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Evaluation of the Different Interpolation Methods to Visualize the Temperature Variability of Bangladesh by Using GIS And RS

Abdul Alim[1]
Khondaker Mohammod Shariful Huda [2]
Sk. Moniruzzaman[3]

Abstract:"Spatial Interpolating Methods" As fundamental Interpolation methods are a tool for estimating spatial continuous data and have been used in a variety of fields related to the Earth's surface. Five spatial interpolation techniques are used in this paper. The interpolation methods used as the determining factor of change and how those method's outcome/predicted data is closely related to the related data in every particular station data were applied in 38 weather stations of Bangladesh, so that, its output would be significant for weather base research and planning in future. Analysis and accuracy comparison was carried out using random point checks against the real data and predicted data of every station which gives us the outcome by the process of "spatial interpolation methods". This paper used five methods IDW (Inverse Distance Weighting), GP (Global Polynomial), KS (Karnel Smothing), RB (Radial Basis), and Kriging, which are the most used techniques of interpolation methods. These experimental shows show the predicted value as well as the predicted map According to the predicted value by interpolating with the nearest weather station's data. Its finding gives up a great massage in which the interpolation method/technique is mostly accurate than others.

Keywords: Spatial interpolation, Interpolation methods, IDW, Kriging, GIS, Remote Sensing, etc.

1. Introduction

The estimation of unknown attribute values at unmeasured/unsampled points using measurements taken at neighboring sites (known values of sampled points) is known as spatial interpolation. Interpolation methods have been used in a variety of fields associated with the Earth's surface as a crucial tool for estimating spatial continuous data. More than ten spatial interpolation models have been established in various sorts of maps by utilizing various interpolation methods, which give a generalization geospatial picture of an area by employing point-based information, as a result of the rising applications of spatial interpolation methods. On how well the spatial interpolators perform, there are still no reliable results. As a result, choosing an effective interpolation method for a particular input dataset might be challenging. These maps provide detailed information

[1] Independent Researcher
[2] Professor, Department of Geography and Environment; Jahangirnagar University, Savar, Dhaka.
[3] Assistant Professor, Department of Environmental Science, University of South Asia, Aminbazar, Savar, Dhaka.

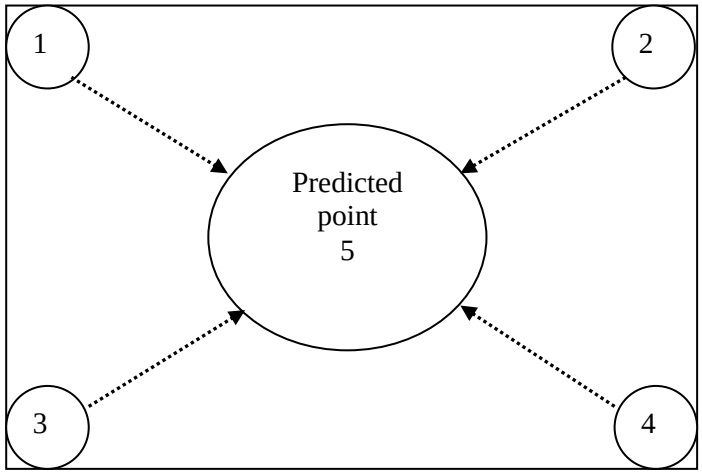
about the appropriate ways from the five methods of interpolation techniques among the numerous research on the comparison of interpolation techniques for creating the interpolation map. This research helps to identify the appropriate methods by differencing among the prediction value and real value of a particular point or particular weather station as well as the total value differentiation of real data and every spatial methodological data from the IDW (Inverse Distance Weighting), GP (Global Polynomial), KS (Karnel Smothing), RB (Radial Basis) and Kriging methods.

2. Interpolation

A technique for creating new data points within the range of a discrete set of known data points is an interpolation, a sort of estimation. Spatial interpolation is the technique of estimating values at additional unknown points by using points with known values. For instance, it would be impossible to find enough evenly distributed weather stations to cover the entire region if you were to create a precipitation (rainfall) map for your country. By sampling data points and interpolating them using a simpler function, interpolation is also used to simplify complex functions. Interpolation methods are generally used for knowing the unknown value from the sample value. It is easier to evaluate, differentiate, and integrate by using the Interpolation methods of GIS and RS software.

2.1 Characteristics of Interpolation Methods

i. *Predictions are based on measurements of adjacent sites or during particular times.*
ii. *A model is chosen to reduce this uncertainty as much as is practical. Predictions have corresponding measurements of uncertainty.*
iii. Predictions can be expressed as the likelihood that certain threshold values will be exceeded.



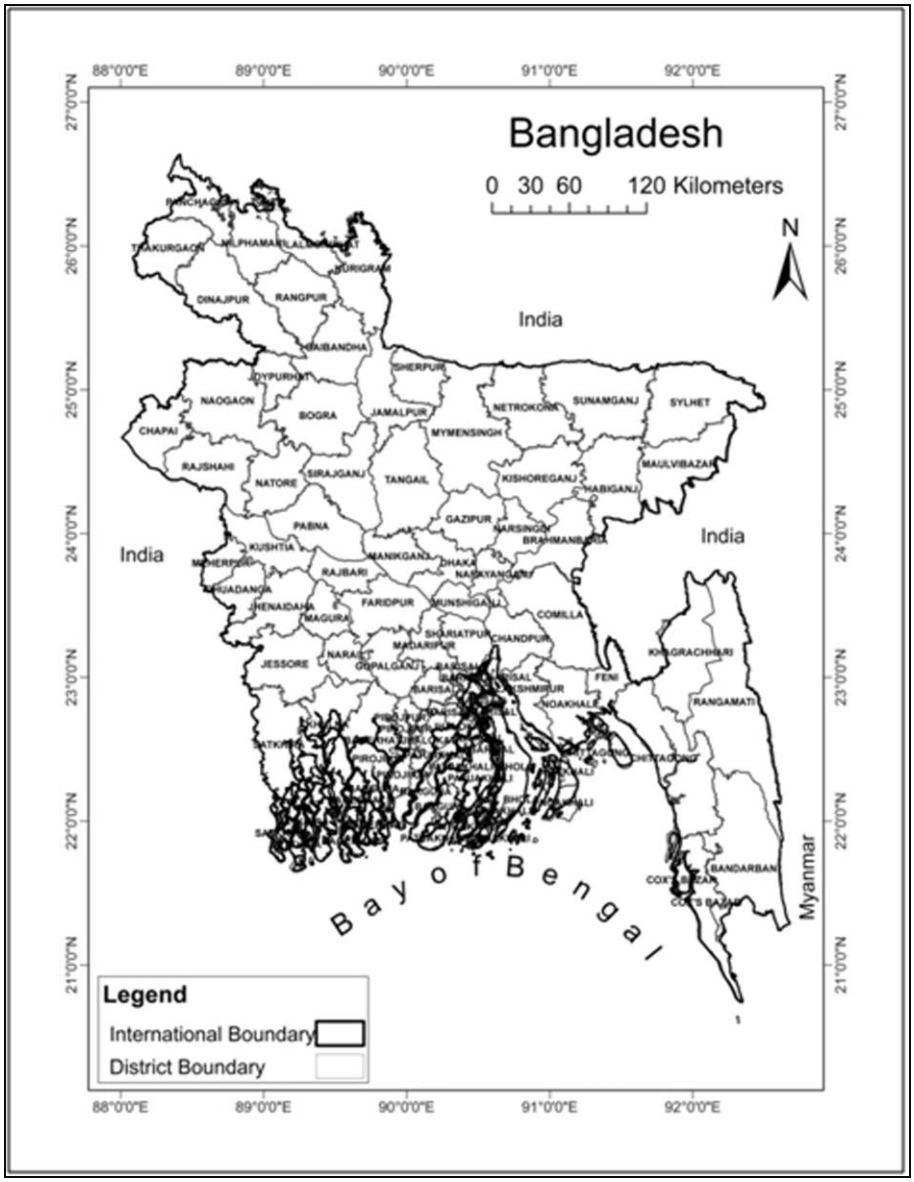
Source: Compiled by Author, 2023.

Figure 01: Example of Interpolation: Boxes 1, 2, 3, and 4 are the know values, from these four values the predicted result is box 5. That is a true example of interpolation.

2.2 Study Area

Geographical Location: *The absolute location of Bangladesh in between 20°34′ to 26°38′ N and 88°01′ to 92°41′ E.*

Relative Location: *The relative location of Bangladesh is in South Asia. Bangladesh is bordered by the Bay of Bengal in the east and west, India is in the three sites of Bangladesh in the north, east, and west and Myanmar is in the southeast side of Bangladesh.*



Source: Compiled by Author, 2023.
Map 01: Study Area Map.

