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COMPARATIVE ANALYSIS OF DIGITAL TERRAIN MODEL (DTM) INTERPOLATION METHODS FOR SUSTAINABLE ENVIRONMENT

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ABSTRACT
The aim of this research is to compare different methods of digital terrain model (DTM) interpolation. The procedure adopted for this research comprises of field reconnaissance, in which the boundary stations were selected and monumented, and a recce diagram was produced. Ground surveying method was adopted in carryout the field observation. The instrument was setup on an existing control with a beacon number SC/BA 299 for connection. The coordinate of the point was collected from the Department of Surveying and Geo-informatics, Federal Polytechnic Bauchi. The spatial data were obtained from the field using Global positioning system (GPS) receiver. The data obtained was exported in to ArcGIS 10.3 version which was for the production of DTM. The DTMs generated were compared and analyzed for further discussion. The generated DTMs are found to be sensitive to height interpolation Methods as well as the terrain nature. Investigations according to this research revealed that (Inverse Distance Weighting) IDW method of interpolation is the method that produced the best result when compared to other methods and kriging interpolation is the the method that produced worst result in term of accuracy. The accuracy of interpolation methods is determined by the value of standard deviation. The higher the value of the standard deviation, the lower the accuracy whereas the lower the value of the standard deviation, the higher the accuracy of the result. The summary of the results

is shown on Table 1. Figures 11, is a bar chart showing the standard deviation of each method adopted and their rank.

Keywords: *Digital Terrain Model, Interpolation, Earth configuration, Spatial Coordinates, Accuracy and Analysis.*

Background of the study

DEMs are generally adopted data structures for storing topographic information and are usually interpolated to establish the values for entire terrain points. DEM is an array representation of squared cells (pixels) with an elevation value associated to each pixel (Alkanalka, 2002). DEMs can be obtained from contour lines, topographic maps, field surveys, photogrammetry techniques, radar interferometry, and laser altimetry (Manuel, 2004). Different interpolation methods applied over the same data sources may result in different results and hence it is required to evaluate the comparative suitability of these techniques. Interpolation techniques are based on the principles of spatial autocorrelation, which assumes that closer points are more similar compared to farther ones (Ashraf 2012). Interpolation methods include Inverse Distance Weighting (IDW), Local Polynomial Method, Nearest Neighbor (NN), Natural Neighbor, Radial Basis Functions (RBFs),Kriging, spine, global polynomial interpolation, Empirical Bayesian kringing and diffusion interpolation with barrier. The Kriging tool fits a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value for each location. Kriging is a multistep process; it includes exploratory statistical analysis of the data, variogram modeling, creating the surface, and (optionally) exploring a variance surface. Interpolation is the process of using points with known values or sample points to estimate values at unknown points. It can be used to predict unknown values for any geographical point data, such as elevation, rainfall, chemical concentrations, noise levels, and so on. The aim of this research is to analyze different DEM interpolation methods. The objectives includes; to

generate DEM using various interpolation methods and to compare different methods of DEM interpolation (Clarke, 2003)..
Marina et al (2016), described the process of creating digital terrain models (DTM) using different interpolation methods. The analysis shows the accuracy of the DTM obtained from topographic maps at different scales and using different interpolation methods. The quality and accuracy of DTM depends on the complexity of the terrain, data sources, and methods of height interpolation. Zahraa (2016), Digital Elevation Model represents a very important geospatial data type in the analysis and modelling of different hydrological and ecological phenomenon which are required in preserving our immediate environment. DEMs are typically used to represent terrain relief. DEMs are particularly relevant for many applications such as lake and water volumes estimation, soil erosion volumes calculations, flood estimate, quantification of earth materials to be moved for channels, roads, dams, embankment etc. (Davidovic, 2015), provides a review of spatial interpolation methods for environmental science and categorized the methods into three as non-geostatistical methods, geostatistical methods and combined methods. Prior to the physical development, it is paramount that the nature of the terrain be taken in to account. This research portray the terrain configuration in order to solve the problem of environmental monitory and planning of engineering/building project, an accurate and up to date Digital terrain model (DTM) and contour map is needed (Rayburg, 2009). On other hand, different researchers compared two or three DEM interpolation method and came up with their respective results but there is no single research that compared more than four DEM interpolation methods. If all the methods of DEM interpolation in ArcGIS is put under consideration, the most accurate method would be determined and use for terrain modeling. Terrain information is very vital for most of the human settlement and used for monitory of physical development. The research is targeted toward planning and monitory of environment for sustainable development. The major problems that prompted this project research includes lack of accurate DEM of the study area, in availability of digital

data set for decision making pertaining terrain configuration and difficulties in choosing appropriate accurate interpolation model. This research might be useful in civil engineering work such as preparation of road project, exaction filling of related volume calculations land stratification studies, and drainage construction work. It is very vital in building construction and environmental planning. The scope of the research covers the entire Bauchi metropolis.

