Gravitasi

Journal available at: https://bestjournal.untad.ac.id/index.php/GravitasiFisika

e-ISSN: 2654-4318 p-ISSN: 1412-2375

Identification of Land Subsidence in Semarang Area Using Gravity Method

S. Rasimeng, S. Noviari, S. Disa, I. Dani, and A. Z. P. Sugiarto*)

Geophysical Engineering Study Program, Lampung University, Bandar Lampung City, Indonesia

Information

Article history:

Received: 11 December 2023

Accepted: 27 August 2024

Published: 30 August 2024

Keywords:

Gravity

Mitigation

Subsidence

Abstract

Semarang area is one of the areas that are vulnerable to deformation. Gravity data processed with Surfer software and Microsoft Excel using gravity corrections, spectrum analysis, and separation of residual and regional anomalies, can then be identified which areas are vulnerable to surface deformation. The results obtained several areas that have the threat of deformation and disasters due to geology, namely in the northeast and southwest of the Semarang area marked by negative green to blue anomalies including Gajah Mungkur, Tugu Muda, Tanah Mas, and Gayamsari areas have negative anomalies, so they are identified as areas with thick sedimentary layers which are one of the causes of surface deformation. In the southeast to northwest of Semarang, Candi Sari, Simpang Lima, Tugu Mas, and Tanjung Mas, marked by yellow to reddish colors, are areas that have positive anomalies, so they are identified as areas that are quite safe in terms of deformation characterized by thin sediment layers.

*) e-mail: azzahraputri258@gmail.com

DOI: 10.22487/gravitasi.v23i1.16874

1. INTRODUCTION

The gravity method is one of the geophysical exploration methods used to identify subsurface structures. The anomalies measured in gravity exploration combine various anomaly sources, including residual anomalies, regional anomalies, and noise. Residual anomalies are the most important as they provide a wide range of information about subsurface structures, geological conditions, and mining materials. Regional anomalies have a wider scope than residual anomalies [1].

The separation of regional and residual anomalies is a crucial stage to clarify anomalies that are near the surface and those that are far from the earth's surface. The residual anomalies obtained are then used for the interpretation of subsurface structures and the identification of potential mineral resources [2]

Gravity data processing produces data that has been adjusted to the Earth's surface conditions. This data is called the Simple Bouguer Anomaly (ABS), which is ready for analysis. However, this data is still a combination of local anomalies and regional anomalies. Regional anomalies represent regional geological conditions, such as basements, folds, and faults. Low-frequency anomalies characterize these anomalies. Local anomalies represent local geological conditions, such as reservoirs, rock intrusions, structure types and shapes, minerals, or ores. These anomalies are characterized by a high-frequency anomaly [3].

Land subsidence is a phenomenon that occurs in many parts of the world, especially in large cities located in coastal areas or alluvial plains. An example of land subsidence in a large city is Tokyo, Japan, which is one of the most urbanized cities. Increased human activities and urbanization in the city have caused a serious environmental problem, namely land subsidence [4].

Several researchers have investigated land subsidence in Indonesia, including in East Java, Indonesia [5] and Semarang, Indonesia [6]. The research shows that land subsidence can reach several meters in a certain period. Severe subsidence can damage infrastructure and economic stability in the region. To accurately determine the condition of land subsidence, a comprehensive monitoring and measurement system is needed. This system should be able to measure land subsidence spatially (in various locations) and non-spatially (in one location). Measurements should be made periodically to get a complete picture of subsidence conditions in the region.

The purpose of this research is to find out the area of Semarang that has the possibility of deformation through the gravity method. Later, the gravity data will be processed with Surfer software and Microsoft Excel. So that further research can be done on mitigation and further education about areas that are vulnerable to deformation.

