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Spatial Modelling and Comparative Assessment of Temperature Interpolation Methods: A Case Study of Iraq Using Kriging and IDW techniques

Farhad Ali Ahmed [1], Badiaa Rahman Khlil [2], Samira Muhamad Salih [3]

[1,2,3] *Sulaimani University: College Administration & Economics, Statistics & Informatics Department, Sulaimani, Iraq*

Farhad.Ahmed@univsul.edu.iq [1]
Badiaa.khalil@univsul.edu.iq [2]
samira.salih@univsul.edu.iq [3]

Abstract: One of the issues facing researchers is forecasting air temperature in places without weather stations. In the effort to interpolate and forecast the spatial air temperature of these regions, spatial interpolation techniques are utilized. Comparing the inverse distance weighted (IDW) and the Kriging interpolation techniques for interpolating and forecasting Iraq's average air temperature is the aim of this study. The data under studied were obtained from 46 Synoptic stations in the country. In this study, R software was used to analyze the data. Based on the results obtained, the method of inverse distance weighted (IDW) with a (RMSE = 0.08) and (MAE = 0.043) shows better results than the Kriging method. Additionally, implementing into consideration the coefficient of determination of the two methods discussed, the (IDW) coefficient of determination (R square = 0.97), indicating it was better able to explain the studying data.

Keywords: Interpolation, Spatial analysis, Kriging, IDW, Forecasting, Temperature

النمذجة المكانية والتقييم المقارن لأساليب التكامل الحراري: دراسة حالة في العراق باستخدام تقنيات Kriging وIDW

د. فرهاد علي احمد ١، م.م. بديعه رحمان خليل ٢، أ.د. سميره محمد صالح ٣

١،٢،٣ *جامعة السليمانية-كلية الإدارة والاقتصاد-قسم الإحصاء والمعلوماتية، السليمانية، العراق*

المستخلص: تُعد عملية التنبؤ بدرجات حرارة الهواء في المناطق التي لا تحتوي على محطات أرصاد جوية من أكثرالتحديات التي تواجه الباحثين. ومن أجل التقدير المكاني والتنبؤ بدرجات الحرارة في مثل هذه المناطق، يتم استخدام تقنيات الاستيفاء المكاني. يهدف هذا البحث إلى مقارنة تقنيات الاستيفاء باستخدام طريقة كريجينج وتقنية الاستيفاء بالمسافة العكسية المرجحة (IDW) لاستيفاء درجة حرارة الهواء المتوسطة في العراق والتنبؤ بها. وقد تم جمع البيانات من ٤٦ محطة أرصاد جوية في أنحاء البلاد. وفي هذه الدراسة، تم تحليل البيانات باستخدام برنامج R. وبحسب النتائج المحصَّلة، فإن طريقة الاستيفاء بالمسافة العكسية المرجحة (IDW) أعطت نتائج أفضل مقارنة بطريقة كريجينج، حيث بلغت جذر متوسط مربع الخطأ (RMSE = 0.08) والخطأ المطلق المتوسط (= MAE

(0.043 . بالإضافة إلى ذلك، فإن تطبيق معامل التحديد للطريقتين اللتين تمت مناقشتهما، وهو معامل التحديد
IDW) (R square = 0.97)) ، مما يشير إلى كفاءتها العالية في تفسير البيانات المدروسة.

الكلمات المفتاحية: الاستيفاء، التحليل المكاني، كريجينج، IDW، التنبؤ، درجة الحرارة.

Corresponding Author: E-mail: Farhad.Ahmed@univsul.edu.iq

Introduction:

Climate change is among the contemporary issues that significantly affects the various facets of human life and the environment. Major climate crises have been brought on by unusual conflict over air pollution, floods, and in some places, unprecedented water shortages. exact and extensive planning is necessary to manage and predict these crises. In many areas of scientific research, new tools have been introduced recently. Depending on its type and the surrounding circumstances, each research tool has potential benefits.[11]

In places where geographical views are not feasible or where the cost of constructing meteorological centers is prohibitively high for various reasons, data collection is not feasible. One of the most effective methods in this area is spatial forecasting and data modeling. The accuracy of models and planning pertaining to this field can be significantly increased by using analytical tools and spatial statistics to close this information gap.[12]