3. Aims and Objectives

The main purpose of this evaluative work is to investigate the different interpolating methods and evaluation of the accuracy level from the different output-generated values of temperature against the specific point.

Considering the above aim of the study, I underpinned the following very specific objectives to carry on my research goals.

i. To collect the station-based temperature data.
ii. To evaluate the various types of interpolating methods and identify the best method for temperature mapping.
iii. To make a temperature zone map by the evaluated method.

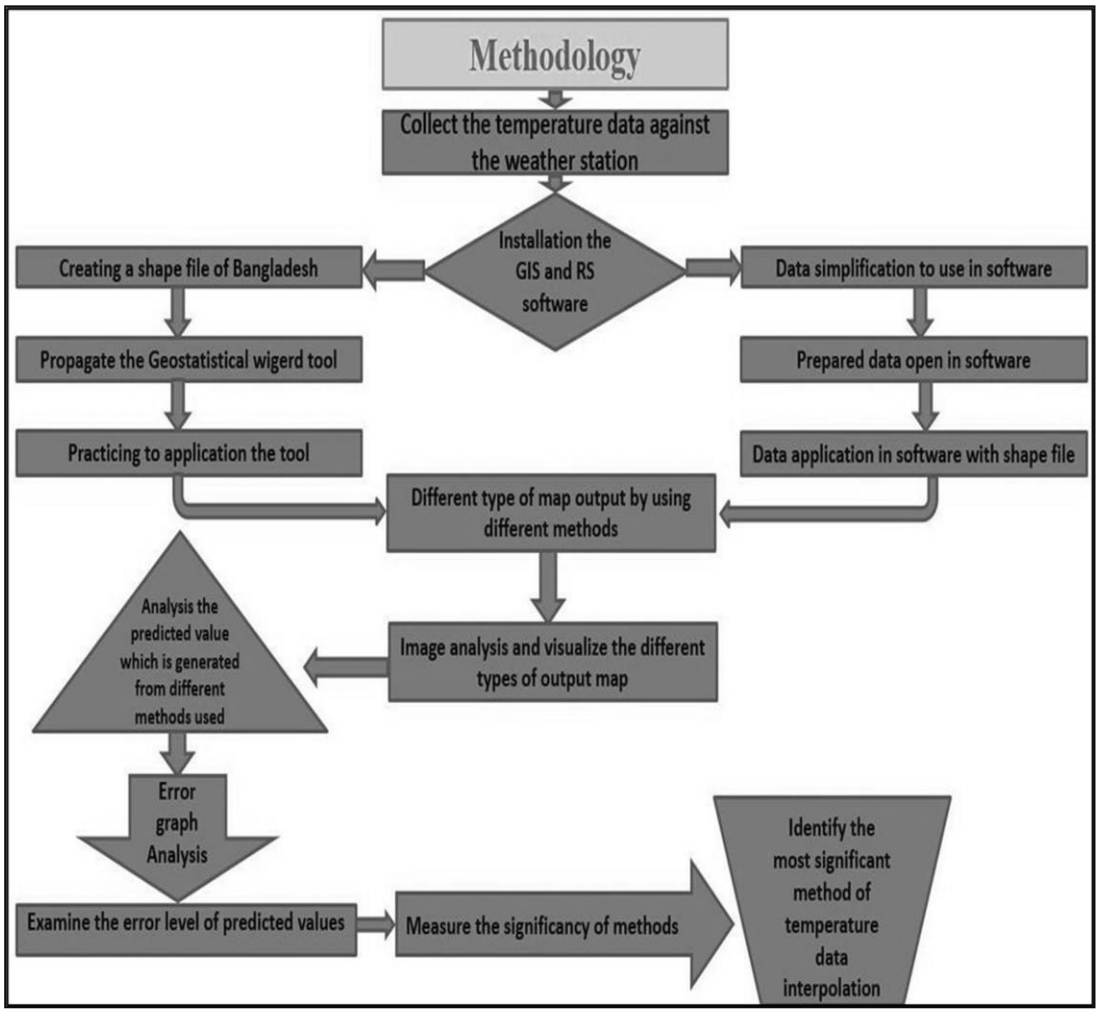


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Figure 02: Methodological Structure.

Table 01: Logical Framework Table of the Research.

Logical Framework			
Title	**Application of different interpolating methods to visualize the Temperature variability of the major climatic zone by using GIS and RS**		
Keywords	Various Interpolating methods	Temperature Variability	Climatic zone
Aim of the research	The broader aim of this research work is to investigate the different interpolating methods, which is giving us the different values of temperature against the specific point.		
Objectives	To Collect the station-based temperature data.		
	To evaluate the various types of interpolating methods and identify the best method for temperature mapping.		
	To make a temperature zone map by the evaluated method.		
Data Sources	Primary data		Secondary data
	Qualitative data		Quantitative data
Data analysis methods	Organization of collected data	Identification of framework	Sorting data with framework
	Descriptive analysis with framework	Second-order analysis	finalize the data
Expected Outcome	Power generation of data analysis, data engineering, and general views of locational temperature		
	Skills development and intelligence of software use. Examine the Modernization techniques of temperature visualization.		
	The imagination of a map, showing the variation of data, and the significance level of interpolating techniques. Judgment to mostly accurate methods.		

Source: Compiled by Author, 2023.

4. Temperature data collection sources

We can gather temperature information for Bangladesh in 2018 from several sources. Here are a few specific sources for Bangladeshi temperature information:

Bangladesh Meteorological Department: The national organization in charge of gathering and examining weather data in Bangladesh is the Bangladesh Meteorological Department (BMD). They offer both historical weather data from earlier years and weather information that is current. We can visit their website at http://www.bmd.gov.bd/ to access the temperature data of Bangladesh.

Global Historical Climatology Network: The National Oceanic and Atmospheric Administration (NOAA) in the United States maintains a database of climate information called the Global Historical Climatology Network (GHCN). Through the National Centres for Environmental Information, we have access to GHCN data. NCEI's website at https:// www.ncei.noaa.gov/ access/metadata/ historical-global- temperature-data/ historical- global- temperature-data.html. The information is offered in several forms, including CSV and NetCDF, and it includes temperature as well as many other climate-related variables.

Climate Data Online: Climate Data Online (CDO) is a web resource offered by NOAA that enables users to look for and download historical weather information for particular places. We can access CDO at https://www.ncdc.noaa.gov/cdo-web/webservices/v2. The data covers a wide range of climate variables, including temperature, and is available in several forms, including CSV, JSON, and NetCDF. For this research purpose, we collected the temperature data of Bangladesh in 2018 from the website http://www.bmd.gov.bd/.

It's important to note that temperature data can vary depending on the location and time of day, so you should make sure to specify your geographic and temporal parameters when searching for temperature data.

5. Different Interpolation Methods

The technique of predicting a function's value between two known data points is called interpolation. In other words, it is the process of identifying a function that can be used to estimate the value of the function at any point in between the known data points and one that fits the given data points. Interpolation can be used in a variety of fields such as mathematics, science, engineering, and computer graphics. It is commonly used to approximate missing data, to smooth out noisy data, or to estimate values of a function at points where no data is available.

There are various types of interpolation techniques, we applied some interpolation techniques. Like as:

i. Inverse Distance Weighting (IDW) Interpolation
ii. Global Polynomial Interpolation
iii. Kernel Smoothing Interpolation
iv. Radial Basis Function, and
v. Kriging

IDW Interpolation: This method involves estimating the value of a function at an unobserved location by assigning weights to the observed points based on the distance from the unobserved location. The closer the observed point, the more weight it is given. Then the weighted average of the observed points is calculated to estimate the value at the unobserved location.

Global Polynomial Interpolation: This method involves fitting a single polynomial function to the entire set of data points. The degree of the polynomial is usually determined by trial and error or by statistical tests. The value of the function at any point can then be estimated by evaluating the polynomial at that point.