Study Area

The study area is Bauchi metropolis, Bauchi state, Nigeria. Bauchi State has a maximum and minimum temperature of about 41°c during the daytime and 23°c at night and a population of about 4,653,066 people.

Material and Methods

The Method adopted for this project research comprises of field reconnaissance, in which the boundary station were selected and monumented and a recce diagram was produced. An existing control with a beacon number SC/BA 299 was used. The instrument was setup on the control point for connection. The coordinate of the point was collected from the Department of Surveying and Geo-informatics, Federal Polytechnic Bauchi. Spatial data were obtained from the field using DGPS receiver. The data obtained was exported to ArcGIS 10.3 version for the production of the DTM. The DTMs generated were compared and analyzed for further discussion and presentation.

Result and Discussion

The software used in carrying out the digital terrain model DTM is ArcGIS 10.3. These are the methods used in generating the DTMs of the study area, Diffusion Interpolation with Barrier, Inverse Distance Weighting, Empirical Bayesian Kriging, Kriging, Spline, Global Polynomial Interpolation, Local Polynomial Interpolation, Radial Basic Function, Natural Neighbor, and Kernel Interpolation with Barriers. The result of the interpolation methods is tabulated in Table 1.The smaller the standard deviation the higher the accuracy of the interpolation methods. The methods of interpolation are arranged in ascending other of accuracy and these methods were ranked as tabulated on Table 1. The DTMs produced are also arranged based on their accuracy as shown below.

Inverse Distance Weighting: The DTM was generated using ArcGIS 10.3 software and the result of the interpolation was produced, based on the result generated the mean of the spot height obtained is 650.2644 and standard deviation extraction is 15.86202. The accuracy of the result was defined base on the standard deviation .This method was found to be the best method and was ranked 1st. The raster DTM is shown in Figure1.

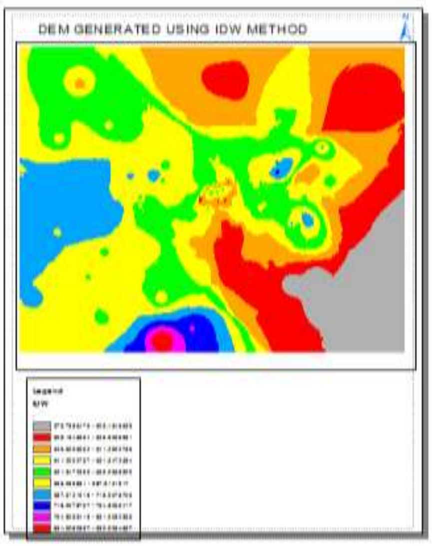

Fig 1: DTM generated using Inverse Distance Weighting (IDW)

Radial Basic Function: The result of the interpolation generated using radial basic function has a mean spot height of 651.77273 and standard deviation extracted is 31.59064. The accuracy of the result was defined base on the standard deviation .This method was found to be the second method based on the accuracy obtained. The raster DTM is shown in Figure 2.

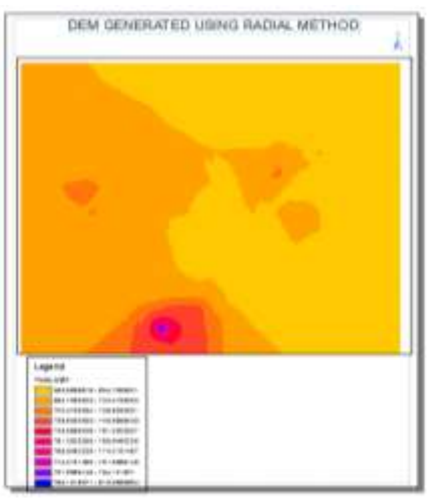

Fig 2: DTM generated using Radial basic function

Spline Method: The result of the interpolation generated has a mean spot height of 651.77272 and standard deviation extracted is 31.590645. The accuracy of the result was defined base on the standard deviation .This method was found to be the third method based on the accuracy obtained in this research. The raster DTM is shown in Figure 3.