In many scientific fields today, the use of interpolation techniques in the analysis of spatial data is crucial. This is why Zhang et al. used Kriging interpolation techniques. (2023) provide highly accurate temperature forecasts for mountainous and inaccessible regions. The researchers came to the conclusion that in places without weather stations, the data gap is filled by using spatial statistical techniques like variogram analysis.[6]

When it comes to modeling spatial changes and structures, this method works well. Kumar and others. (2018) used the technique of inverse distance weighted (IDW) interpolation to model the spatial distribution of rainfall in India. Using this method, each point's weight is determined by how far away it is from the forecasted point. When predicting temperature and precipitation in regions with limited data, the inverse distance weighted (IDW) method works particularly well. [9]

This study demonstrated that this method can model temperature in places without weather stations with a respectable level of accuracy. Jafari and associates. (2023) forecasted and modeled precipitation data using Inverse Distance Weighting (IDW). This method uses topographic and geographical features to weight data points rather than the inverse of distance. forecasting precipitation in regions with particular geographical features will be noticeably more accurate with this method, despite the fact that it requires more precise data. The "gstat" package in R was used in this study to show how to efficiently interpolate temperature and precipitation data over a range of geographic areas. [10]

This study aims to analyze meteorological data using tools from spatial statistics. Better knowledge of climate change and workable ways to mitigate its effects can be obtained with this method. Temperature data was modeled and predicted using the interpolation method. These methods have been processed and examined using R software. These tools make it possible to accurately identify spatial patterns and create forecast maps.

Data Sources and Collection Methodologies

1- Data sources:

In this study, the official website of the country's meteorology was used to collect the understudy data. The collected data included the average daily temperature in September as the key and dependent variable, as well as geographical coordinate data (longitude, latitude and altitude above sea level) as independent variables, collected from 46 meteorological stations throughout the country. The data studied will be used to build and analyze a spatial model of air temperature, and to forecast temperatures in areas that lack meteorological stations for whatever reason.

2- Methodology:

Within the framework of spatial statistics analysis, several methodological approaches were adopted to modelling and foretasting air temperature data for the meteorological centres in Iraq. In this study, The Kriging method, the variogram analysis statistical tool and Distance-Weighted Methods (IDW) have been used as spatial interpolation approaches. These techniques are appropriate for modeling spatial temperature variations and forecasting values for locations where direct measurements are not available.

A. Spatial Variation Interpolation

The majority of interpolation techniques are based solely on mathematics and certainty. The statistical structures of the data are not given much consideration in traditional interpolation techniques.[5] In spatial interpolation problems, given a set of spatial data, whether discrete or related to subareas, a function must be found that best represents the surface. This function must be able to forecast the values at other points or subareas in an acceptable way. This section will be covered Kriging and inverse distance weighted (IDW) techniques that have produced remarkable spatial interpolation outcomes.[1]

(1) Kriging

The term Kriging actually refers to a set of techniques for local estimation. This technique overcomes many of the shortcomings of classical interpolation methods in spatial data. The basic idea behind this technique is to treat natural features as location-dependent random variables. For this reason, it is relatively consistent with geographic realities and, due to its randomness, provides the ability to provide accurate statistical estimates with minimal and calculable variance.[4] Kriging is categorized as a point and existence interpolator, which is appropriate for interpolating data such as geographic locations and temperature. In this method, the spatial correlation between data is expressed explicitly and scientifically using a variogram. The kriging technique is suitable for modeling changes in temperature data in areas where data is not available.[3]
The following is the formula used in the Kriging model:

$$K(s_0) = \mu(s_0) + \sum_{i=1}^{m} \lambda_i [K(s_i) - \mu(s_i)] \qquad (1)$$

Where:
$K(s_0)$: forecasted value at s_0.
$\mu(s_0)$: trend model at s_0.
λ_i : the weights derived from the correlation function of spatial.
$K(s_i)$: observed values at s_i .