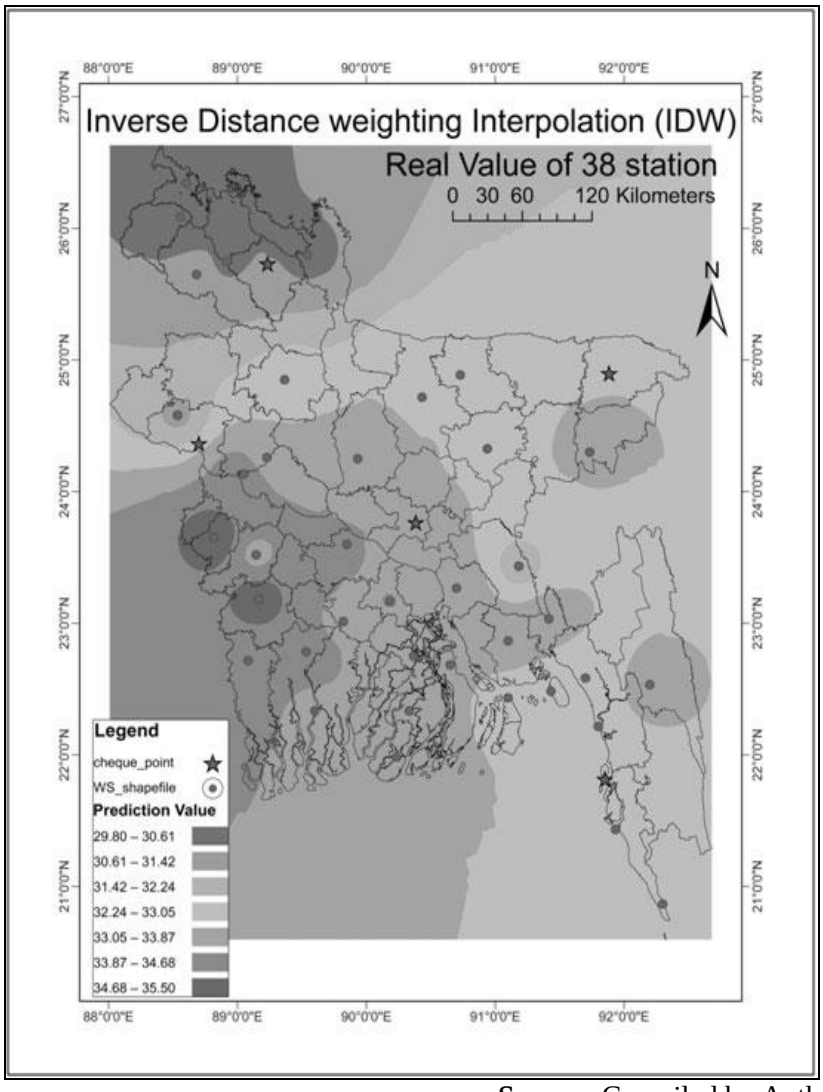
Kernel Smoothing Interpolation: This method involves estimating the value of a function at an unobserved location by using a weighted average of the observed points. The weight assigned to each point is determined by a kernel function that depends on the distance between the observed point and the unobserved location.

Radial Basis Function Interpolation: This method involves fitting a radial basis function (such as a Gaussian function) to the observed data points. The function is then used to estimate the value of the function at any unobserved location within the range of the data. The parameters of the radial basis function are determined by trial and error or by statistical tests.

Kriging Interpolation: This method involves estimating the value of a function at an unobserved location by using a weighted average of the observed points. The weights

assigned to each point are determined by a mathematical model that takes into account the spatial correlation between the observed points. This method is often used in geo-statistics and is particularly useful when the data is spatially auto-correlated. These interpolation methods are widely used in various fields such as geography, geology, environmental science, and engineering. The choice of method depends on the specific requirements of the problem at hand, such as the type and amount of data available, the accuracy needed, and the computational resources available.

5. Output map from different interpolation methods



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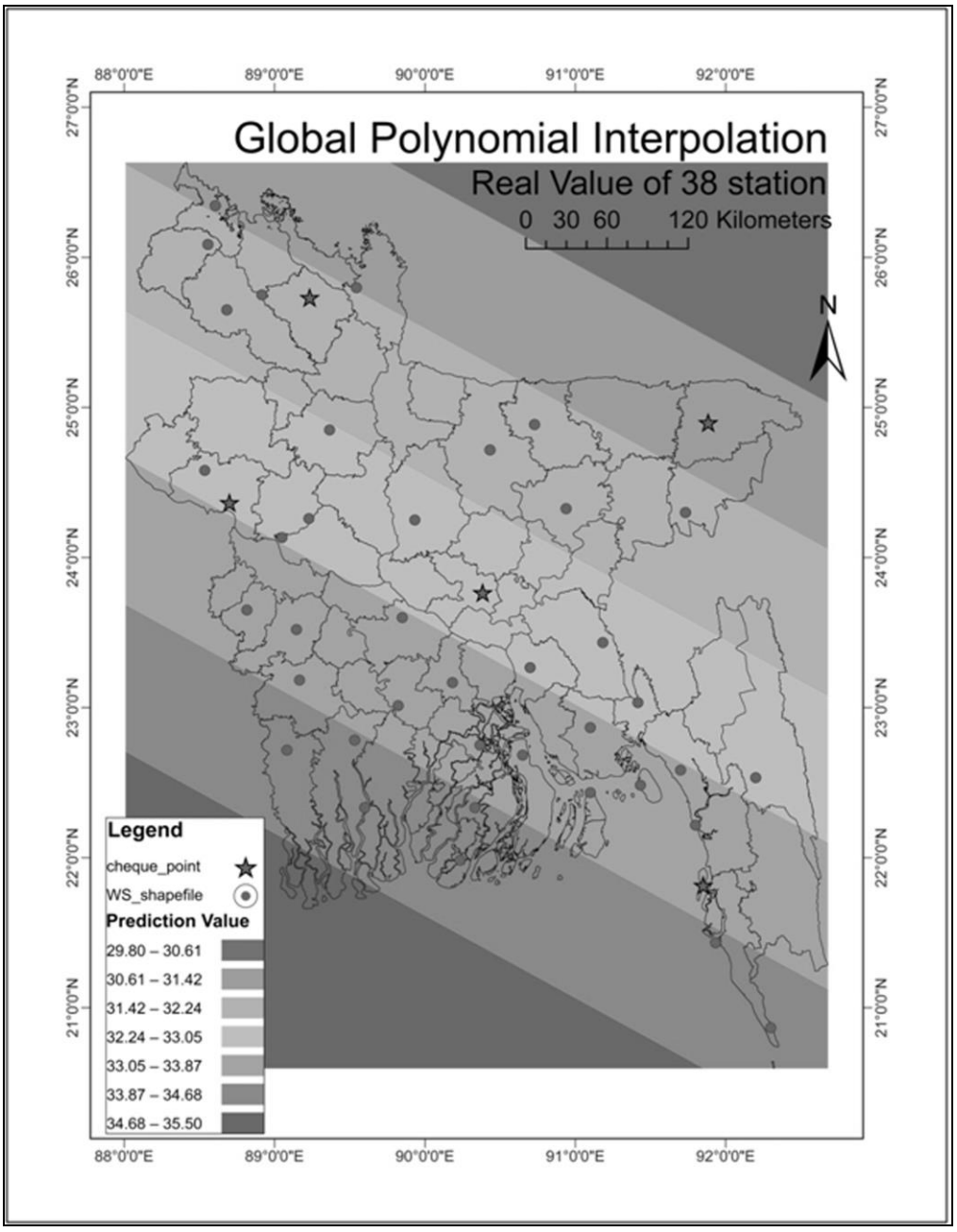
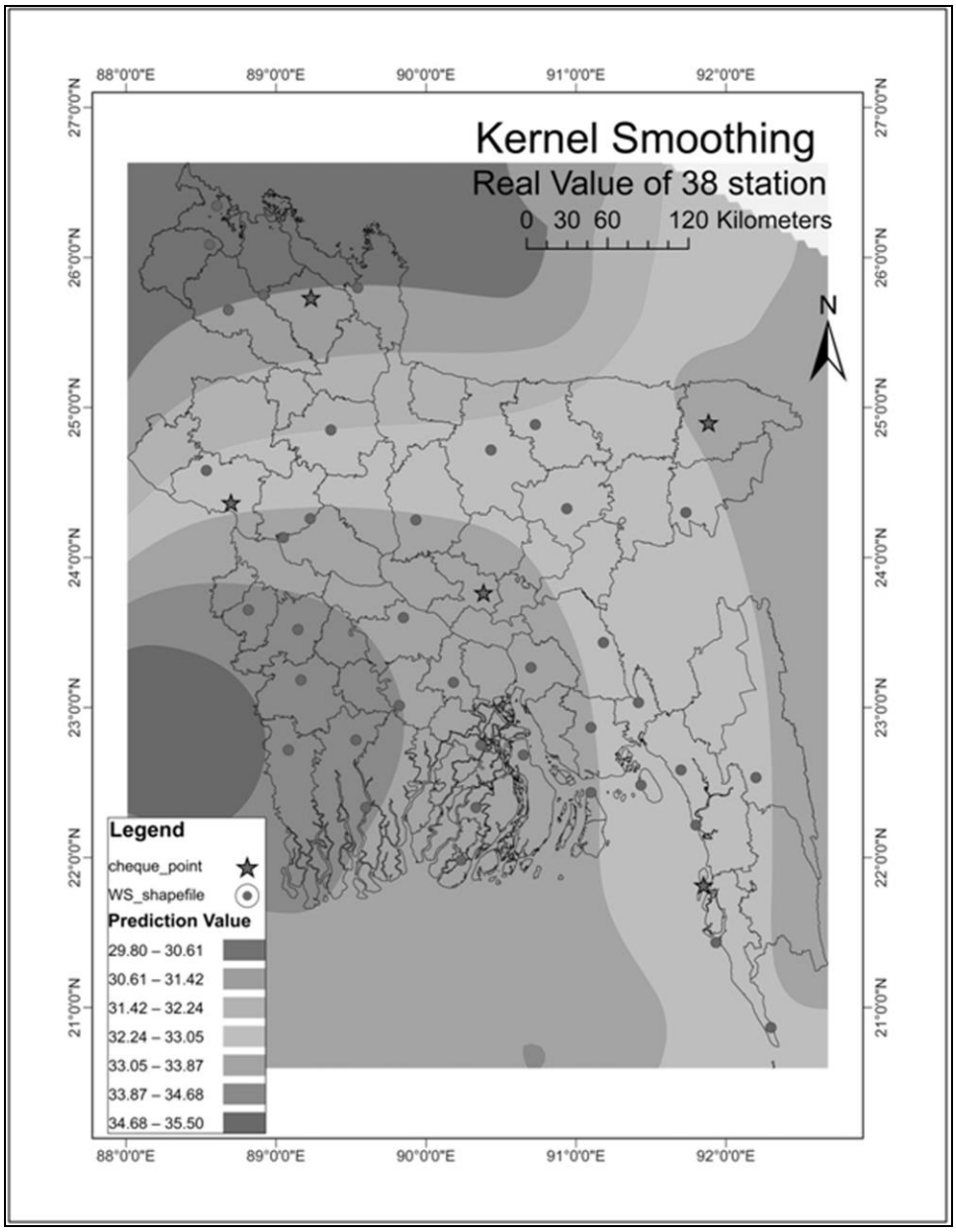
Map 02: Output of Inverse Distance Weighting (IDW) Interpolation method (Temperature map of Bangladesh).



