Comparison of IDW and Kriging Interpolation Methods Using Geoelectric Data to Determine the Depth of the Aquifer in Semarang, Indonesia

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ABSTRACT

Several areas in Semarang City have been unable to get a clean water supply through the Local Water Company (PDAM) channel. One of the solutions that can be done to overcome this problem is by utilizing groundwater, which can be obtained by building a deep well made to obtain rock layers that can accommodate and drain groundwater (aquifer layer). To find out the approximate depth of the aquifer layer, it is necessary to conduct a preliminary investigation before drilling. There are so many methods that can be done, and one of them is by using the geoelectric method. After using the geoelectric method, we can determine the distribution of the depth of the aquifer in Semarang City by using interpolation analysis. In this study, the IDW and Kriging interpolation methods were used. The two methods were then compared to show the difference in the distribution of aquifer depths in areas that lack clean water using the two interpolation methods above. Besides that, we are using RMSE and MAPE analysis to find the error rate of the two methods. The results obtained were the RMSE of the IDW and Kriging methods amounting to 5,829 and 5,433, and the MAPE results were 10.90% and 10.34%. Based on this, the Kriging method tends to have better results when interpolating using geoelectric data. With this research, it is hoped to provide knowledge to determine the most suitable interpolation method used in determining the depth of the aquifer and also can be used as an illustration of the depth of the aquifer in the area that lacked clean water in Semarang City, so that it can be used as a reference in estimating the design of good deep development more accurately.

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1. INTRODUCTION

Semarang City is one of the big cities in Central Java Province because it is a strategic city that can be reached by land, air, or sea. The city, the capital of Central Java Province, has 1,729,428 people, with population growth in 2016 of 1.66% [1]. The large population and high population growth will result in increasing human needs. There are several kinds of basic human needs that can be described in Abraham Maslow's Hierarchy of Needs. According to Abraham Maslow's Hierarchy of Needs, water is included as one of the most important factors of human needs [2]. Water can be used for various things, such as drinking water, washing clothes, cooking, etc. Therefore, getting clean water easily becomes mandatory for all people.

However, several areas in Semarang City do not even get clean water supply through the Local Water Company (PDAM) channel. PDAM is a Regional Owned Enterprise (BUMD), which is engaged in providing clean water needed by the community. PDAM has the main task of providing clean water to improve the community's welfare regarding social, health, and public service aspects and contribute to regional income [3]. One of the solutions made by the Semarang City government to distribute clean water is by distributing clean water assistance to deprived areas. Based on the Regional Disaster Management Agency (BPBD), which is the agency tasked with managing natural disasters that occur in disaster-prone areas, revealed that in the city of Semarang, several areas received clean water assistance in 2019.

These areas include Kelurahan Rowosari, Kecamatan Tembalang, Kelurahan Muktiharjo Lor, Kecamatan Genuk, Kelurahan Tinjomoyo Kecamatan Banyumanik, Kelurahan Mangunharjo, Kecamatan Tembalang, Kelurahan Jabungan Kecamatan Banyumanik [4]. If the solution to the shortage of clean water is always carried out by assisting the government, the surrounding people in the area will become dependent on the government. When there is a shortage of clean water, but the government cannot assist, the surrounding people in the area cannot do anything and will always lack clean water for their daily needs.

One way that can be done to overcome this problem is by utilizing groundwater which can be obtained by building a deep well. The deep well is made to obtain rock layers or geological formations where certain volumes of water can find their way (permeability) into wells, and water springs are referred to as aquifer layers [5]. This rock layer will be used as a source of clean water in the future. To find out the approximate depth of the rock layer, it is necessary to conduct a preliminary investigation before drilling. One of them is by using the geoelectric method. By using this method, the results will be obtained in the form of the resistivity of each rock layer so that the types of rock that exist can be classified based on the rock's resistivity level.

After knowing the depth of each layer estimated as the aquifer layer at each point in the surrounding area, a map of the distribution of the aquifer depth in the city of Semarang is made. Making the map is done using the interpolation method so that the parts where the geoelectric data cannot be retrieved can be estimated at their depth. Making the aquifer depth distribution map is very important because it estimates the depth of deep wells that need to be built to affect the Budget Plan for good deep construction. Therefore, it is vital to know the most accurate interpolation method based on the results of geoelectric data in the field.

The interpolation method itself is divided into several types, and various interpolation techniques have been proposed to estimate the unobserved values, such as inverse distance weighted, splines, and Kriging [6][7]. This research uses two types of interpolation methods: Inverse Distance Weighted (IDW) [7] and kriging methods.

The research contributes to providing knowledge to determine the most suitable interpolation method for the aquifer's depth. In addition, this research also shows the differences in the distribution of aquifer depth in areas that lack clean water in Semarang City using the two interpolation methods above. It is expected that this research can be used to illustrate the depth of the aquifer in the area that lacks clean water so that later it can be used as a reference in estimating the design of good deep development more accurately.

2. METHOD

There are four stages in doing this research, which are shown in Fig. 1. The preliminary stage, data collection stage, data processing stage, and comparison of the two interpolation methods.