(2) Variogram

This analysis is an important method in spatial autocorrelation statistics that evaluates the spatial relationship between data points. It displays the general shape, the degree of fluctuation, and the spatial scale of spatial variation of the variables.[11] Variograms measure the value difference between pairs of points as a function of their separation. this is important for recognize spatial construction and the extent of relationship between the data. Variogram mathematical models play a

key role in the kriging technique of data fitting, which is crucial for accurately forecasting values in areas with scanty or lack of data.[8]
The variogram is defined as follow:

$$\gamma(v) = \frac{1}{2} var(T(s) - T(s+v)) \qquad (2)$$

Where:
$\gamma(v)$: variogram at separation (v).
$T(s), T(s+v)$: observed values at (s) and (s + v).
Var: the variance between two points, demonstrating spatial change in the data.

B. Inverse Distance Weighted technique (IDW)

All interpolation techniques are developed based on the theory that points near one another are more correlated and comparable than points farther apart. First low of Tobler, referred to as geography's first low, was proposed in (1970) and serves as the foundation for this approach.[7] The general idea is based on the assumption that the characteristic of an un sampled point is the weighted average of the known values in the neighbourhood. This method is regarded as one of the simplest interpolation methods due to its reasonable computation time, the possibility of increased modelling accuracy, and the lack of requirement for calculations to estimate statistical assumptions.[2]
This technique will be utilized to interpolate spatial data, which is based on the concept of distance weighting. It may be utilized to estimate air temperature observation for an unknown location from known data for locations that are adjacent to unknown locations.[13]
The Inverse Distance Weighted technique is defined by the following formula:

$$\hat{T}_p = \sum_{i=1}^{M} w_i T_i \qquad (3) \qquad\qquad w_i = \frac{s_i^{-\alpha}}{\sum_{i=1}^{M} s_i^{-\alpha}} \qquad (4)$$

Where
$\hat{T}_p$: unknown temperature data
T_i: known temperature in known Meteorologicalstations
M: amounts of Meteorological satiations
s_i: the separation from each point to the calculated point
α: the control parameter power, which is typically taken to be 2.

3. Findings and analysis of results

introduction

The methods for interpolating spatial data were presented and described in the previous section. The consequences of applying Inverse Distance Weighted (IDW) and kriging techniques to the studied data will be discussed in this section.

A. Review of research data

The data under study include geographical data (longitude, latitude, and altitude) as independent variables and average September air temperature data as dependent variable. These data are collected from 46 meteorological stations, which were collected from the nation's official meteorological website. Figure (1) illustrates each station's position.