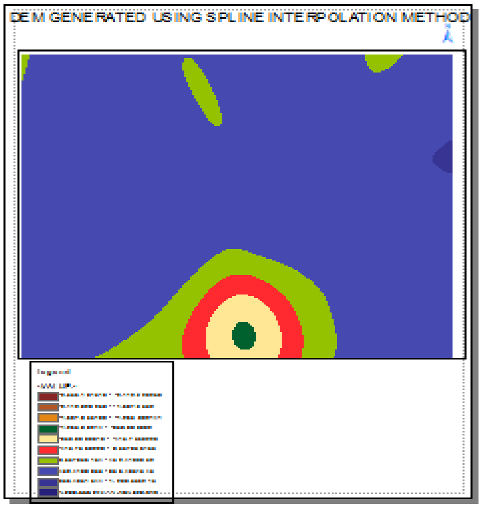

Fig 3: DTM generated using Spline Interpolation

Global Polynomial Interpolation: The result of the interpolation generated using this method has a mean sport height 651.071057 and standard deviation of 32.22123. The accuracy of the result was defined base on the standard deviation. This method was found to be the fourth based on the result obtained. The raster DTM is shown in Figure 4.

Fig 4: DTM generated using Global polynomial interpolation

Diffusion Interpolation with Barrier: The result of the interpolation using this method has a mean spot height of 649.00057 and standard deviation is 34.9723. The accuracy of the result was defined base on the standard deviation. This method was found to be fifth method. The raster DTM is shown in Figure 5.

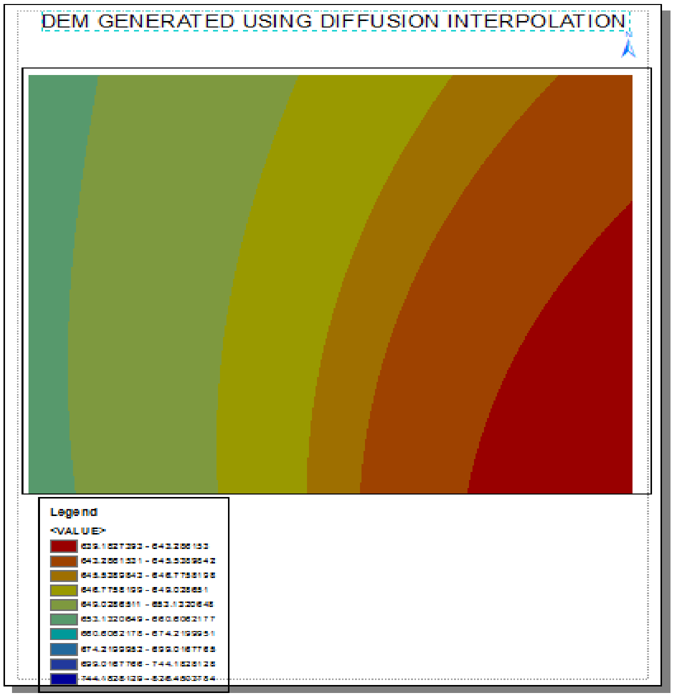

Fig 5: DTM generated using Diffusion interpolation

Natural Neighbor: The result of the interpolation generated using natural neighbor has a mean spot height of 654.47018 and standard deviation of 36.98463. The accuracy of the result was defined base on the standard deviation .This method was found to be sixth method based the result extracted. The raster DTM is shown in Figure 6.