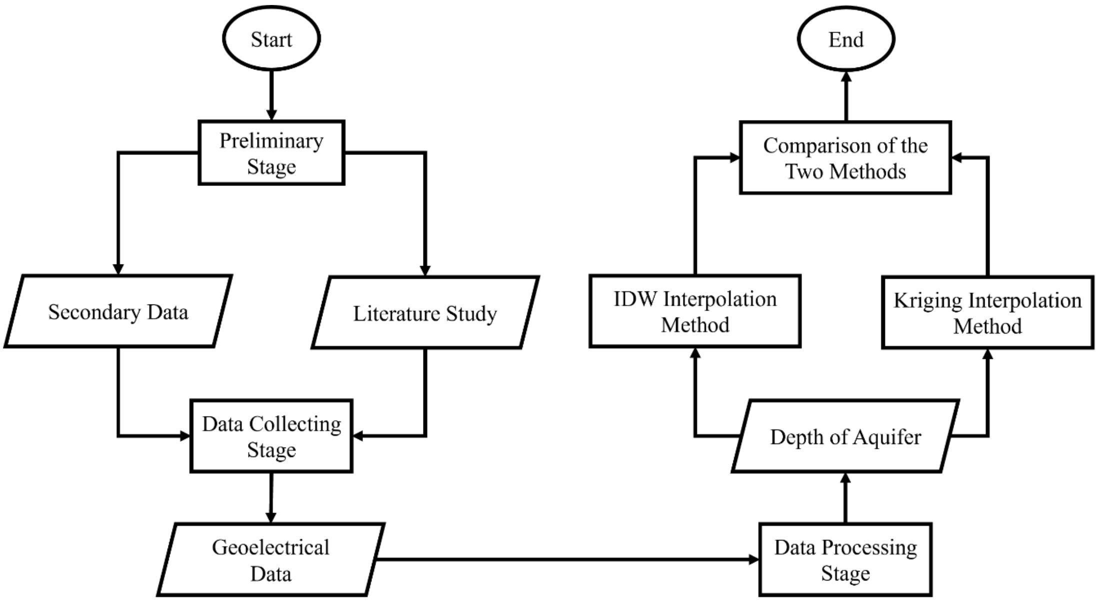

Fig. 1. Research flowchart diagram

2.1. Preliminary Stage

The preliminary stage is to conduct a literature study to commemorate similar studies related to this research. Then, look for secondary or supporting data to facilitate the collection of main data, namely administrative maps and geological maps in the city of Semarang. The administrative map of Semarang City is needed as a layout for the depth distribution of deep aquifers in Semarang City from the results of interpolation using geoelectric data. The map is downloaded from *https://tanahair.indonesia.go.id/portal-web*.

2.2. Data Collection Stage

In the data collection stage, data is obtained directly in the field using geoelectric tools. This method is done by injecting a strong electric current into the ground 200 meters to the left and right of the center of the geoelectric device. The geoelectric method injects a strong electric current into the ground. The data obtained from the geoelectric device is the potential difference between each rock layer below the ground surface. Furthermore, the apparent resistivity of each rock layer below the soil surface can be calculated using the electric current and the known potential difference.

$$\rho_a = K\,\frac{\Delta V}{I} \tag{1}$$

where ρ_α is resistivity (ohm), K is geometric factor, ΔV is electric potential difference (volts) and I is electric current (ampere) [8].

2.3. Data Processing Stage

In the third stage, the known apparent resistivity calculation results will then be analyzed and processed using IP2Win software to interpret the original resistivity and the depth and thickness of the existing rock layers. With this knowledge, it is possible to determine the depth of each aquifer layer at the points where the data has been taken.

2.4. Data Processing Stage

In this stage, the aquifer depth data that has been obtained previously will be analyzed to make the distribution of aquifer depth in the city of Semarang. The distribution of the aquifer layer can be made using the interpolation method. The interpolation methods used in this study are IDW and Kriging.

The Inverse Distance Weighting (IDW) is a deterministic (mechanical) technique [7][8]. An interpolation method utilizes the concept that the value at an unsampled point is determined by a linear combination of values at known sample points. IDW considers distance as a weighting parameter so that the area that becomes the sample point will have a more excellent value in the surrounding area than the sample point farther away [9].

On the other side, Kriging is classified into stochastic interpolation methods where the weight for each sampled point is defined using distance and spatial arrangement among those points, which in addition to estimating values, also determines the estimation error rate at each point [9]. This method uses a semi-variogram that represents spatial differences and values between all data samples [10].

This research used these two methods because both methods rely on the similarity of nearby sample points to estimate values and create a surface [11], ignore the variety of uncertainties in multi-source data [12], and two most commonly used spatial interpolation methods [9].

The formula of the Inverse Distance Weighting (IDW) algorithm is as follows:

$$\begin{gathered}
\hat{z}(x_0, y_0) = \sum_{i=1}^{n} \lambda_i z(x_i, y_i) \\
\lambda_i = (1/d_i)/(\sum_{k=0}^{n} (1/d_i) \\
d_i = \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2}
\end{gathered} \tag{2}$$

where is the eigenvalue attribute of the pre-estimation point, λ_i is the weight of the sample point for the estimated point, and d_i is the distance from the sample point to the predicted point [13].

Then, the Kriging interpolation formula is as follows:

$$\hat{z}(x_0, y_0) = \sum_{i=1}^{n} \omega_i z(x_i, y_i)$$
$$\sum_{k=0}^{n} \omega_i = 1 \tag{3}$$

In the equations is the eigenvalue predicted by the surrounding sample points. And $z(x_i, y_i)$ is the eigenvalue of the surrounding known sample points. ω_i is the weight coefficient of sample point $z(x_i, y_i)$ to $\hat{z}(x_0, y_0)$ [13].

Several interpolation methods will be used to determine the most suitable method for mapping aquifer layers based on geoelectric data. To determine the accuracy of the interpolation method in this research is using Leave-One-Out Cross-Validation (LOOCV). LOOCV is a method that eliminates the value of the observations one by one that will be predicted and will be interpolated with data from the remaining observational value data that has been omitted. So that it will be known the magnitude of the predicted value at each of the omitted observation values. One of the drawbacks of this validation method is the large level of computation if the number of n values is vast [14]. So, validation using LOOCV is very good if the value of n or the observation data is not too much.