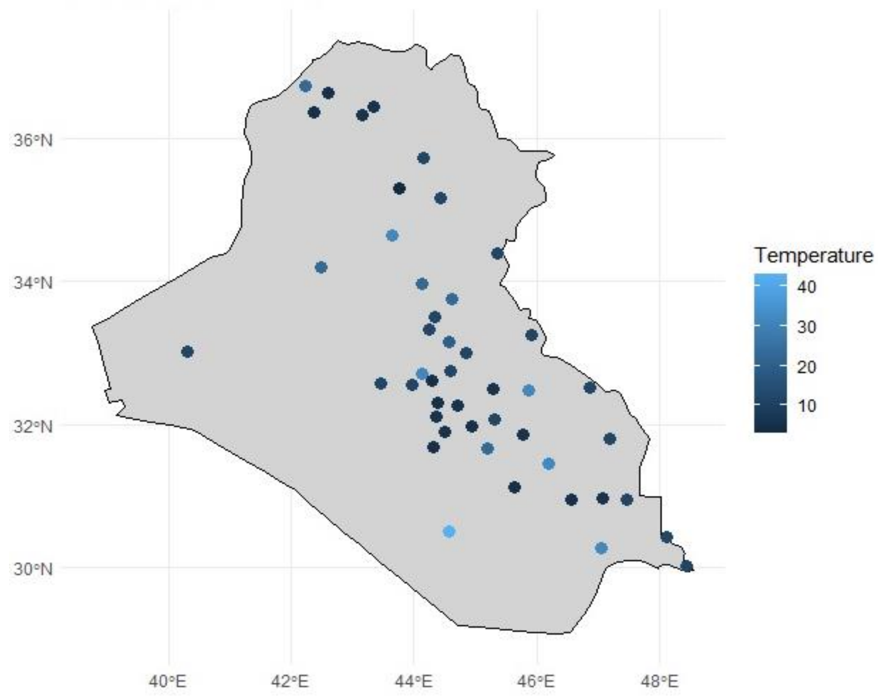


Fig (1) represents the locations of meteorological stations

Found by researchers

Considering the country's geographic location and the locations of meteorological stations, it has been shown that there is an obvious relation between population distribution and locations of meteorological stations. It is understandable why there are barely any meteorological stations built in regions with challenging conditions and low population density. This is evident in Figure (1), where there are fewer canters in the country's eastern regions, which have a more unfavourable climate (hotter and drier).

Per the data presented in Table (1), the average air temperature at the stations under study is (32.22°C), which is slightly cooler than the nation's long-term temperature (34°C -36°C). The data under study have a standard deviation rate of (1.78), indicating that they are spread (1.78°C) around the mean. The data has a modest skewness of (-0.62), which suggests that it has little propensity to be below average in temperature. This degree of skewness is probably the result of relatively low air temperatures that have been seen in high-altitude regions. Some stations have recorded temperatures that are much warmer or colder than the average, as indicated by the kurtosis of (0.73). Notably, the lowest recorded air temperature was (27°C), while the highest recorded temperature was (35.19°C).

Taking into account that the data's skewness and kurtosis fall within a reasonable range (±1). Additionally, the hypothesis that the data is normal can be accepted based on the findings of the Shapiro statistical test (0.98) and the p-value rate (0.98), both of which are greater than (0.05).

Table (1): represent the ddescriptive indices and normality test results

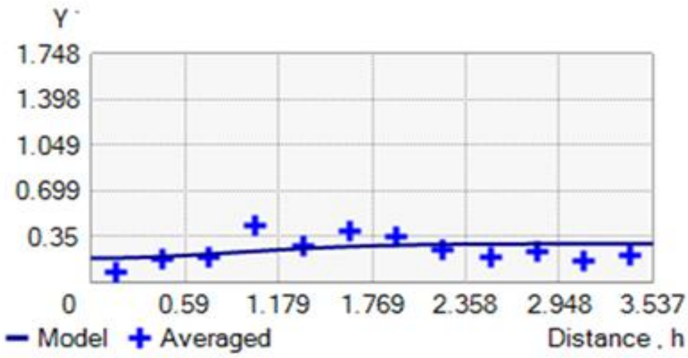
Average	S. D	Skew	Kurtosis	Min	Max	Shapiro-Wilk	p-value	Passed normality
32.22	1.78	-0.62	0.73	27.00	35.19	0.98	0.13	P > 0.05

B. kriging technique

The spatial correlation characteristic between data at various distances is shown in Spatial model specifications (variogram)، table (2). Due to the existence of small-scale changes, there is some fluctuation at the graph's commencement. The variogram rate then rises until it achieves the highest correlation level (sill = 1.9311) within its range (23.9026). The wavy spatial pattern in the data under consideration is shown by the subsequent variations, though. The Hole Effect model has been utilized for fitting, and it performs an acceptable task of explaining the behavior of the data and the current variations. Which is illustrated in Figure (2). These characteristics aid in precise kriging predictions and improve comprehension of the intricate relationships among geographical data. Furthermore, it can be suggested that this model could explain the level of data correlation given the extremely low value of the Nugger parameter (0.000) that was found.

Table (2): Represent the Spatial model specifications (variogram)

Model	Nugget	Sill	Ratio
Hole Effect	0.000	1.9311	23.9026



Fiq (2): Represent the Variogram with fitted Hole Effect model

Table (3) indicates some of the outcomes derived from Process (Kriging's) forecasting. This table illustrates these points' real temperatures against their forecasted temperatures based on their geographic coordinates. The variation between the actual and forecasted information is shown in the table's final column. The outcomes discussed in this column highlight the accuracy with which the model forecasted the studied data.