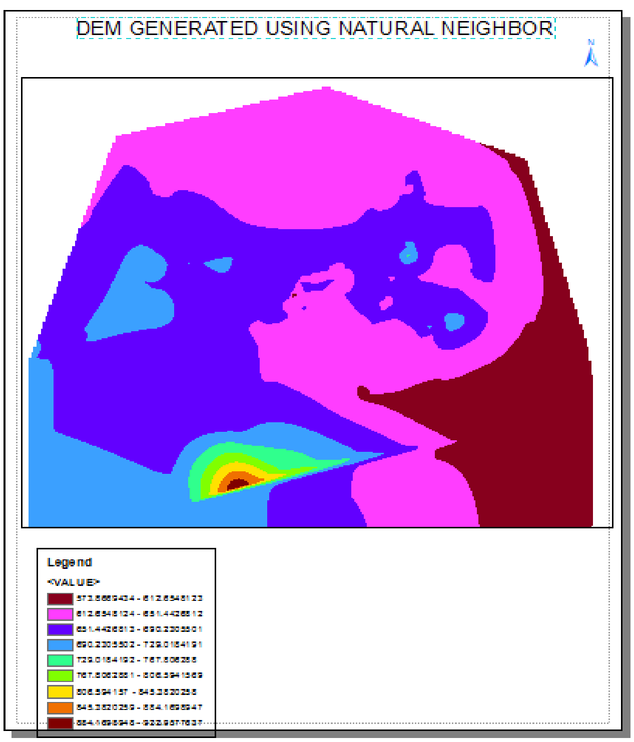

Fig 6: DTM generated using Natural Neighbor

Empirical Bayesian Kriging: The result of the interpolation generated using this method has a mean spot height of 648.02212 and standard deviation of 44.0538. The accuracy of the result was defined base on the standard deviation extracted. This method was found to be the seventh method based the result extracted. The raster DTM is shown in Figure 7.

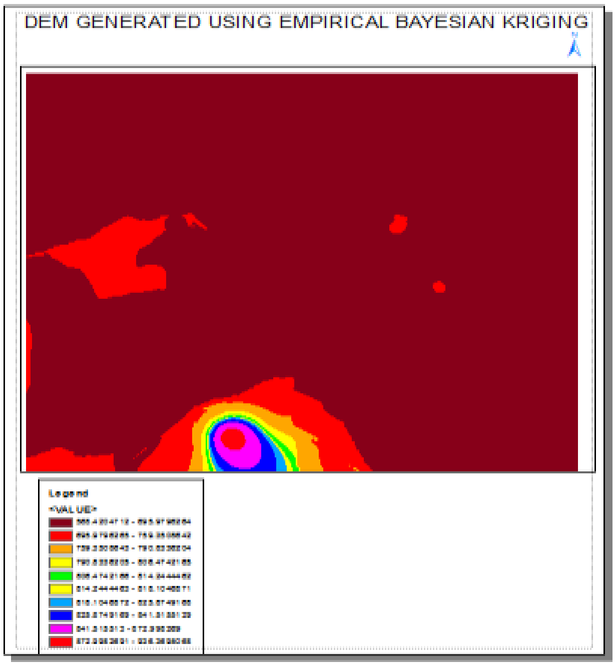

Fig 7: DTM generated using Empirical Bayesian

Kernel Interpolation with Barrier: The result of the interpolation generated using this method has a mean spot height of 656.54536 and standard deviation of 46.81387. The accuracy of the result was defined base on the standard deviation extracted. This method was found to be the eighth method based the result extracted. The raster DTM is shown in Figure 8.

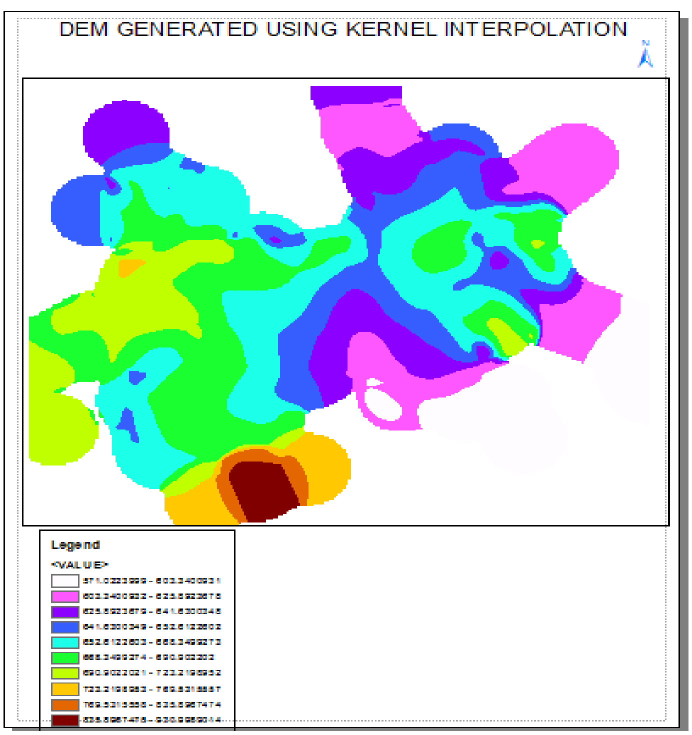

Fig 8: DTM generated using Kernel Interpolation

Local Polynomial Interpolation: The result of the interpolation generated using this method has a mean spot height of 656.54536 and standard deviation of 46.81387. The accuracy of the result was defined base on the standard deviation extracted. This method was found to be the ninth method based the result extracted. The raster DTM is shown in Figure 9.