Source: Compiled by Author, 2023.

Map 03: Output of Global Polynomial Interpolation method (Temperature map of Bangladesh).

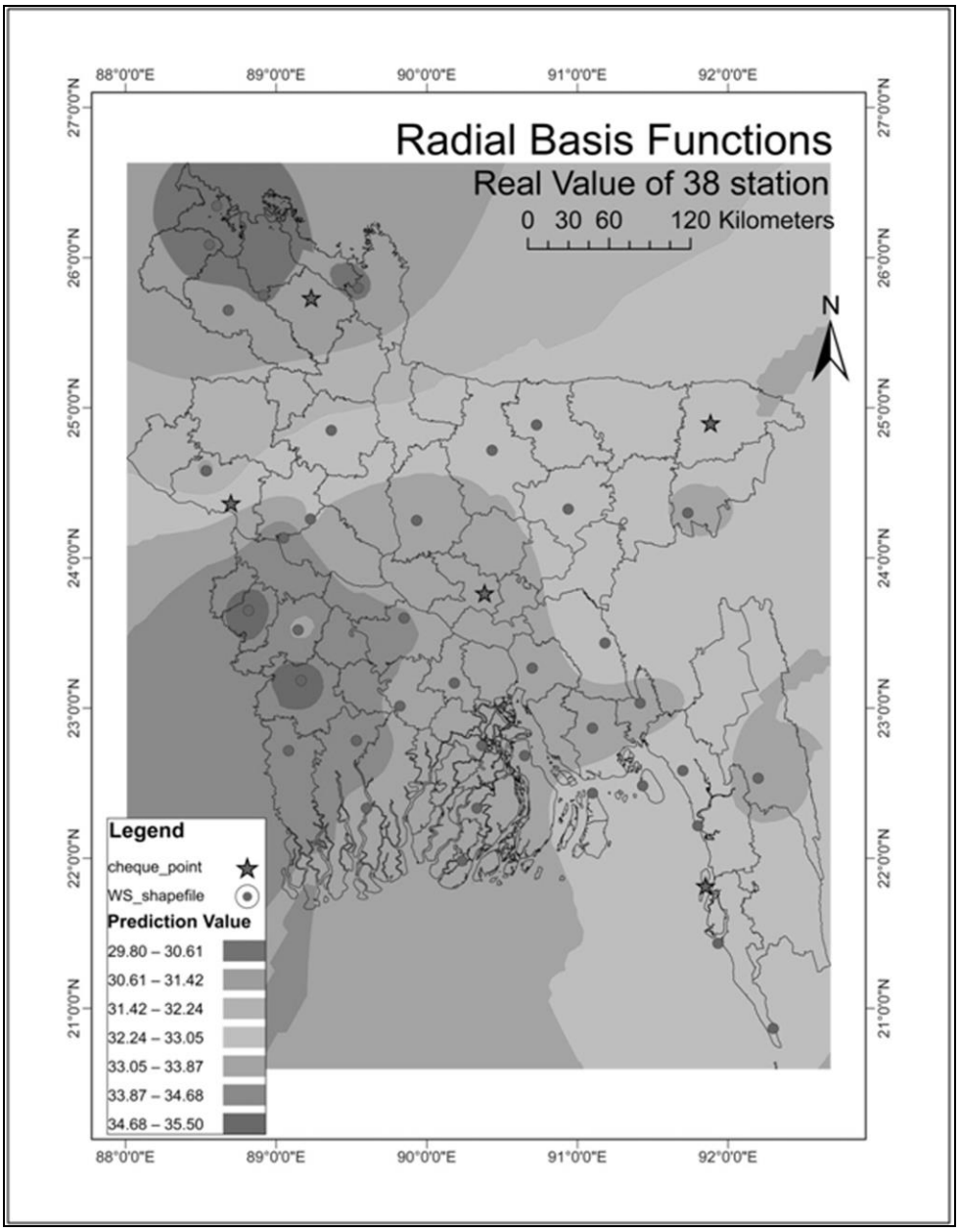
Global polynomial interpolation gives a result across lines according to the high and lower values of temperature of different locational weather stations. It's had the most possibility of error. Because the nearest values are significant for the nearest temperature.



Source: Compiled by Author, 2023.

Map 04: Output of Kernel Smoothing Interpolation method (Temperature map of Bangladesh).

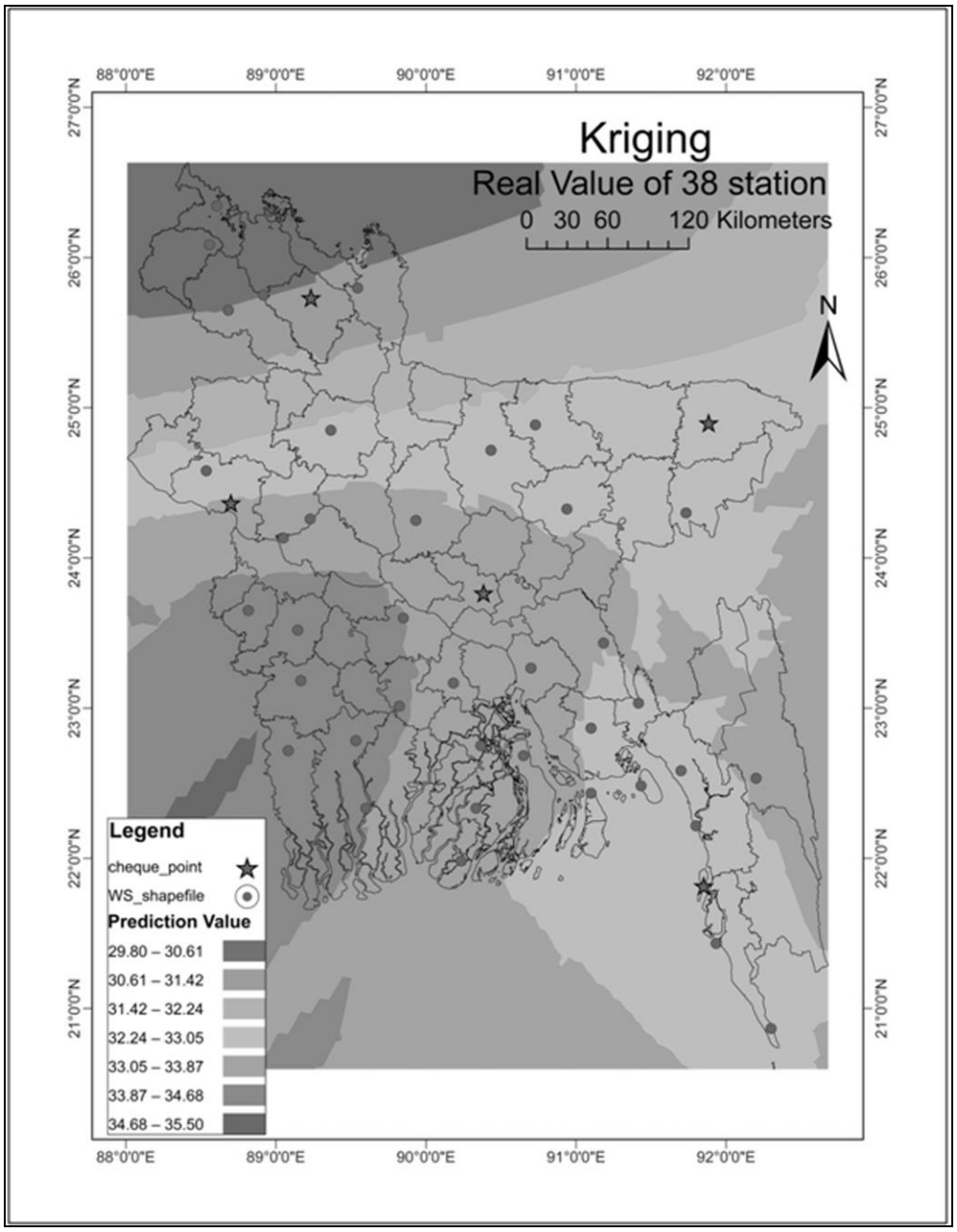
The result of the Zone of kernel smoothing map is much better than the Global polynomial methods. This method gives an output by compromising every weather station's data.