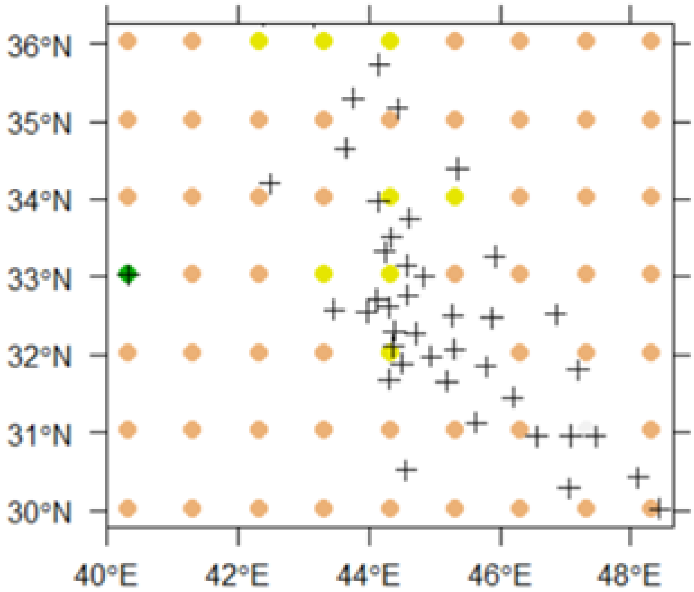
Table (3): Represents some of the outcomes derived from Process (Kriging's) forecasting

Longitude	Latitude	Real Value	Forecasted Value	R.F difference
44.23	33.32	31.5	31.56	-0.06
44.33	33.5	31.48	31.5	-0.03
44.56	33.14	31.7	31.71	-0.01
47.45	30.94	35.19	35.03	0.42
48.44	30.02	33.5	33.36	-0.01
48.11	30.42	33.84	33.68	0.04

Using a square grid and the ordinary kriging method, Temperature forecasting was carried out following variogram analysis of the data under study and model fitting. Table (4) results show that the model's accuracy was satisfactory in the majority of the research region, with forecasted data falling between (45) and (32) and the forecasted error's variance (rate of uncertainty) ranging between (0) and (1.98). (32.29) showed the highest density of forecasted values. The spatial distribution of the obtained results is presented in Figure (3).

Table (4): represent the accuracy of forecasted data

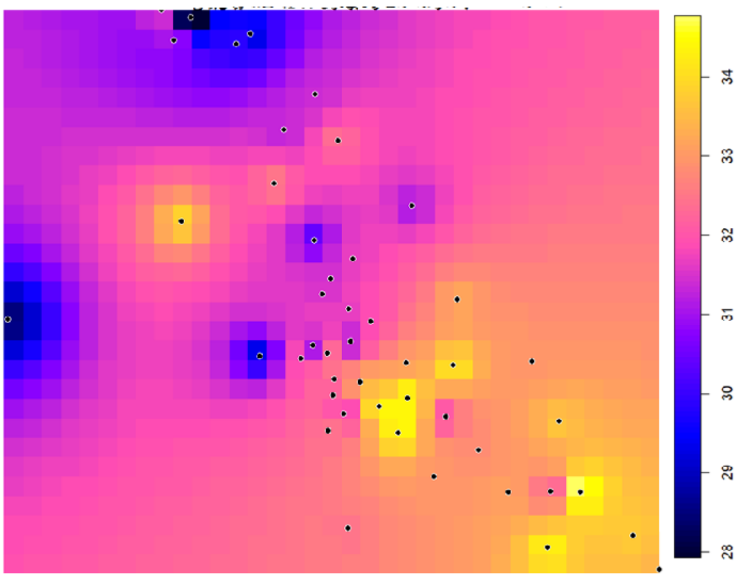
	Actual data	Forecasted Value	Variance
Min	27	28.38	0
Mean	32.22	32.3	1.823
Max	35.19	34.88	1.98



Fiq (3): Represent the spatial distribution of the obtained results

C. Inverse Distance Weighted technique (IDW)

The results of interpolation grids using (IDW) technique are displayed in Figure 33. This technique uses a grid to divide the study region into 5000 points according to geographic location. This method can be used to forecast each of these points. This figure also displays the actual points. The locations of the primary samples that served as the foundation for interpolation are represented by these points. and the minimum and maximum temperatures in the research area are represented by the colors yellow and purple.



