Paper no. 2656, 2000, [Online]. Available: [http://www.sdr.co.jp/papers/n\\_tech\\_and\\_application.pdf](http://www.sdr.co.jp/papers/n_tech_and_application.pdf)
- [18] N. Sitorus, S. Purwanto, and W. Utama, "Analisis Nilai Frekuensi Natural dan Amplifikasi Desa Olak Alen Blitar Menggunakan Metode Mikrotremor HVSR," *J. Geosaintek*, vol. 3, no. 2, p. 89, 2017, doi: 10.12962/j25023659.v3i2.2962.
- [19] L. I. Juarzan, W. A. W. Jafar, L. H. Hamimu, and I. Indrawati, "Analisis Ketebalan Lapisan Sedimen Menggunakan Metode Horizontal to Vertical Spectral Ratio (HVSR) di Wilayah Pesisir Kecamatan Moramo Kabupaten Konawe Selatan," *J. Rekayasa Geofis. Indones.*, vol. 5, no. 03, pp. 137–145, 2023, doi: 10.56099/jrgi.v5i03.27.
- [20] F. Alfadilah, - Syafriani, - Hamdi, L. Dwiridal, and F. S. Rahmatullah, "Analysis of b-Value and Peak Ground Acceleration (PGA) in West Sumatra Province using Maximum Likelihood Method and Empirical Formula (Earthquake data Period 2007-2020)," *Pillar Phys.*, vol. 15, no. 1, pp. 61–68, 2022, doi: 10.24036/12553171074.
- [21] dan H. Febriani, Daruwati., "Analisis Nilai Peak Ground Acceleration dan Indeks Kerentanan Seismik Berdasarkan Data Mikroseismik Pada Daerah Rawan Gempa Bumi Di Kota Bengkulu," *J. Ilm. Edu Researcb*, vol. 2, no. 2, pp. 85–90, 2013.
- [22] K. Gupta and N. Satyam, "Estimation of Arias intensity and peak ground acceleration (PGA) using probabilistic seismic hazard assessment of Uttarakhand state (India)," *Arab. J. Geosci.*, 2022, doi: 10.1007/s12517-022-09733-9.
- [23] D. Ambarsari, "Analisis Mikrotremor Dengan Metode HVSR Untuk Mikrozonasi Kabupaten Gunungkidul Yogyakarta," p. 95, 2017, [Online]. Available: <https://repository.its.ac.id/72120/>
- [24] B. Harlianto and N. Sugianto, "Earthquake-prone Zonation of North Bengkulu Based on Peak Ground Acceleration of Katayama's and Kanai's Formula," *Int. J. Adv. Eng. Manag. Sci.*, vol. 2, no. 11, pp. 1857–1861, 2016, [Online]. Available: [www.ijaems.com](http://www.ijaems.com)
- [25] C. Series, "Analysis of peak ground acceleration (PGA) using the probabilistic seismic hazard analysis (PSHA) method for Bengkulu earthquake of 1900 – 2017 period Analysis of peak ground acceleration (PGA) using the probabilistic seismic hazard analysis (PSHA)," 2017, doi: 10.1088/1742-6596/1282/1/012054.
- [26] Rahmania, Rasmid, M. Arisalwadi, and F. D. Sastrawan, *Microzonation Mapping in Supporting Construction Plan, New Capital City of Indonesia (Case Study: Sepaku Sub-district, Panajam Paser Utara Regency)*, vol. 1. Atlantis Press International BV, 2023. doi: 10.2991/978-94-6463-228-6\_10.
- [27] R. Hafid, Supriyadi, N. K. N, T. A, and F. Rohmaniyah, "Percepatan Tanah Berdasarkan Data Mikroseismik Wisata Bantir Sumowono Semarang," *Unnes Phys. J.*, vol. 6, no. 1, pp. 54–59, 2017.