Source: Compiled by Author, 2023.

Map 05: Output of Radial Basis Functions Interpolation method (Temperature map of Bangladesh).

Radial Basis Function methods give an output by the compromising of station-based data by the fitting of visual outlook. This method involves fitting a radial basis function (such as a Gaussian function) to the observed data points.



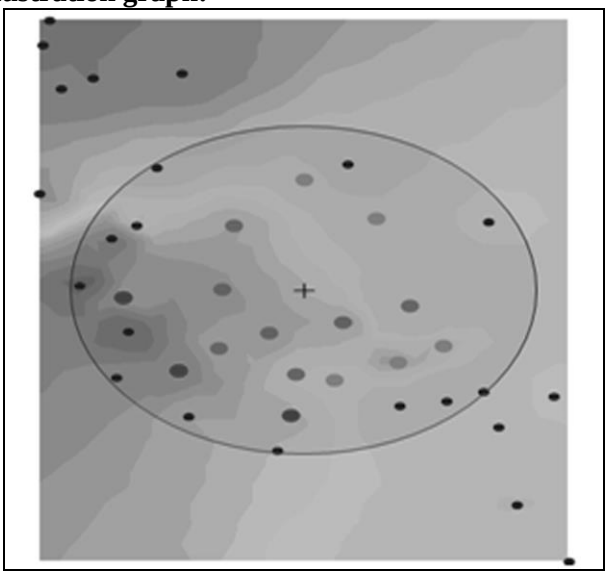
Source: Compiled by Author, 2023.

Map 06: Output of Kriging Interpolation method (Temperature map of Bangladesh).

Kriging Interpolation methods is giving the output by the spatial correlation between the observed points. This method is often used in geo-statistics and is particularly useful when the data is spatially auto-correlated.

6. Visualization and Evaluation of the interpolation techniques:

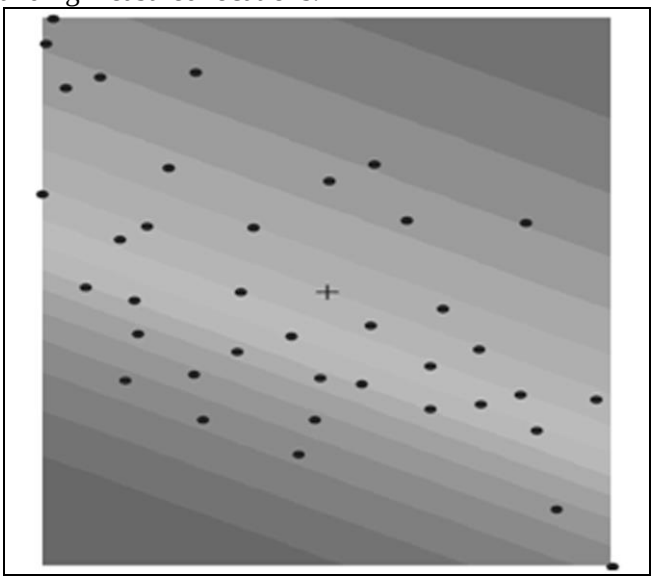
Neighborhood illustration graph:



Source: Compiled by Author, 2023.

Figure 03: Neighborhood illustration graph of Inverse Distance Weighting (IDW) Interpolation.

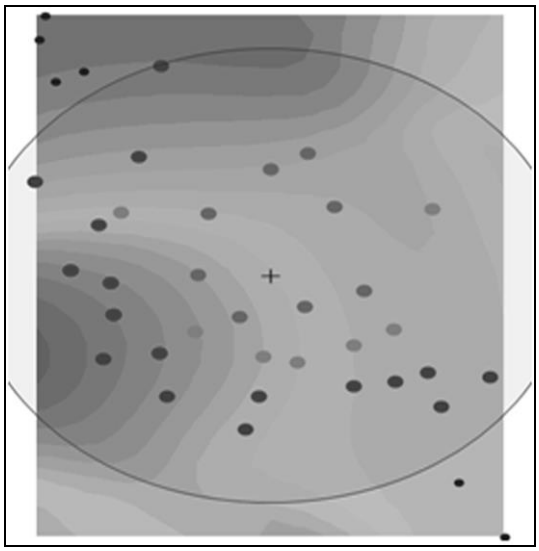
By emphasizing each neighbor's spatial influence and relative relevance in the IDW interpolation process, this neighborhood graph highlights the links between the target place and its surrounding measured locations.



Source: Compiled by Author, 2023.

Figure 04: Neighborhood illustration graph of Global Polynomial Interpolation.

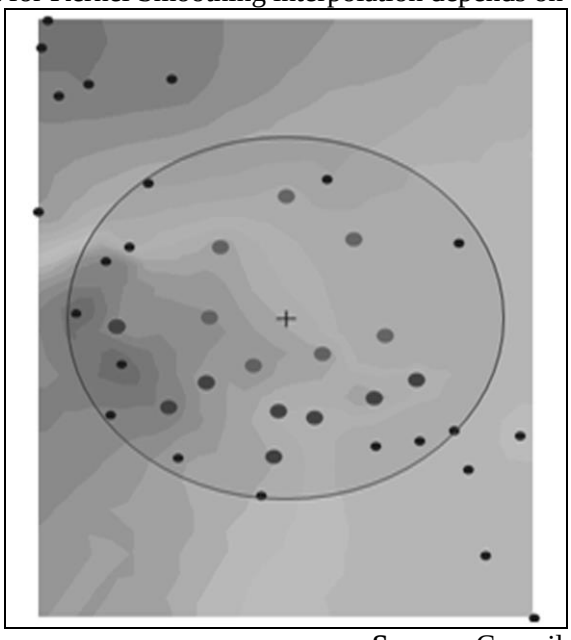
The links between the data points are represented by the neighborhood graph of the global polynomial interpolation; there is no weighting based on distance or regional influences. Instead of taking into account specific neighborhoods, the polynomial function is designed to fit the entire dataset as a whole.



Source: Compiled by Author, 2023.

Figure 05: Neighborhood illustration graph of Kernel Smoothing Interpolation.

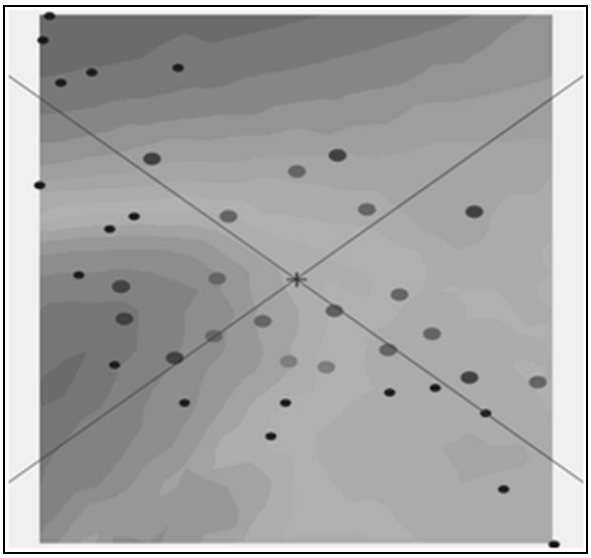
Typically, the kernel function and a bandwidth parameter that regulates the neighborhood's size are used to determine the weights. The range of adjacent points that are taken into account for Kernel Smoothing interpolation depends on the bandwidth.



Source: Compiled by Author, 2023.

Figure 06: Neighborhood illustration graph of Radial Basis Function Interpolation.

In this graph, each data point is represented by a node, and the connections between the real and predicted values are represented by the nodes' edges. The linkages show which data points are close to one another.