Fiq (4): Represent the results of Interpolation grids by (IDW)

Table (5) indicates some of the outcomes derived from Process (IDW's) forecasting. This table illustrates these points' real temperatures against their forecasted temperatures based on their geographic coordinates. The variation between the actual and forecasted information is shown in the table's final column. The outcomes discussed in this column highlight the accuracy with which the model forecasted the studied data.

Table (5): Represents some of the outcomes derived from (IDW's) forecasting

Longitude	Latitude	Real Value	Forecasted Value	R.F difference
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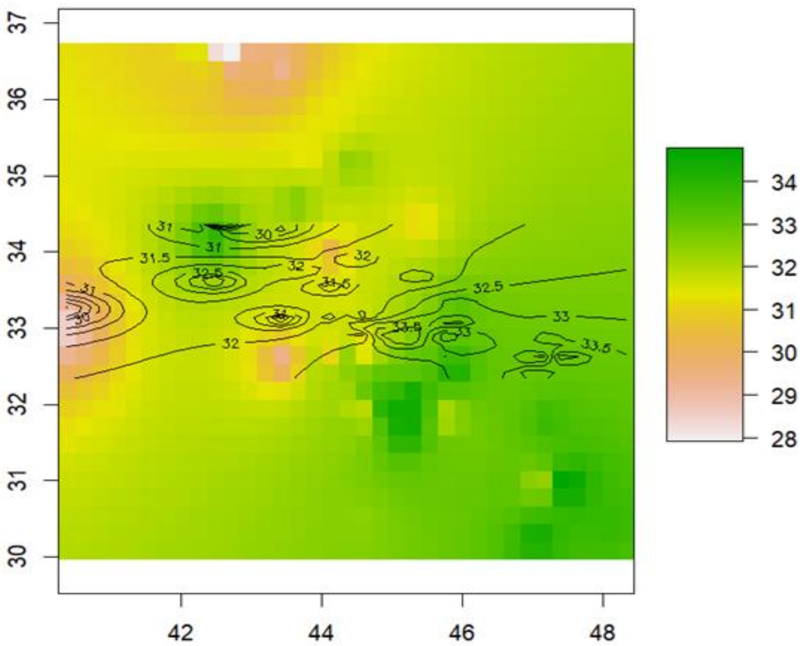
44.33	33.5	31.48	31.51	-0.03
44.56	33.14	31.7	31.71	-0.01
47.45	30.94	35.19	34.77	0.42
48.44	30.02	33.5	33.51	-0.01
48.11	30.42	33.84	33.8	0.04

In addition, Figure (5) demonstrates various locations with identical temperatures. Solid lines are utilized to connect the isothermal spots on this map. Accordingly, consistent temperatures are recorded (Figure 5). The degree of spatial variation at these sites is shown by the density and shape of these lines. There is less variability when these lines are farther apart, and the variations are more pronounced when they are closer.



Fiq (5): Represent the various locations with identical temperatures

The outcomes of the two kriging and inverse weighting techniques were thoroughly examined in the preceding sections. The effectiveness of these two approaches will be contrasted in this section. In accordance with Table (6) and the outcomes derived from various standards for assessing forecasting and forecasting model accuracy. The kriging method yielded root mean square error and mean absolute error values of (0.0714) and (0.0436), respectively, while the inverse weighting method produced results of (0.25) and (0.144), respectively. Likewise, in turn. Additionally, it is determined that the kriging method has demonstrated greater efficiency in this study based on the coefficient of determination (R^2) that was acquired for the (IDW) method (0.97) and for the kriging method (0.94).

Table (6): Represents the assessing and forecasting model accuracy

Techniques	RMSE	MAE	R Square
IDW	0.0714	0.0436	0.97
Kriging	0.25	0.144	0.94

Conclusion:

Inverse Distance Weighted (IDW) and Kriging techniques, two interpolation techniques, were investigated and compared in the current study. The average temperature of locations lacking meteorological stations was forecast using spatial data collected from the nation's meteorological stations, which included geographic coordinates (latitude and longitude) and average air temperatures, in order to more accurately assess these two techniques. It can be established that both techniques have an acceptable capacity of estimating the average temperature of the areas under study based on their evaluations of the evaluation criteria of (RMSE), (MAE) and (R square). Notwithstanding recognizing that both methods' results are acceptable, it can be concluded that the (IDW) technique is more effective at estimating the points under study based on the findings of the aforementioned criteria. The maps that are presented additionally demonstrate this superiority obvious. The (IDW) technique has performed better on the investigated geographic data, reducing the error and improving the R square, considering into account the attributes that were utilized to construct its model.