After knowing the results of the predictions of each point that has been interpolated, then we calculate the Root Mean Squared Error (RMSE) and the Mean Absolute Percentage Error (MAPE) to compare and determine the level of prediction error for each interpolation method. RMSE is a good performance metric for accuracy. Like RMSE, MAPE also has the same units as the original values. It is often smaller than RMSE, and if the model values are very close to the observed ones, then the reverse could be valid [15]. The calculation to determine the RMSE value is by using the following formula.

$$RMSE = \sqrt{\sum_{i=1}^{N} \frac{\left(I_{i,exp} - I_{i,cal}\right)^2}{N}} \tag{4}$$

where N is the number of data points, $I_{i,exp}$ and $I_{i,cal}$ are the experimental (predicted value) and theoretical (actual value) [16].

Meanwhile, the calculation to determine the MAPE value is by using the following formula,

$$MAPE = \sum_{t=0}^{N} \frac{\left|\left(\frac{A_t - F_t}{A_t}\right) 100\right|}{N} \tag{5}$$

with A_t is the actual value, F_t is the predicted value, and N is the amount of data [17].

3. RESULTS AND DISCUSSION

Before this research, there have been several previous studies discussing the comparison of interpolation methods. For example, for bathymetric interpolation analysis in the Saldanha Bay, IDW consistently performed better than OK [18]. The analysis of the interpolation method in Viçosa City, Brazil, shows that the kriging interpolation method is also better than IDW in the bathymetry area [19]. Furthermore, the assessment of statistical interpolation methods suited for gridded rainfall datasets in the Emilia-Romagna region (Italy) has shown that Ordinary Kriging (OK) generally outperforms the other methods. In contrast, the Thin Plate Spline (TPS) method shows better performance through visual inspection on a monthly scale [20].

Then, the interpolation analysis to determine the distribution of slowly available potassium (SAK) in Tongzhou District, Beijing, China, indicates that the Kriging interpolation method is the best in this case [21]. Analysis of the aerial photo interpolation method for making DEM maps in Pesawaran District, Lampung, Indonesia, shows that the Triangulated Irregular Network (TIN) interpolation method is the best method to make DEM compared to using the IDW and Kriging interpolation methods [22]. The analysis of the interpolation method for groundwater level mapping in Sleman, Yogyakarta, Indonesia, states that the Kriging interpolation method is better than the IDW method [23].

Then, in Tehran, Iran, the Kriging method is better for conducting an interpolation analysis of air pollution in the city [24]. Research also states that there are differences in each interpolation method, which best depends on the soil's depth. This was done during a soil moisture mapping analysis in the Loess Highlands, China. The RBFNN-RK method is optimal for a depth of 0-10 cm, 100-200 cm, and 300-400 cm from the soil layer. IDW is the best method for depths of 200 to 300 cm and 400 to 500 cm of subsoil. Then, OK is optimal for 10 to 40 cm and a subsoil depth of 40 to 100 cm [25].

A study in Korea using weather data found that cokriging is more suitable for temperature interpolation than other interpolation methods. On the other hand, the IDW method is preferable and suitable for rainfall interpolation [26]. A comparison of spatial interpolation methods for estimating the precipitation distribution in Portugal got a result that empirical Bayesian kriging regression (EBKR) performs best compared to the other interpolation methods like local polynomial interpolation (LPI), global polynomial interpolation (GPI), radial basis function (RBF), inverse distance weighted (IDW), ordinary cokriging (OCK), and universal cokriging (UCK) [27].

Based on the previous studies, no research has conducted interpolation analysis to determine the depth of the aquifer using the IDW and Kriging interpolation methods. Therefore, this study will be one of the first to address this issue. After collecting field data using geoelectric methods and analyzing using IP2Win software, the results of aquifer depth in Semarang City and their coordinates are shown in Table 1.

Table 1. The depth of the aquifer in Semarang

Location	**Coordinates**		**Depth (m)**
	Easting (X)	**Northing (Y)**	
Kelurahan Tegal Sari, Kec. Candisari	436162	9225207	56
Kelurahan Wonosari, Kec. Ngaliyan	421918	9228627	54
Kelurahan Gondoriyo, Kec. Ngaliyan	425039	9226890	55
Kelurahan Tandang, Kec. Tembalang	438778	9224380	44
Kelurahan Kandri, Kec. Gunungpati	428920	9219980	43
Kelurahan Pudakpayung RW 15, Kec. Banyumanik	435490	9215650	45
Kelurahan Rowosari, Kec. Tembalang	444398	9218928	38
Kelurahan Wates, Kec. Ngaliyan	424909	9225120	55
Kelurahan Purwoyoso, Kec. Ngaliyan	430204	9225798	41
Kelurahan Pudak Payung RW 14	435786	9215726	38
Kelurahan Cangkiran RW 4	424264	9215395	56
Kelurahan Sekaran	432916	9220203	42
Kelurahan Wonosari RW 3	422343	9228728	50
Kelurahan Wonosari RW 1	421779	9228679	48
Kelurahan Kalipancur RW 1	432096	9225175	44
Kelurahan Bambankerep	428718	9224299	47
Kelurahan Pedurungan Kidul	442852	9222202	39
Kelurahan Penggaron Kidul	443288	9224454	41
Kelurahan Tlogosari Wetan RW 1	441609	9226849	48
Kelurahan Mangkang Wetan RW 1	423661	9229326	44
Kelurahan Cangkiran RW 3	423597	9216191	56
Kelurahan Pesantren RW 1	424156	9224100	48
Kelurahan Gedawang RW 7	436384	9215655	29
Kelurahan Padangsari RW 16	436385	9215956	33
Kelurahan Siwalan RW 4	439468	9229031	56
Kelurahan Bangetayu Wetan RW 1	442582	9227881	42
Kelurahan Genuksari RW 3	442995	9229425	51
Kelurahan Gunungpati	429005	9215966	52
Kelurahan Pakintelan RW 5	432666	9216828	42
Kelurahan Cepoko RW 01	428564	9218524	46
Kelurahan Mangunharjo RW 3	440659	9222169	50
Kelurahan Ngadirgo RW 2	423559	9223555	42