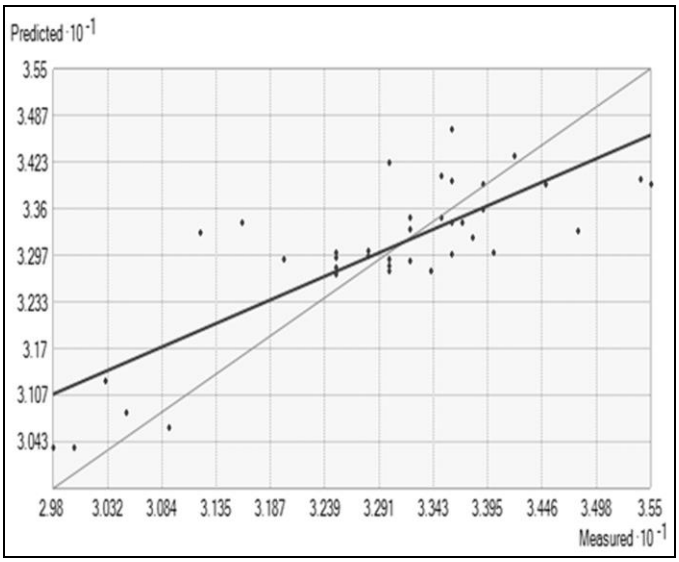


Source: Compiled by Author, 2023.

Figure 07: Neighborhood illustration graph of Kriging Interpolation.

By simulating the geographical dependence between the data points, kriging interpolation takes the spatial autocorrelation of the data into account. By applying a statistical model to the collected data, it estimates the unmeasured values at the unobserved places.

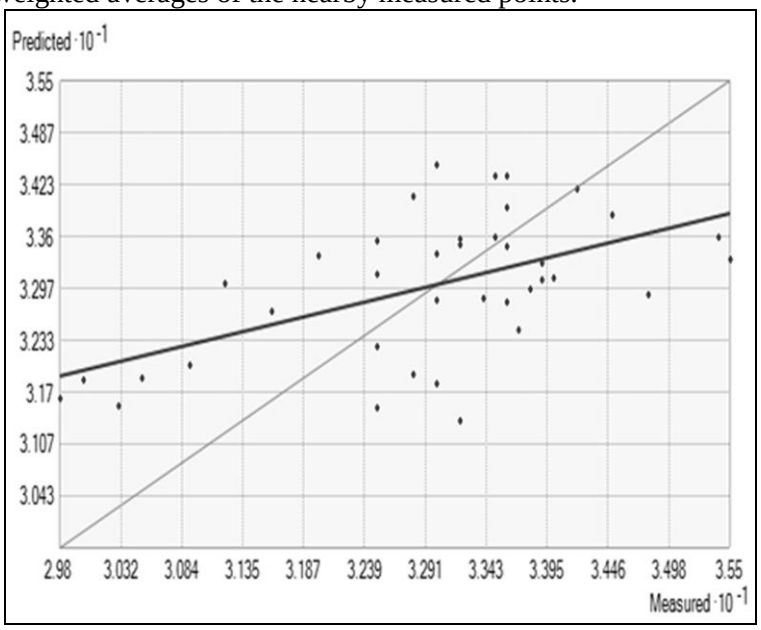
Prediction graph:



Source: Compiled by Author, 2023.

Figure 08: Prediction graph of Inverse Distance Weighting (IDW) Interpolation.

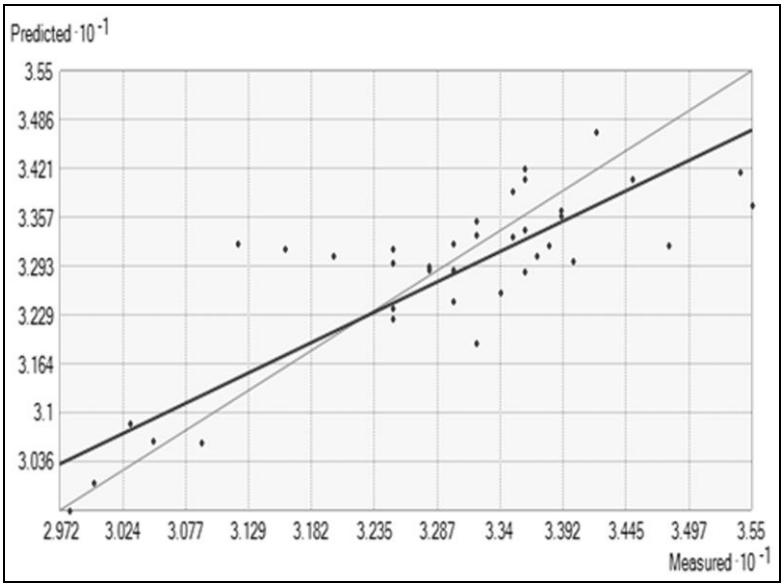
The graph showed that, the gradual change or interpolation of values across the grid based on the weighted averages of the nearby measured points.



Source: Compiled by Author, 2023.

Figure 09: Prediction graph of Global Polynomial Interpolation.

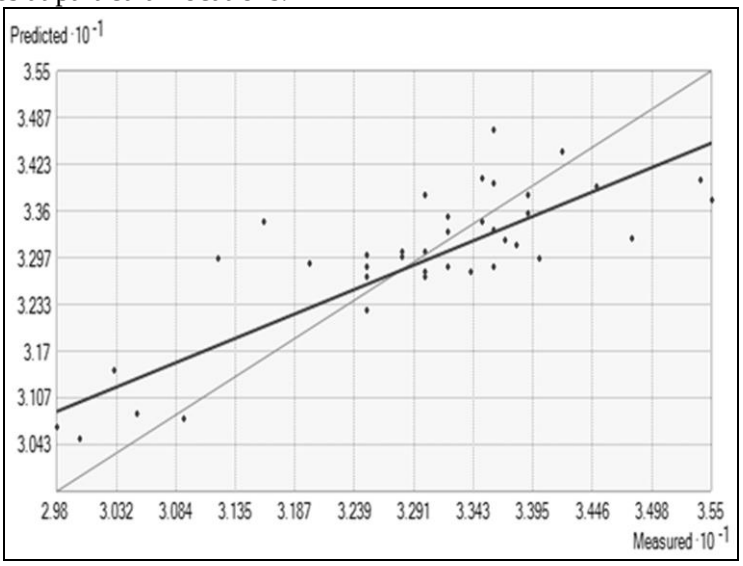
The graph displayed extra points or a curve that represented their interpolated estimated positions by the method of Global Polynomial Interpolation.



Source: Compiled by Author, 2023.

Figure 10: Prediction graph of Kernel Smoothing Interpolation.

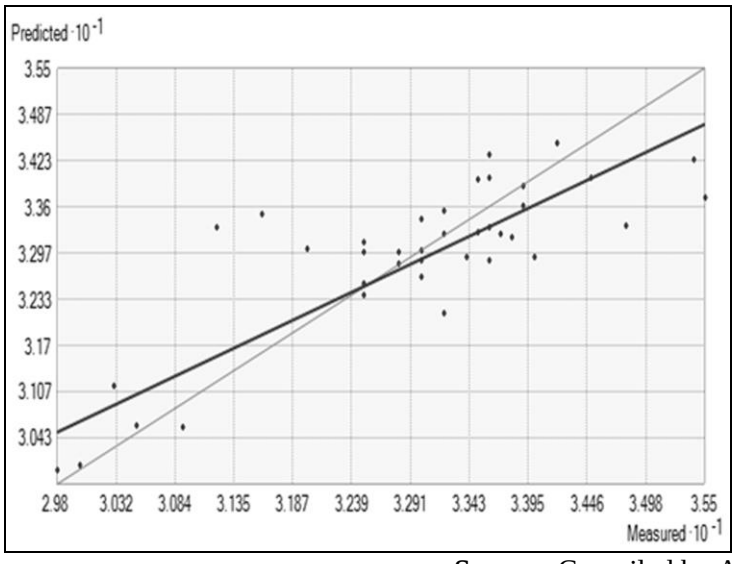
The estimated values' smooth distribution over the domain is demonstrated visually by the graph's representation of the kernel smoothing curve or surface. Based on the kernel smoothing technique, the interpolated estimated positions reveal information about the projected values at particular locations.



Source: Compiled by Author, 2023.

Figure 11: Prediction graph of Radial Basis Function Interpolation.

The graph showed the smooth surface, the interpolated predicted positions, the measured data points, and the effect of the radial basis functions are all represented visually. The basis of the RBF interpolation technique offers insights into the projected values at particular locations.