2. RESEARCH METHOD

In this research, the research area is Semarang City (Figure 1) using the gravity method. Semarang City's gravity data was subjected to a series of corrections, such as drift correction, tidal, latitude, Bouguer, and free air [7] Tidal correction is carried out to eliminate the influence of the presence of objects in space that have a large gravitational force [8]. Drift correction is carried out to eliminate the effects of reading errors of the tools used. Tool reading errors can affect the value of the gravity field [9]. The shape of the ellipsoid earth can affect the calculation so it is necessary to make latitude corrections [10]. Equation 1 is a mathematical calculation of latitude correction g_0 in m/s^2.

$$g_0 = 9.780318(1 + 0.0053024\, Sin^2\phi\ 0.0000059\, Sin^2 2\phi) \qquad 1)$$

Altitude differences also affect the value, so it is necessary to make corrections by not ignoring the mass called Bouguer correction [11].

$$BC = 0{,}0004191\, \rho\Delta h \qquad 2)$$

Free air correction is done to reduce the influence of elevation h on the earth's gravity [12].

$$FAC = -0{,}3086\, h \qquad 3)$$

The result of the correction that has been done is the complete Bouguer anomaly (CBA) value which is influenced by the rock mass density below the earth's surface [13]. The CBA value will be processed into a map for the slicing process using Surfer 13 software. In this process, a straight slice is made to perform spectrum analysis. Spectrum analysis will separate the values of regional anomalies and residual anomalies that overlap in the CBA calculation [14]. In the spectrum analysis conducted using Microsoft Excel software, the window width value is also obtained to perform the moving average filter process [15].

$$\Delta g_R(i) = \frac{\Delta g(i-n) + \cdots + \Delta g(i) + \cdots + \Delta g(i+n)}{N} \qquad 4)$$

where Δg_R is the regional anomaly, $n = (N-1)/2$ and N is the window width. The value of N must be an odd number. The results of the moving average in the form of regional anomalies can be further processed into residual anomalies by reducing regional anomalies with Bouguer anomalies [16]. The residual anomaly is made in the form of a map so that areas that have the potential to experience subsidence can be seen [17].