Coordinates above using map datum World Geodetic System (WGS) 1984 and standard The Universal Transverse Mercator (UTM) 49S. WGS 1984 is a coordinate system mainly used in navigation tools [28]. The Universal Transverse Mercator (UTM) is a projection coordinate system and can also be called a Cartesian coordinate system [29], while 49S indicates the location where this research was conducted.

The data has been used as the basis for the interpolation method to be carried out, which is IDW and Kriging. Thus, the results of the two methods' interpolation are shown in Fig. 2.

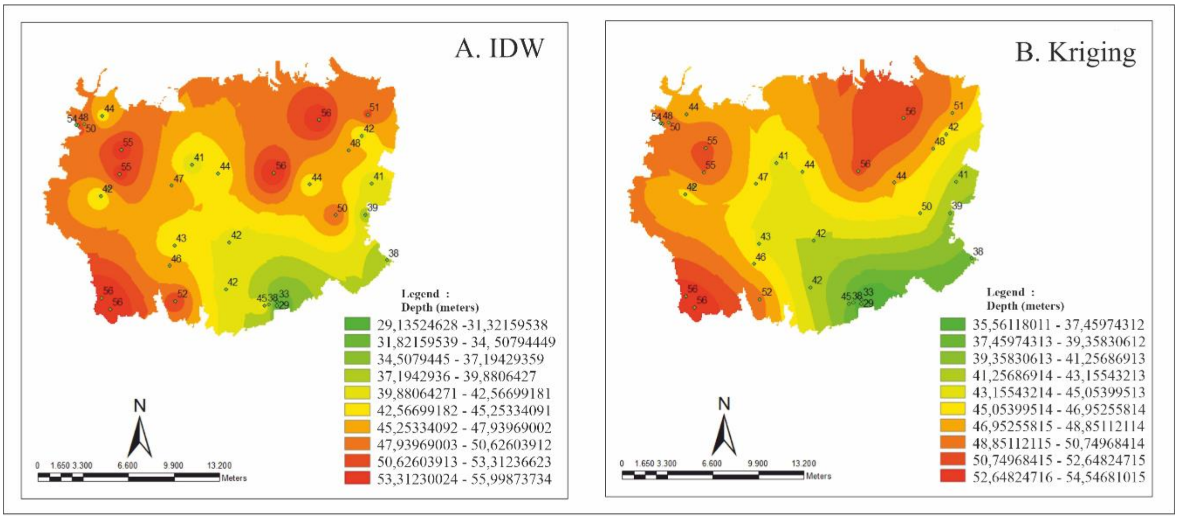

Fig. 2. IDW method interpolation results (a) & Kriging (b) in Semarang City

The results of the interpolation of the two methods show that in the southern and eastern areas of Semarang City, the depth of the aquifer is much lower than in the northern and western parts. This is also in line with the elevation or height of the land in the city of Semarang. In the southern part of Semarang City, where the elevation is high, the depth of the aquifer is getting lower. Then, the northern part of Semarang City, which has a lower elevation than the southern part, results in a deeper aquifer depth.

There are several differences in the interpolation results between the IDW and Kriging methods. The minimum depth value found in the IDW method is 29.13 meters, while the Kriging method is 35.56 meters. The maximum value of IDW is 55.99 meters, and Kriging is 54.54 meters. Then, the mean of the IDW method is 46.4 meters, and Kriging is 46.6 meters.

As seen in the northern part of the map, in the IDW method, the two points with a high depth, namely 56 meters, are not related to each other. In the Kriging method, there are equations and a relationship of depth distribution between the two points with the same relative depth. In the eastern part, there is a basin pattern in the IDW method because the observation data indicates that at that point, it does have a lower depth when compared to the surrounding area, 44 meters. However, in the Kriging method, this observation point does not show a basin pattern where there is a difference in depth from the surrounding area.

The IDW method in this research has characteristics that are pretty clear in the differences in each area according to the observed value of the aquifer depth. This follows the characteristics of the IDW method, which still displays measured values at sample locations where there are observed values [30][31]. The Kriging method has characteristics that make the map results of this method smoother the difference in depth because it is more dependent on predictions from the results of the overall observation data. With this method, it will not always be following the same value for one point of the observed data only. Furthermore, to clarify the distribution of aquifer depth in areas of Semarang City that are still short of water, an analysis of the IDW and Kriging interpolation methods was carried out. Fig. 3 are the results of the interpolation of the IDW and Kriging methods in areas that still lack clean water according to the Semarang City BPBD (2019) [4].

In the area of Kelurahan Rowosari Kecamatan Tembalang, the results of the IDW and Kriging look a little different in Fig. 3. Especially in the east and south. The predictive value in the IDW method shows that the minimum value is 38 meters which is located in the eastern part. Whereas in the Kriging method, the minimum value of this method is 37.99 meters and is located on the southern part of the map. The maximum values of IDW and Kriging are respectively 41.48 meters and 40.28 meters which are located in the northern part. Then, the average value of the predicted aquifer depth is 39.68 meters and 39.05 meters for the IDW and Kriging methods, respectively.