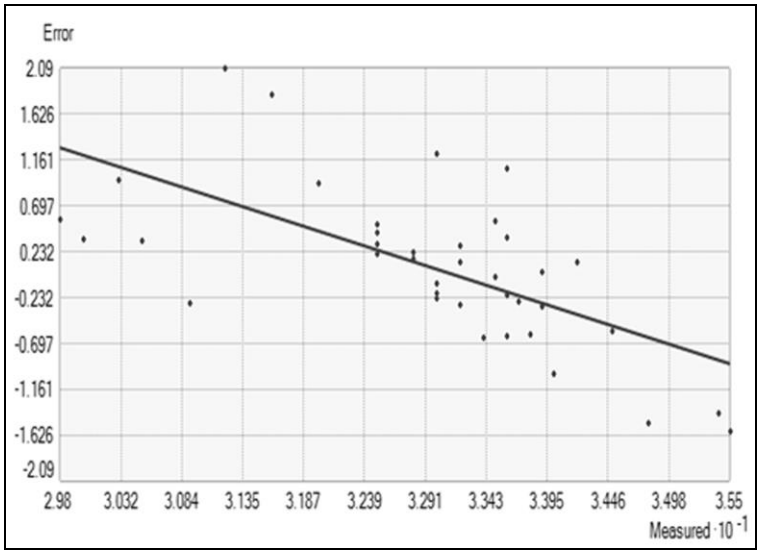


Source: Compiled by Author, 2023.

Figure 12: Prediction graph of Kriging Interpolation.

By observing the graph, we can discover the spatial patterns, variability, and uncertainty of the calculated values. Capturing the underlying spatial structure and variability, aids in identifying spatial linkages and trends in the data.

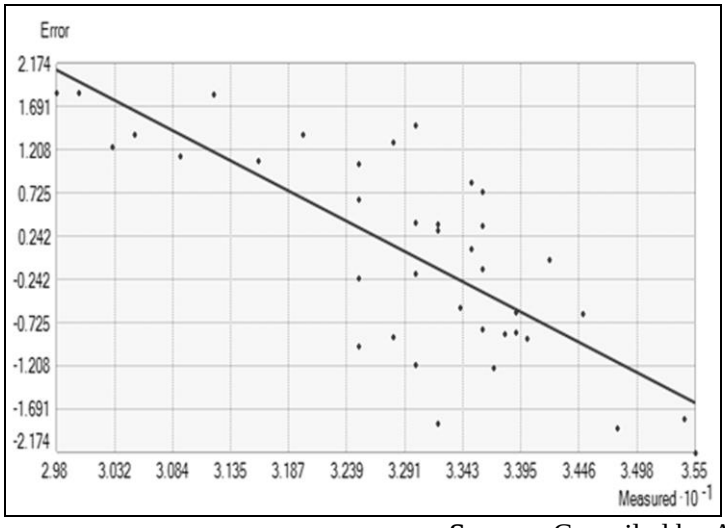
Error graph:



Source: Compiled by Author, 2023.

Figure 13: Error graph of Inverse Distance Weighting (IDW) Interpolation.

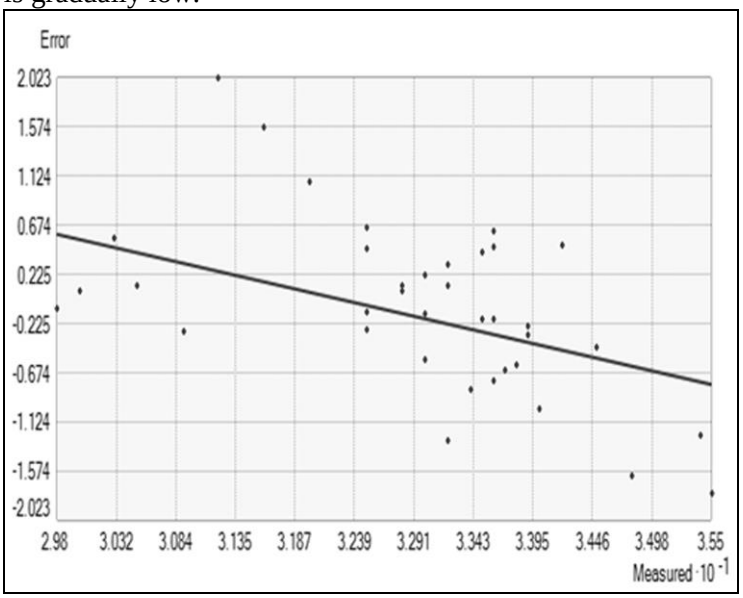
This graph clearly showed the accuracy level of prediction. Close points of the line are more accurate and some points are more distant from the line those are more errors of prediction.



Source: Compiled by Author, 2023.

Figure 14: Error graph of Global Polynomial Interpolation.

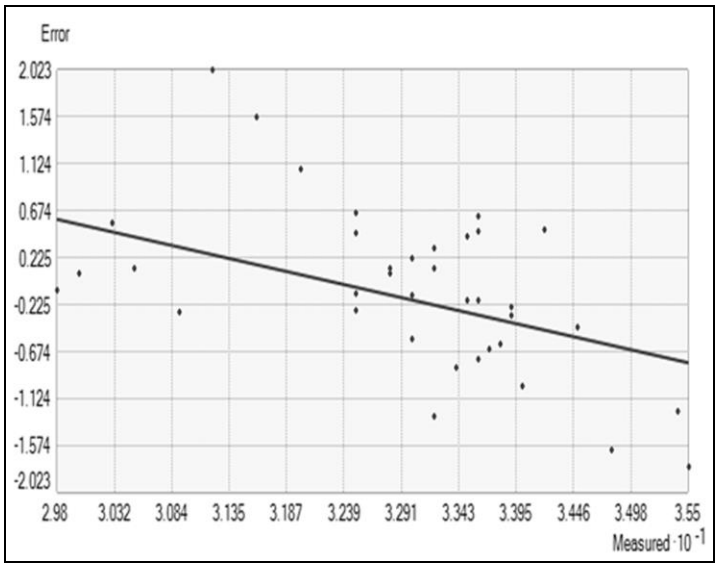
The graph showed that most of the points are more distant from the standard line. So, Its accuracy level is gradually low.



Source: Compiled by Author, 2023.

Figure 15: Error graph of Kernel Smoothing Interpolation.

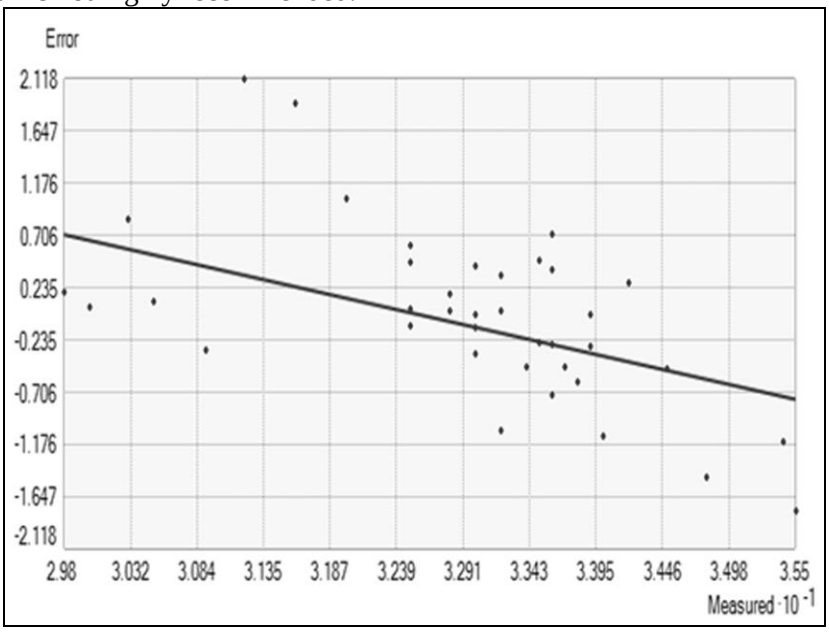
The error graph showed the difference between the actual measured values and the estimated values obtained through the interpolation process. It also showed insights into the accuracy and quality of the interpolation method by Kernel smoothing interpolation method which visualized the errors at different locations.



Source: Compiled by Author, 2023.

Figure 16: Error graph of Radial Basis Function Interpolation.

The graph showed a comprehensive assessment of the accuracy and reliability of the Radial Basis Function interpolation method. There are some points in the graph that are more distant from the standard line. So, the accuracy level of Radial Basis Function interpolation is not highly recommended.



Source: Compiled by Author, 2023.

Figure 17: Error graph of Kriging Interpolation.

The graph showed the assessment of the accuracy and reliability of the Kriging interpolation method. Most of the points in the graph are very close to the standard line. There are only 2 or 3 points that are distant from the standard line. So, the accuracy level of Kriging interpolation is mostly accurate. So the Kriging Interpolation is highly recommended for temperate data interpretation.