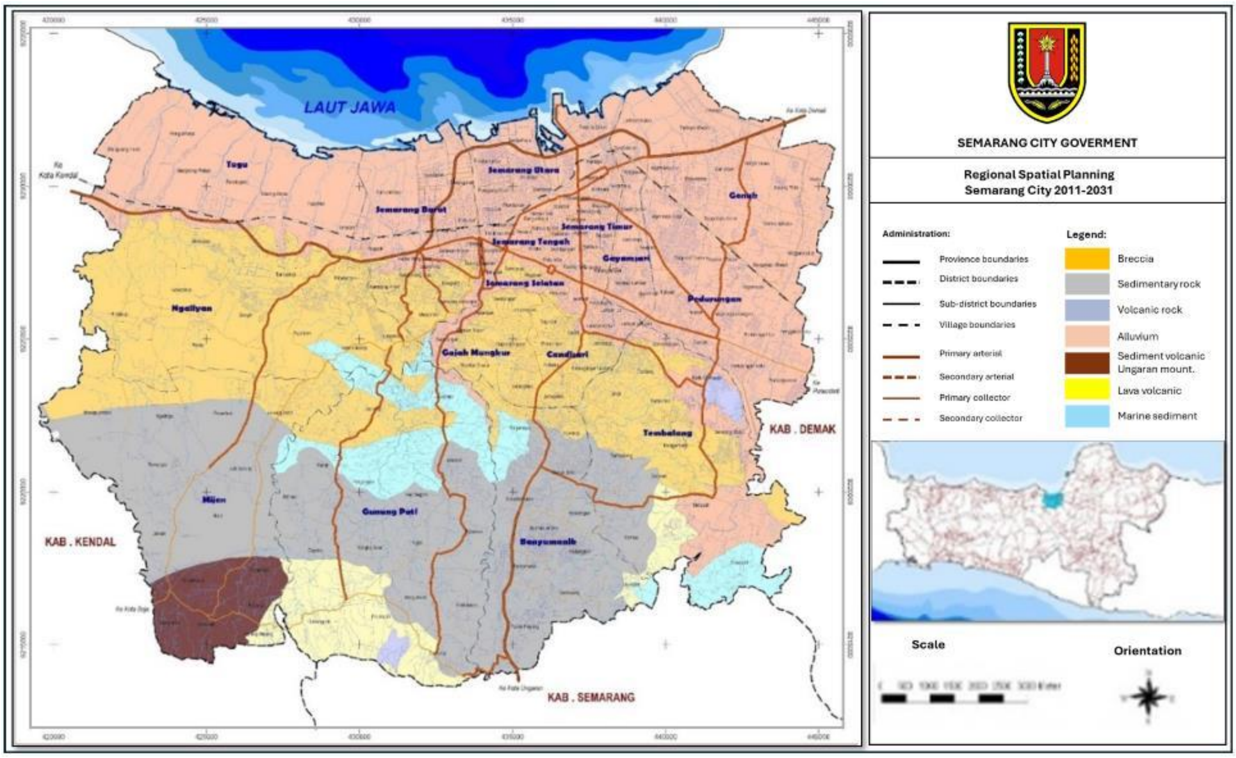

Figure 1. Map of the research area (Bappeda Semarang 2011)

3. RESULT AND DISCUSSION

The results in the form of a complete Bouger anomaly (CBA) were obtained by making corrections to gravity data, such as FAA (Free Air Anomaly) corrections and others (Figure 2). The CBA values that have been obtained are then processed using gravity data processing software. Slice with a straight vertical line to obtain a complete Bouger anomaly profile.

After getting the results of a vertical slice of one path, a spectrum analysis was carried out (as in Figure 3) with the aim of obtaining a separation of residual and regional values from the Semarang CBA values. The spacing used is 100, so after carrying out spectrum analysis calculations such as changing the domain using FFT, changing the previously imaginary value to a real number, and so on, a window width of 11.

In Figure 2, there are points. These points are the result of a plot between the wave number value and the Ln (Gabs) value. These points are then separated by residual and regional values. where regional values will be characterized by linear guide lines that, if connected, will be more slanted or steeper. On the other hand, the residual line that is formed when a linear auxiliary line is drawn will be more sloping. from the residual and regional separation in Figure 2 will produce a linear equation. This linear equation is used in further processing to obtain the window width value.

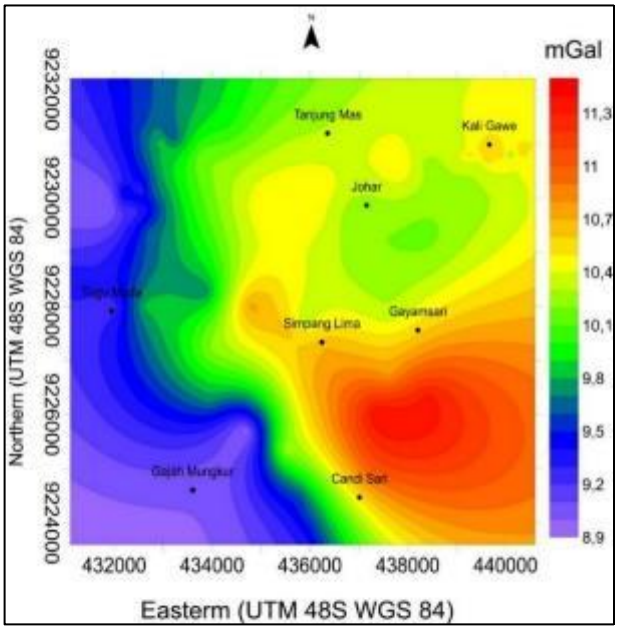

Figure 2. Complete Bouguer Anomaly (CBA) map that has undergone various correction processes