There is quite a visible difference in aquifer depth predictions between the IDW and Kriging methods in this region. In the northern part of the map in Fig. 4, it can be seen that IDW has a reasonably high depth, starting from 54 meters and decreasing in depth towards the south. As for Kriging, the northern part of the map has a lower depth than IDW, which is about 50 meters and extends sideways towards the south of the map. The minimum values for the IDW and Kriging methods are 52.1 meters and 50.83 meters. Furthermore, the difference in the maximum value of the two methods is the IDW of 56 meters and the Kriging method of 51.88 meters. Then, the average value of the aquifer depth prediction in this area using the IDW method is 54.62

meters, while the Kriging method is 51.39 meters. This IDW method has a range value between the minimum and maximum values and the average depth prediction value higher than the Kriging method.

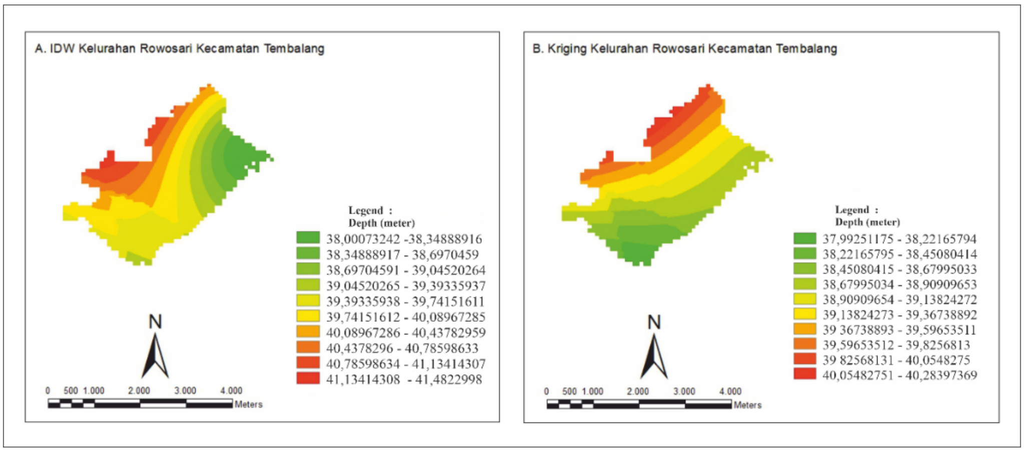

Fig. 3. IDW method interpolation results (a) & Kriging (b) in Kelurahan Rowosari Kecamatan Tembalang

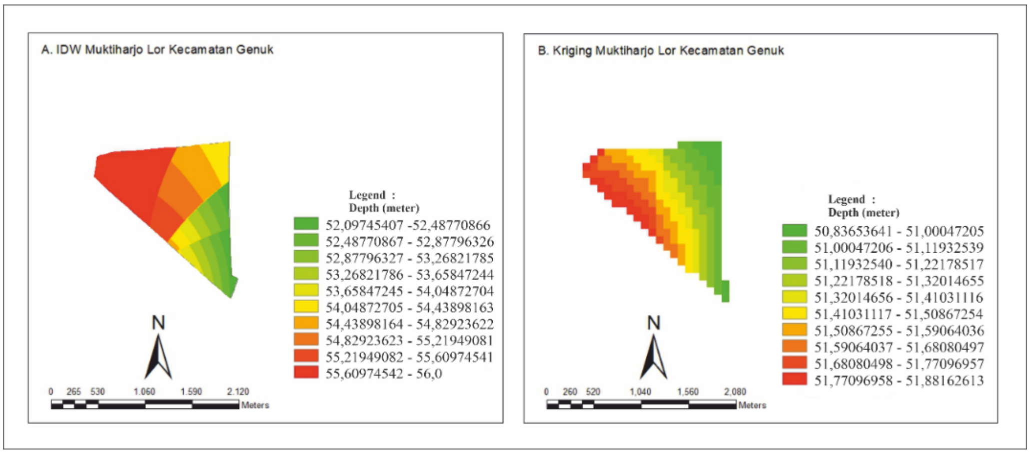

Fig. 4. IDW method interpolation results (a) & Kriging (b) in Kelurahan Muktiharjo Lor Kecamatan Genuk

There is not much difference in the interpolation results in this area in Fig. 5. The depth distribution in each area on the map is almost the same between the two methods. The minimum values for the IDW and Kriging methods are 42.28 meters and 43.38 meters, while the maximum values are 46.89 meters and 46.59 meters, respectively. Then the average aquifer depth value in this area is 44.22 meters for IDW and 45.16 meters for the Kriging method.

The difference in the distribution of aquifer depths in this area is visible in the northern area of the map in Fig. 6. The IDW method has a high depth distribution and is centered on the north. While the Kriging method, the high depth on the map spreads from the north and goes west. The minimum value using IDW in this area is 43.6 meters, and using Kriging is 41.99 meters. Then, the maximum value in the IDW method is 49.94 meters, and Kriging is 45.19 meters. While the average depth value using the IDW method is 46.7 meters, and Kriging is 43.78 meters.

The results of the IDW and Kriging methods in Kelurahan Jabungan Kecamatan Banyumanik in Fig. 7, get results in the form of a minimum value of 33.67 meters and 35.76 meters. The maximum values for each IDW and Kriging method are 38.97 meters and 39.96 meters. Meanwhile, the average predicted aquifer depth in this area is 36.73 meters and 37.46 meters for the IDW and Kriging methods, respectively. This shows that there is not a significant difference between the IDW and Kriging methods. A noticeable difference is found in the northern part of the map, where the distribution looks different.