7. Summary and Conclusion

Every prediction and error graph helps to visualize, evaluate and compare the results of different interpolation methods for statistical evaluation and visualization. Comparing the interpolated values to the original temperature data with prediction data as well as its give us absolute errors with real data.

it enables accurate evaluation. By quantifying the differences between the original data and the interpolated values, the error analysis yields a statistical measure of performance. Plotting the prediction and error graphs for each method makes comparative evaluation simpler. The procedure enables iterative enhancement and amplification of the interpolation techniques. It is crucial to remember that this assessment should be supported by additional statistical methods and validation strategies, such as cross-validation, hypothesis testing, and comparison with actual data. After seeing the all documentation, like the map, Neighborhood graph, Prediction graph, Error graph, prediction values tale, and level of error of sample point.

Table 02: Prediction values and level of error for the all-weather station.

ID No	Real Value	IDW		GPL		Kernel		Radial		Kriging	
		Predicted Value	Error	Predicted Value	Error	Predicted Value	Error	Predicted Value	Error	Predicted Value	Error
0	29.8000	30.3615	0.5615	31.6429	1.8429	29.7167	-0.0833	30.6738	0.8738	30.0015	0.2015
1	30.0000	30.3575	0.3575	31.8495	1.8495	30.0743	0.0743	30.5281	0.5281	30.0717	0.0717
2	30.3000	31.2593	0.9593	31.5479	1.2479	30.8562	0.5562	31.4488	1.1488	31.1586	0.8586
3	30.5000	30.8502	0.3502	31.8727	1.3727	30.6263	0.1263	30.8610	0.3610	30.6104	0.1104
4	30.9000	30.6262	-0.2738	32.0384	1.1384	30.6062	-0.2938	30.7868	-0.1132	30.5856	-0.3144
5	31.2000	33.2900	2.0900	33.0339	1.8339	33.2234	2.0234	32.9648	1.7648	33.3176	2.1176
6	32.5000	32.7106	0.2106	32.2671	-0.2329	32.2312	-0.2688	32.2599	-0.2401	32.3911	-0.1089
7	33.0000	32.8216	-0.1784	31.8149	-1.1851	32.4615	-0.5385	32.7286	-0.2714	32.6439	-0.3561
8	32.5000	32.9376	0.4376	31.5217	-0.9783	32.3900	-0.1100	32.7276	0.2276	32.5503	0.0503
9	33.0000	34.2259	1.2259	32.8259	-0.1741	33.2318	0.2318	33.8158	0.8158	33.4399	0.4399
10	32.8000	33.0342	0.2342	31.9266	-0.8734	32.8767	0.0767	32.9867	0.1867	32.9855	0.1855
11	34.8000	33.3068	-1.4932	32.9082	-1.8918	33.1942	-1.6058	33.2440	-1.5560	33.3454	-1.4546
12	33.7000	33.4268	-0.2732	32.4761	-1.2239	33.0611	-0.6389	33.2161	-0.4839	33.2322	-0.4678
13	33.2000	32.9007	-0.2993	31.3495	-1.8505	31.9168	-1.2832	32.8593	-0.3407	32.1521	-1.0479
14	35.5000	33.9306	-1.5694	33.3259	-2.1741	33.7343	-1.7657	33.7633	-1.7367	33.7423	-1.7577
15	33.6000	34.6835	1.0835	33.4793	-0.1207	34.2228	0.6228	34.7172	1.1172	34.3268	0.7268
16	33.9000	33.9350	0.0350	33.0740	-0.8260	33.6624	-0.2376	33.8357	-0.0643	33.8941	-0.0059
17	31.6000	33.4257	1.8257	32.6875	1.0875	33.1658	1.5658	33.4735	1.8735	33.5010	1.9010
18	35.4000	34.0008	-1.3992	33.6046	-1.7954	34.1713	-1.2287	34.0221	-1.3779	34.2581	-1.1419
19	33.5000	34.0467	0.5467	33.6053	0.1053	33.9273	0.4273	34.0593	0.5593	33.9818	0.4818
20	33.9000	33.5896	-0.3104	33.2891	-0.6109	33.5840	-0.3160	33.5686	-0.3314	33.6164	-0.2836
21	33.8000	33.2082	-0.5918	32.9616	-0.8384	33.2042	-0.5958	33.1521	-0.6479	33.1947	-0.6053
22	33.6000	32.9781	-0.6219	32.8067	-0.7933	32.8615	-0.7385	32.8641	-0.7359	32.8710	-0.7290
23	34.2000	34.3323	0.1323	34.1825	-0.0175	34.6943	0.4943	34.4112	0.2112	34.4902	0.2902
24	34.5000	33.9352	-0.5648	33.8750	-0.6250	34.0697	-0.4303	33.9439	-0.5561	34.0147	-0.4853
25	33.2000	33.4948	0.2948	33.5857	0.3857	33.5271	0.3271	33.5361	0.3361	33.5595	0.3595
26	33.2000	33.3306	0.1306	33.5087	0.3087	33.3319	0.1319	33.3259	0.1259	33.2360	0.0360
27	34.0000	33.0012	-0.9988	33.0990	-0.9010	32.9987	-1.0013	32.9701	-1.0299	32.9157	-1.0843
28	33.6000	33.9887	0.3887	34.3454	0.7454	34.0761	0.4761	33.9790	0.3790	33.9972	0.3972
29	33.6000	33.4088	-0.1912	33.9538	0.3538	33.4162	-0.1838	33.3609	-0.2391	33.3298	-0.2702
30	32.5000	33.0116	0.5116	33.5498	1.0498	33.1507	0.6507	33.0090	0.5090	33.1151	0.6151
31	32.0000	32.9326	0.9326	33.3849	1.3849	33.0785	1.0785	32.8887	0.8887	33.0453	1.0453
32	32.5000	32.8108	0.3108	33.1480	0.6480	32.9704	0.4704	32.8480	0.3480	32.9785	0.4785
33	33.4000	32.7673	-0.6327	32.8501	-0.5499	32.5805	-0.8195	32.7788	-0.6212	32.9257	-0.4743
34	33.0000	32.7729	-0.2271	33.3921	0.3921	32.8727	-0.1273	32.7754	-0.2246	32.8741	-0.1259

ID No	Real Value	IDW		GPL		Kernel		Radial		Kriging	
		Predicted Value	Error	Predicted Value	Error	Predicted Value	Error	Predicted Value	Error	Predicted Value	Error
35	33.5000	33.4836	-0.0164	34.3438	0.8438	33.3167	-0.1833	33.4551	-0.0449	33.2510	-0.2490
36	32.8000	32.9702	0.1702	34.0914	1.2914	32.9298	0.1298	33.0472	0.2472	32.8285	0.0285
37	33.0000	32.9216	-0.0784	34.4864	1.4864	32.8713	-0.1287	33.0613	0.0613	33.0030	0.0030
Total	**1252.0000**	**1255.0696**	**3.0696**	**1253.7059**	**1.7059**	**1248.8845**	**-3.1155**	**1253.9479**	**1.9479**	**1251.4364**	**-0.5636**

Source: Prepared by the author from Temperature data by using GIS, 2023.

Table 03: Level of error only cheque sample point. Cheque Sample Points: Rangpur, Rajshahi, Sylhet, Dhaka, and Chittagong.

Differences Between Real value and Predicted value by using different interpolation methods						
Name of Station	**Real Value**	**Prediction Values**				
		IDW	**Global polynomial**	**Karnel Smoothing**	**Radial Basis**	**kriging**
Rangpur	30.5	30.6	31.59	30.75	30.81	30.6
Rajshahi	35	34.89	32.96	32.93	32.85	35.07
Sylhet	30.5	30.22	31.18	33.21	32.99	30.56
Dhaka	33.7	33.7	32.82	33.27	33.38	33.9
Chittagong	33	32.99	33.98	32.88	32.93	32.8
Total	**162.7**	**162.4**	**162.53**	**163.04**	**162.96**	**162.93**
Level of Error	**0**	**0.3**	**0.17**	**-0.34**	**-0.26**	**0.03**

Source: Prepared by the author from Temperature data by using GIS, 2023.

After seeing the all documentation, like the map, Neighborhood graph, Prediction graph, Error graph, prediction values, and level of error in the cheques sample point table, the minimum difference of the Kriging Interpolations results from the real value and the maximum difference of the Radial Basis Interpolation method. S0, it's clear that the Kriging is the Best Method to interpolate the temperature data.

At last, after visualizing the tabulation data, map, and graph. It's clear that the minimum differences from real value to prediction values of the Kriging method. Then, the appropriation level of Global Polynomial Method. Then, the Radial Basis Functions method, then the IDW, and last is the Karnel Smoothing method. This serial is also the less error level to high error level of the interpolation methods of temperature data. So, the Kriging method is the best method for the interpolation of temperature data.

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