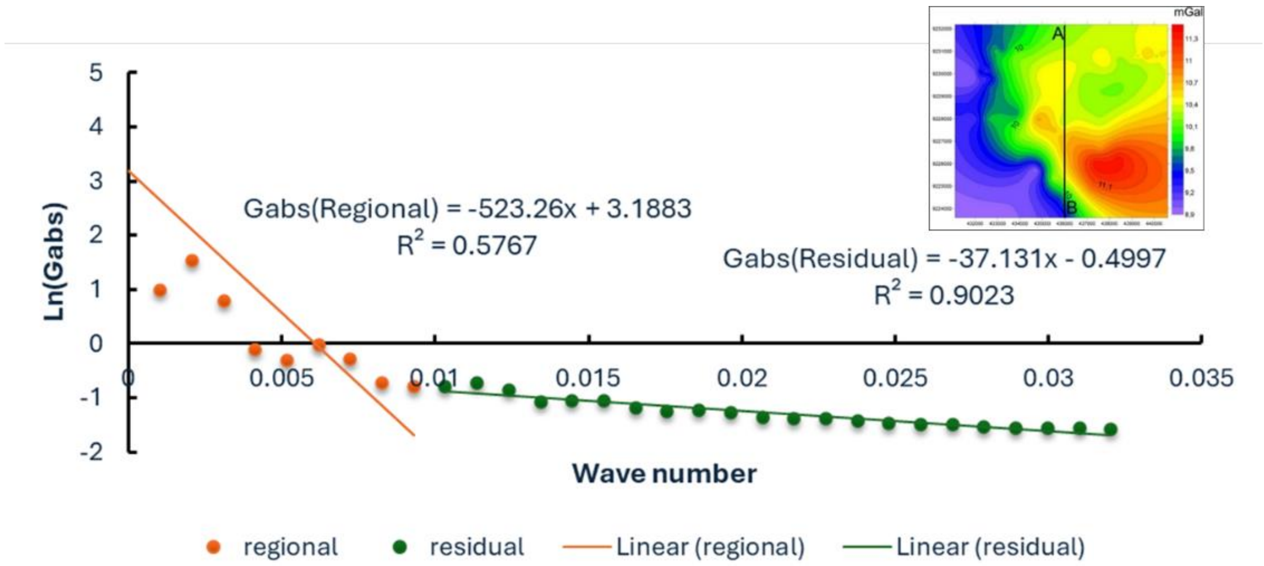

Figure 3. Separation between residual CBA and regional CBA using the spectrum analysis method

This window width value is used as a moving average parameter, whereas for the CBA Semarang window width, it is 11 x 11. This filter will provide a continuously moving average of the values, so that a new value is obtained as a result of the moving average. The results of the moving average filter will produce a regional anomaly map like the following image.

Regional anomalies represent large-scale variations caused by changes in the Earth's crust, while residual anomalies represent small-scale variations remaining after the effects of regional anomalies are removed. The regional anomaly results obtained from the moving average filter will be used to obtain residual anomalies by utilizing math tools in gravity data processing software. This tool will subtract the CBA value that has been corrected from the value of the moving average filter (regional map). So the results of the residual map formed are as Figure 4. Follows.

From the residual map, it is found that the low anomaly reaches -0.45 mGal with a high anomaly of 0.3 mGal, whose contact is limited by a gravity anomaly of zero value. High anomalies are identified as areas that have a thin sedimentary rock layer, whereas low anomalies are identified as areas with a thick sedimentary rock layer. Areas that have thick layers of sediment are more vulnerable to land subsidence and other disasters such as liquefaction and flooding. Areas with high anomalies have a lower threat of disasters caused by surface land subsidence. From Figure 4, it can be seen that the southeast to northwest part of the Semarang area, including the Candi Sari, Simpang Lima, Tugu Mas, and Tanjung Mas areas, which are marked by yellow to reddish colors, are areas that have positive anomalies with a value of 0 mGal to 0.3 mGal., so it can be said that this area is an area that is quite safe from the threat of land subsidence because the sediment layer is not thick. Meanwhile, in the northeast and southwest parts of the