After the analysis of the IDW and Kriging interpolation methods is carried out and the results are obtained as above, then re-analyzed, a training data and test set will be made using the LOOCV method to obtain the magnitude of the difference between the predicted value and the observed value. After the difference between the predicted value and the observed value is known, the interpolation method error rate will be calculated. This method determines the error rate of this method using the Root Mean Squared Error (RMSE) and Mean

Absolute Percentage Error (MAPE). The results of the RMSE and MAPE are in Table 2. There is a slight difference between IDW and Kriging in the RMSE results. Meanwhile, MAPE is not too different. With the above RMSE and MAPE results, it can be seen that the Kriging method has a lower error rate when compared to the IDW interpolation method.

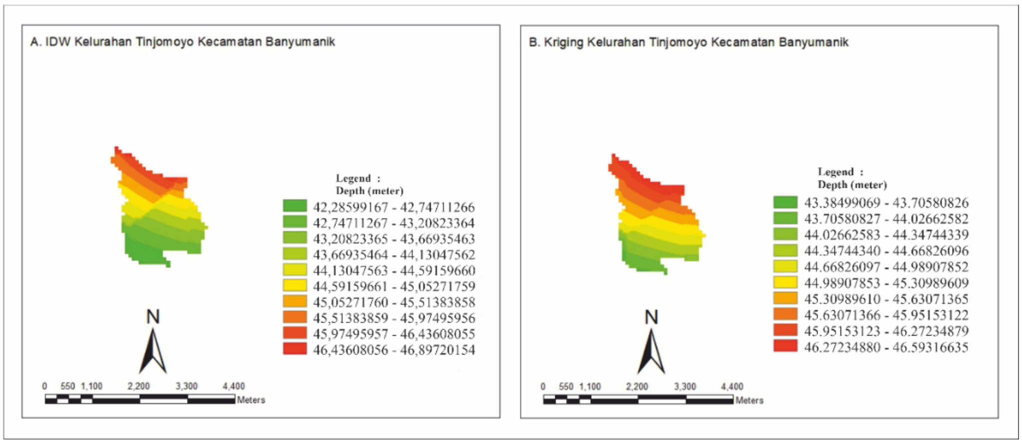

Fig. 5. IDW method interpolation results (a) & Kriging (b) in Kelurahan Kelurahan Tinjomoyo Kecamatan Banyumanik

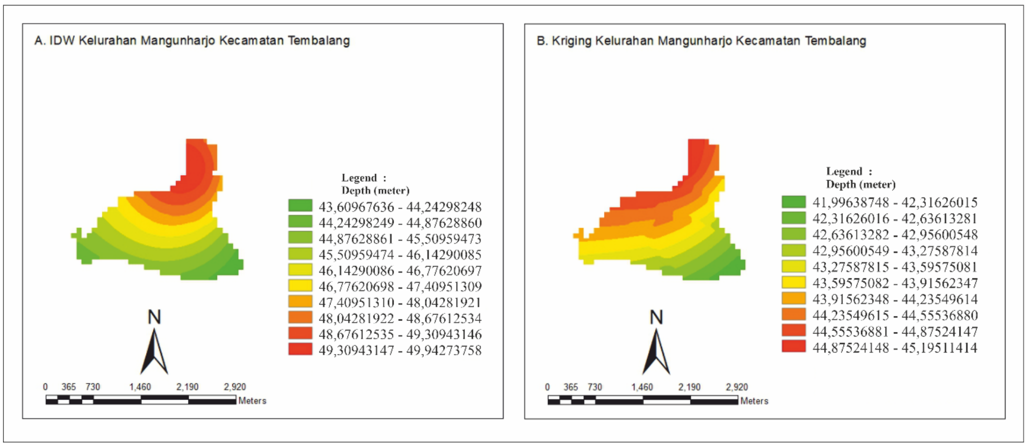

Fig. 6. IDW method interpolation results (a) & Kriging (b) in Kelurahan Mangunharjo Kecamatan Tembalang

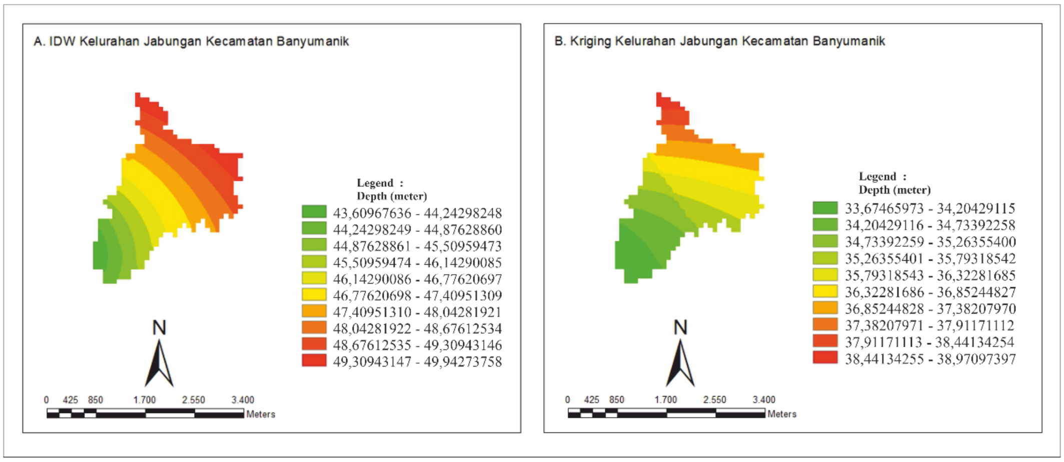

Fig. 7. IDW method interpolation results (a) & Kriging (b) in Kelurahan Jabungan Kecamatan Banyumanik