Recommendation:

Spatial techniques for interpolation can substantially overcome the drawbacks brought on by the lack of actual data and the requirement for more stations, particularly in consideration of the constantly changing climate and the absence of monitoring stations in various geographic areas. The stability and effectiveness of these interpolation techniques can be investigated in future studies using an increasing variety of data. It can be challenging to determine vegetation cover and altitude in places without collecting data from locations. The spatial correlation between the data serves as the foundation for the kriging method's performance, which occasionally decreases the model's efficiency compared to other spatial techniques (such as IDW used in this study). However, on its own, this technique constitutes one of the most successful interpolation techniques.

References

1- Fotheringham, Stewart, and Peter Rogerson, eds. Spatial analysis and GIS. Crc Press, 2013.

2- Lam, Nina Siu-Ngan. "Spatial interpolation methods: a review." The American Cartographer 10, no. 2 (1983): 129-150.

3- Lim, Ah-Young, Yalda Jafari, Jamie M. Caldwell, Hannah E. Clapham, Katy AM Gaythorpe, Laith Hussain-Alkhateeb, Michael A. Johansson et al. "A systematic review of the data, methods and environmental covariates used to map Aedes-borne arbovirus transmission risk." *BMC infectious diseases* 23, no. 1 (2023): 708.

4- Maleika, Wojciech. "Inverse distance weighting method optimization in the process of digital terrain model creation based on data collected from a multibeam echosounder." Applied Geomatics 12, no. 4 (2020): 397-407.

5- Masroor, Kazhal, Farzad Fanaei, Somayeh Yousefi, Mohammad Raeesi, Hossein Abbaslou, Abbas Shahsavani, and Mostafa Hadei. "Spatial modelling of PM2. 5 concentrations in Tehran using Kriging and inverse distance weighting (IDW) methods." Journal of Air Pollution and Health 5, no. 2 (2020): 89-96.

6- Oliver, Margaret A., and Richard Webster. "Kriging: a method of interpolation for geographical information systems." International Journal of Geographical Information System 4, no. 3 (1990): 313-332.

7- Setianto, Agung, and Tamia Triandini. "Comparison of kriging and inverse distance weighted (IDW) interpolation methods in lineament extraction and analysis." Journal of Applied Geology 5, no. 1 (2013).

8- Shukla, Komal, Prashant Kumar, Gaurav S. Mann, and Mukesh Khare. "Mapping spatial distribution of particulate matter using Kriging and Inverse Distance Weighting at supersites of megacity Delhi." Sustainable cities and society 54 (2020): 101997.

9- Singh, Prafull, and Pradipika Verma. "A comparative study of spatial interpolation technique (IDW and Kriging) for determining groundwater quality." GIS and geostatistical techniques for groundwater science (2019): 43-56.

10- Yang, Wenjie, Yue Zhao, Dong Wang, Huihui Wu, Aijun Lin, and Li He. "Using principal components analysis and IDW interpolation to determine spatial and temporal changes of surface water quality of Xin'anjiang river in Huangshan, China." International journal of environmental research and public health 17, no. 8 (2020): 2942.

11- Zhang, Han, You Tian, and Pengfei Zhao. "Dispersion curve interpolation based on kriging method." Applied Sciences 13, no. 4 (2023): 2557.

12- Zhang, Han, You Tian, and Pengfei Zhao. "Dispersion curve interpolation based on kriging method." Applied Sciences 13, no. 4 (2023): 2557.

13- Zhao, Wei, Yuping Zhong, Qinglan Li, Minghua Li, Jia Liu, and Li Tang. "Comparison and correction of IDW based wind speed interpolation methods in urbanized Shenzhen." Frontiers of Earth Science 16, no. 3 (2022): 798-808.