Semarang area, which are marked by green to blue with a value of 0 mGal to -0.45 mGal, including the Gajah Mungkur, Tugu Muda, Tanah Mas, and Gayamsari areas, there are anomalies that tend to be negative. This is identified as an area that has a thick sediment layer and is likely to experience land subsidence. If local communities that have negative anomalies continuously exploit groundwater, this will speed up the land subsidence process. Apart from that, this area is also vulnerable to liquefaction and flood disasters. Therefore, it is necessary to carry out mitigation and education to avoid the dangers of land subsidence and disasters due to the geological conditions of the Semarang area.

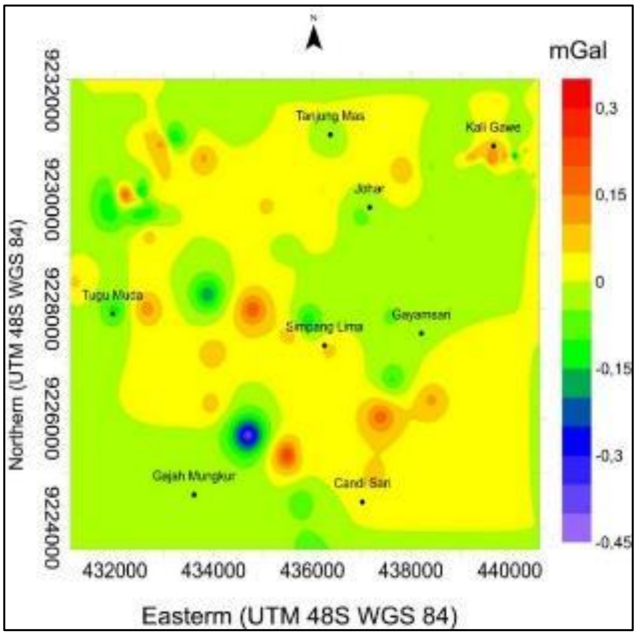

Figure 4. Complete Bouguer Anomaly (CBA) residual map results

4. CONCLUSION

Based on the results of the study, it can be concluded that in the northeast and southwest of Semarang City marked by green to blue color with a value of 0 mGal to -0.45 mGal including Gajah Mungkur, Tugu Muda, Tanah Mas, and Gayamsari areas have anomalies that tend to be negative, this is identified as an area that has a thick sediment layer and is likely to experience Land Subsidence. Meanwhile, areas with high anomalies, namely in the southeast to the northwest of Semarang City, including Candi Sari, Simpang Lima, Tugu Mas, and Tanjung Mas, which are marked with yellow to reddish colors, are areas that have positive anomalies worth 0 mGal to 0.3 mGal, so it can be said that this area is fairly safe in terms of surface land subsidence due to not thick sediment layers.

REFERENCES

[1] S. Supriyadi, K. Khumaedi, S. Sugiyanto, and F. Setiaswan, "Pemisahan Anomali Regional dan Residual Data Gayaberat Studi Kasus di Kota Lama Semarang," Physics Education Research Journal, vol. 1, no. 1, pp. 29–36, 2019.

[2] M. F. Umam, Y. Alhidayah, and R. Fauziyah, "Analisis Material Endapan Vulkan Gunung Semeru Kabupaten Lumajang." Majalah Pembelajaran Geografi 2.1: 92-98, 2019.

[3] R. J. Blakely, Potential theory in gravity and magnetic applications. Cambridge University Press, 1996.

[4] T. Hayashi, T. Tokunaga, M. Aichi, J. Shimada, and M. Taniguchi, "Effects of human activities and urbanization on groundwater environments: an example from the aquifer system of Tokyo and the surrounding area," Science of the total environment, vol. 407, no. 9, pp. 3165–3172, 2009.