Table 2. Results of RMSE and MAPE analysis

Methods	RMSE	MAPE (%)
IDW	5.829	10.90
Kriging	5.433	10.34

4. CONCLUSION

Based on the interpolation result of aquifer depth in Semarang City, there is a difference in the distribution of aquifer depth predictions between the IDW and Kriging methods. In the IDW method, there are apparent differences in depth predictions from one area to another. As previously explained, this IDW method still displays the measured values at the sample location. So, the part where the sample data and its surroundings will be more accurate. However, because the amount of observation data available is not too much and the location is irregular, significant differences are obtained from one area to another. This is because IDW depends on observational data, so if there is one observation data whose value is abnormal, it will continue to follow the observed data, resulting in a significant difference in aquifer depth between the surrounding area. Meanwhile, in Kriging, if there is data with abnormal values, the difference in the estimated depth to the surrounding area tends to be smoother. It does not depend on data from observations in one area only.

The RMSE results of the IDW and Kriging methods are 5,829 and 5,433, and the MAPE results are 10.90% and 10.34%, indicating that the Kriging interpolation method to determine aquifer depth in Semarang City based on geoelectric yield data is a better method than the IDW method. Although the difference is not that far, it can be used in determining which interpolation method is suitable to determine the depth of the aquifer.

Therefore, in the future, it is necessary to conduct more in-depth research on the distribution map of the aquifer layer in Semarang City using these two interpolation methods or other interpolation methods. This is because the data obtained to conduct this research is still quite small. Thus, the results may change using more evenly distributed data. In addition, other interpolation methods may be better than the two methods used in this study.

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REFERENCES

[1] Badan Pusat Statistik Kota Semarang, "Kota Semarang Dalam Angka 2019," *BPS Kota Semarang, CV. Citra Yunda*, 2019.

[2] Dr. E. O. Aruma, Dr. Melvins Enwuvesi Hanachor, "Abraham Maslow's Hierarchy of Needs and Assessment of Needs in Community Development," *International Journal of Development and Economic Sustainability*, vol. 5, no. 7, pp. 15-27, 2017.

[3] D. Dariana and W. Desriyanti, "Analisis Sistem Informasi Akuntansi Pembayaran Biaya Tagihan Pemakaian Air Bersih Pada Perusahaan Daerah Air Minum (PDAM) Cabang Bengkalis," *JAS (Jurnal Akuntansi Syariah)*, vol. 1, no. 2, pp. 207-230, Dec. 2017, https://ejournal.stiesyariahbengkalis.ac.id/index.php/jas/article/view/113.

[4] Badan Penanggulangan Bencana Daerah Kota Semarang, "Droping Bantuan Air Bersih," 2019, *https://bpbd.semarangkota.go.id/detailpost/droping-bantuan-air-bersih*.

[5] S. A. O and A. A. A, "Aquifer, Classification and Characterization," in *Aquifers - Matrix and Fluids*, InTech, 2018, https://doi.org/10.5772/intechopen.72692.

[6] A. Bărbulescu, C. Șerban, and M.-L. Indrecan, "Computing the Beta Parameter in IDW Interpolation by Using a Genetic Algorithm," *Water*, vol. 13, no. 6, p. 863, 2021, https://doi.org/10.3390/w13060863.

[7] W. Maleika, "Inverse distance weighting method optimization in the process of digital terrain model creation based on data collected from a multibeam echosounder," *Appl. Geomatics*, vol. 12, no. 4, pp. 397–407, 2020, https://doi.org/10.1007/s12518-020-00307-6.

[8] F. D. Sastrawan, Asrafil, and E. G. Prasetya, "Depth estimation of the aquifer layer using the geoelectric resistivity method," *J. Phys. Conf. Ser.*, vol. 1434, no. 1, p. 012004, Jan. 2020, https://doi.org/10.1088/1742-6596/1434/1/012004.

[9] S. Boroomand Nasab, A. Ali Naseri, A. Soltani Mohammadi, and A. Sayadi Shahraki, "Estimation of groundwater depth using ANN-PSO, kriging, and IDW models (case study: Salman Farsi Sugarcane Plantation)," *Cent. Asian J. Environ. Sci. Technol. Innov.*, vol. 3, pp. 91–101, 2021, doi: https://doi.org/10.22034/cajesti.2021.03.01.

[10] F. Abdullah, E. Yulianto, Novrizal, and A. Riyanto, "Pseudo 3D seismic using kriging interpolation," *J. Phys. Conf. Ser.*, vol. 1725, no. 1, p. 012075, 2021, https://doi.org/10.1088/1742-6596/1725/1/012075.

[11] R. E. Ouabo, A. Y. Sangodoyin, and M. B. Ogundiran, "Assessment of Ordinary Kriging and Inverse Distance Weighting Methods for Modeling Chromium and Cadmium Soil Pollution in E-Waste Sites in Douala, Cameroon," *J. Heal. Pollut.*, vol. 10, no. 26, p. 200605, 2020, https://doi.org/10.5696/2156-9614-10.26.200605.

[12] D. Che and Q. Jia, "Three-Dimensional Geological Modeling of Coal Seams Using Weighted Kriging Method and Multi-Source Data," *IEEE Access*, vol. 7, pp. 118037–118045, 2019, https://doi.org/10.1109/ACCESS.2019.2936811.
[13] P. Wang, Z. Feng, Y. Tang, and Y. Zhang, "A Fingerprint Database Reconstruction Method Based on Ordinary Kriging Algorithm for Indoor Localization," in *2019 International Conference on Intelligent Transportation, Big Data & Smart City (ICITBS)*, 2019, pp. 224–227, https://doi.org/10.1109/ICITBS.2019.00060.
[14] D. Berrar, "Cross-Validation," in *Encyclopedia of Bioinformatics and Computational Biology*, Elsevier, 2019, pp. 542–545, https://doi.org/10.1016/B978-0-12-809633-8.20349-X.
[15] M. W. Liemohn, A. D. Shane, A. R. Azari, A. K. Petersen, B. M. Swiger, and A. Mukhopadhyay, "RMSE is not enough: Guidelines to robust data-model comparisons for magnetospheric physics," *J. Atmos. Solar-Terrestrial Phys.*, vol. 218, p. 105624, 2021, https://doi.org/10.1016/j.jastp.2021.105624.
[16] A. Atia, F. Anayi, and G. Min, "Improving Accuracy of Solar Cells Parameters Extraction by Minimum Root Mean Square Error," in *2020 55th International Universities Power Engineering Conference (UPEC)*, 2020, pp. 1–6. https://doi.org/10.1109/UPEC49904.2020.9209780.
[17] U. Khair, H. Fahmi, S. Al Hakim, and R. Rahim, "Forecasting Error Calculation with Mean Absolute Deviation and Mean Absolute Percentage Error," *J. Phys. Conf. Ser.*, vol. 930, p. 012002, 2017, https://doi.org/10.1088/1742-6596/930/1/012002.
[18] I. Henrico, "Optimal interpolation method to predict the bathymetry of Saldanha Bay," *Trans. GIS*, vol. 25, no. 4, pp. 1991–2009, 2021, https://doi.org/10.1111/tgis.12783.
[19] I. O. Ferreira, D. D. Rodrigues, G. R. dos Santos, and L. M. F. Rosa, "In Bathymetric Surfaces: IDW Or Kriging?," *Bol. Ciências Geodésicas*, vol. 23, no. 3, pp. 493–508, 2017, https://doi.org/10.1590/s1982-21702017000300033.
[20] Y. Liu, L. Zhuo, M. Pregnolato, and D. Han, "An assessment of statistical interpolation methods suited for gridded rainfall datasets," *Int. J. Climatol.*, Oct. 2021, https://doi.org/10.1002/joc.7389.
[21] L. Liu, Y. Jin, J. Wang, Q. Hong, Z. Pan, and J. Zhao, "Comparation of Spatial Interpolation Methods on Slowly Available Potassium in Soils," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 234, p. 012018, 2019, https://doi.org/10.1088/1755-1315/234/1/012018.
[22] Juwita A, Hepi H. H, "Analisa Data Foto Udara untuk DEM dengan Metode TIN, IDW, dan Kriging," *JURNAL TEKNIK* ITS, vol. 5, no. 2, 2016, https://doi.org/10.12962/j23373539.v5i2.17382.
[23] S. P. Sejati, "Perbandingan Akurasi Metode Inverse Distance Weighting dan Kriging dalam Pemetaan Kedalaman Muka Airtanah," *Majalah Geografi Indonesia*, vol. 33, no. 2, 2020, https://doi.org/10.22146/mgi.41473.
[24] M. Kazhal, F. Farzad, Y. Somayeh, R. Mohammad, A. Hossein, S. Abbas, and H. Mostafa, "Spatial Modeling of PM2.5 Concentrations in Tehran Using Kriging and Inverse Distance Weighting (IDW) Methods," *Journal of Air Pollution and Health (Spring 2020)*, vol. 5, no. 2, pp. 89-96, 2020, https://publish.kne-publishing.com/index.php/JAPH/article/view/4237.
[25] B. Xie, X. Jia, Z. Qin, C. Zhao, and M. Shao, "Comparison of interpolation methods for soil moisture prediction on China's Loess Plateau," *Vadose Zo. J.*, vol. 19, no. 1, 2020, https://doi.org/10.1002/vzj2.20025.
[26] A. Jo, J. Ryu, H. Chung, Y. Choi, and S. Jeon, "Applicability of Various Interpolation Approaches for High Resolution Spatial Mapping of Climate Data in Korea," *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.*, vol. XLII–3, pp. 703–710, Apr. 2018, https://doi.org/10.5194/isprs-archives-XLII-3-703-2018.
[27] A. Antal, P. M. P. Guerreiro, and S. Cheval, "Comparison of spatial interpolation methods for estimating the precipitation distribution in Portugal," *Theor. Appl. Climatol.*, vol. 145, no. 3–4, pp. 1193–1206, Aug. 2021, https://doi.org/10.1007/s00704-021-03675-0.
[28] İ. Musayev and M. Gojamanov, "Geodetic Errors Arising from the Differences Between Sk-42 and Wgs-84 Coordinate Systems when Implemented in Modern Weapons Systems," *Konya J. Eng. Sci.*, vol. 9, no. 2, pp. 306–313, Jun. 2021, https://doi.org/10.36306/konjes.788599.
[29] B. H. Sayed and L. E. George, "Flat Model for Representing Contiguous UTM Coordinates over Iraq Territory," *Iraqi J. Sci.*, vol. 61, no. 4, pp. 908–919, 2020, https://doi.org/10.24996/ijs.2020.61.4.24.
[30] T. Chen, L. L. Ren, and F. Yuan, "Comparison of spatial interpolation schemes for rainfall data and application in hydrological modeling," *Water*, vol. 9, no. 5, pp. 342-342, 2017, https://doi.org/10.3390/w9050342.
[31] Z. Li, K. Wang, H. Ma, and Y. Wu, "An Adjusted Inverse Distance Weighted Spatial Interpolation Method," in *2018 3rd International Conference on Communications, Information Management and Network Security (CIMNS 2018)*, 2018, pp. 128-132,, https://doi.org/10.2991/cimns-18.2018.29.

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