[5] D. D. Wardhana, H. Harjono, and S. Sudaryanto, "Struktur bawah permukaan Kota Semarang berdasarkan data gayaberat," Riset Geologi dan Pertambangan-Geology and Mining Research, vol. 24, no. 1, pp. 53–64, 2014.

[6] H. Z. Abidin, H. Andreas, I. Gumilar, Y. Fukuda, Y. E. Pohan, and T. Deguchi, "Land subsidence of Jakarta (Indonesia) and its relation with urban development," Natural hazards, vol. 59, pp. 1753–1771, 2011.

[7] M. I. Sugita, A. F. Janah, and D. Rahmawati, "Analisis Data Gaya Berat Di daerah Bendan Duwur Semarang," Journal of Research and Technology, vol. 6, no. 1, pp. 81–90, 2020.

[8] L. Zulfawati, S. Minardi, and L. M. Angraini, "Analisis Spektrum Pada Data Gaya Berat Daerah Lombok Tengah Dan Lombok Timur Untuk Menentukan Estimasi Ketebalan Sedimen," Jurnal Inovasi dan Pembelajaran Fisika, vol. 6, no. 1, pp. 34–44, 2019.

[9] Muhammad Nursalam, "Fault Analysis With Gravity Data Using Svd (Second Vertical Derivative) Method In 'MN' Geothermal Region," Universitas Hasanuddin, 2021.

[10] H. Manik, C. A. N. Bujung, and J. Tumangkeng, "Anomali Medan Gravitasi Untuk Identifikasi Patahan Daerah Manifestasi Panas Bumi Di Sekitar Gunung Tampusu," Jurnal FisTa: Fisika dan Terapannya, vol. 1, no. 2, pp. 73–79, 2020.

[11] F. Jusmi, "Pemetaan Anomali Bouguer Lengkap dan Topografi Serta Penentuan Densitas Bouguer Batuan Daerah Panas Bumi Pamancalan," Dinamika, vol. 9, no. 1, pp. 1–9, 2018.

[12] J. Jamaluddin, M. Maria, H. Ryka, and R. S. Afifah, "Pemodelan Bawah Permukaan Bantar Karet, Jawa Barat Menggunakan Metode Gravitasi," Jurnal Geocelebes, vol. 3, no. 2, pp. 59–65, 2019.

[13] A. J. Karunianto, D. Haryanto, F. Hikmatullah, and A. Laesanpura, "Penentuan anomali gayaberat regional dan residual menggunakan filter Gaussian Daerah Mamuju Sulawesi Barat," Eksplorium: Buletin Pusat Teknologi Bahan Galian Nuklir, vol. 38, no. 2, pp. 89–98, 2017.

[14] J. Purnomo, S. Koesuma, and M. Yunianto, "Pemisahan anomali regional-residual pada metode gravitasi menggunakan metode moving average, polynomial dan inversion," Indonesian Journal of Applied Physics, vol. 3, no. 1, p. 10, 2013.

[15] K. Supriyadi, M. Ikhsan, and Y. P. Katinavia, "Kajian Dinamika Muka Airtanah di Kawasan Kota Lama Semarang Menggunakan Metode Mikrogravitasi Antar Waktu," Risalah Fisika, vol. 3, no. 1, pp. 21–25, 2019.

[16] M. Kobe, G. Gabriel, A. Weise, and D. Vogel, "Time-lapse gravity and leveling surveys reveal mass loss and ongoing subsidence in the urban subversion-prone area of Bad Frankenhausen, Germany," Solid Earth, vol. 10, no. 3, pp. 599–619, 2019.

[17] M. S. Rosid, R. A. Prastama, M. Yusuf, Y. Daud, and A. Riyanto, "Monitoring of Jakarta subsidence applying 4D microgravity survey between 2014 and 2018," Geomate Journal, vol. 20, no. 79, pp. 132–138, 2021.