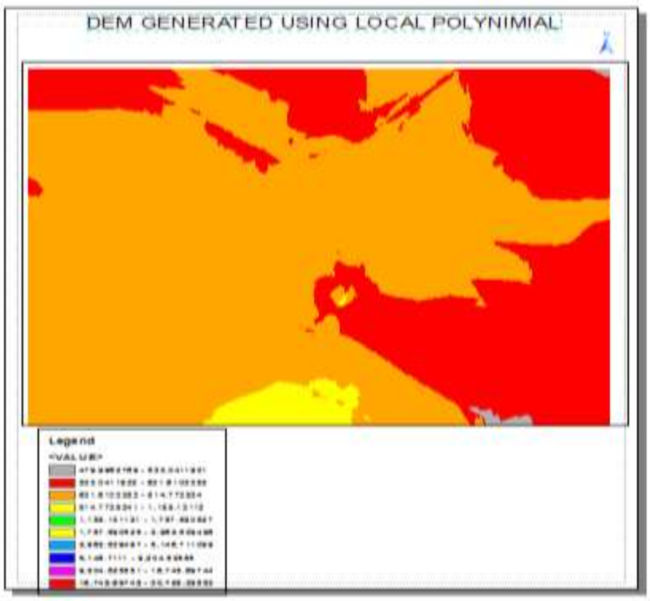

Fig 9: DTM generated using Local Polynomial

Kriging: The result of the interpolation generated using this method has a mean spot height of 644.95293 and standard deviation of 51.54530. The accuracy of the result was defined base on the standard deviation extracted. This method was found to be the tenth method based the result extracted. The raster DTM is shown in Figure 10.

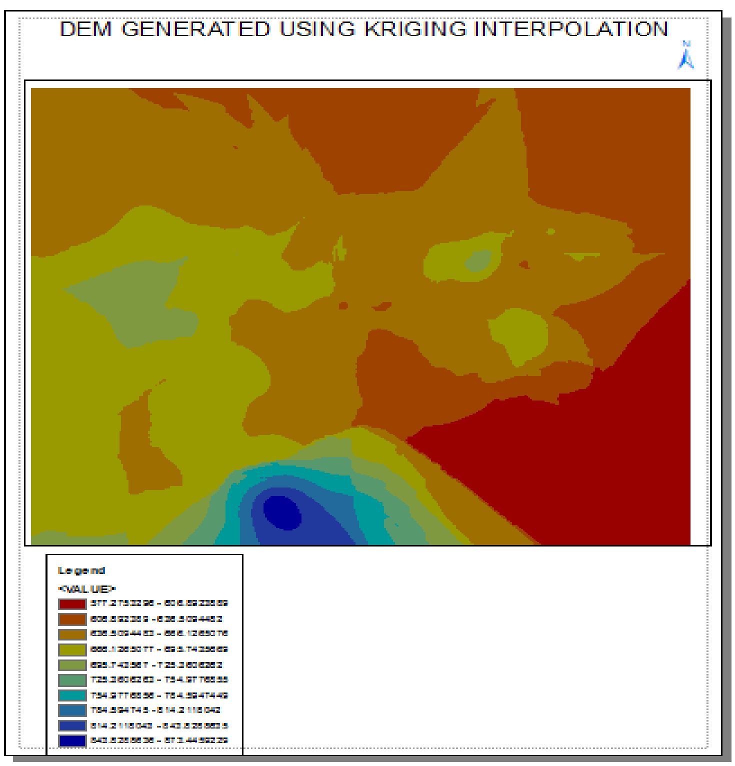

Fig 10: DTM generated using Kriging

Table 1: Summary of the Results of Interpolation Methods

Method of interpolation	Mean	Standard Deviation	RANK
IDW	650.26442	15.86202	1
Radial Function	651.77273	31.59064	2
Spline	651.77272	31.59065	3
Global Polynomial	651.07106	32.22123	4
Diffusion	649.00057	34.97232	5
Natural Neighbor	654.47018	36.98463	6
Empirical Bayesial Kriging	648.02213	44.05386	7
Kernel Interpolation	656.54526	46.81387	8
Local Polynomial	646.66152	48.3598	9
Kriging	644.95293	51.5453	10

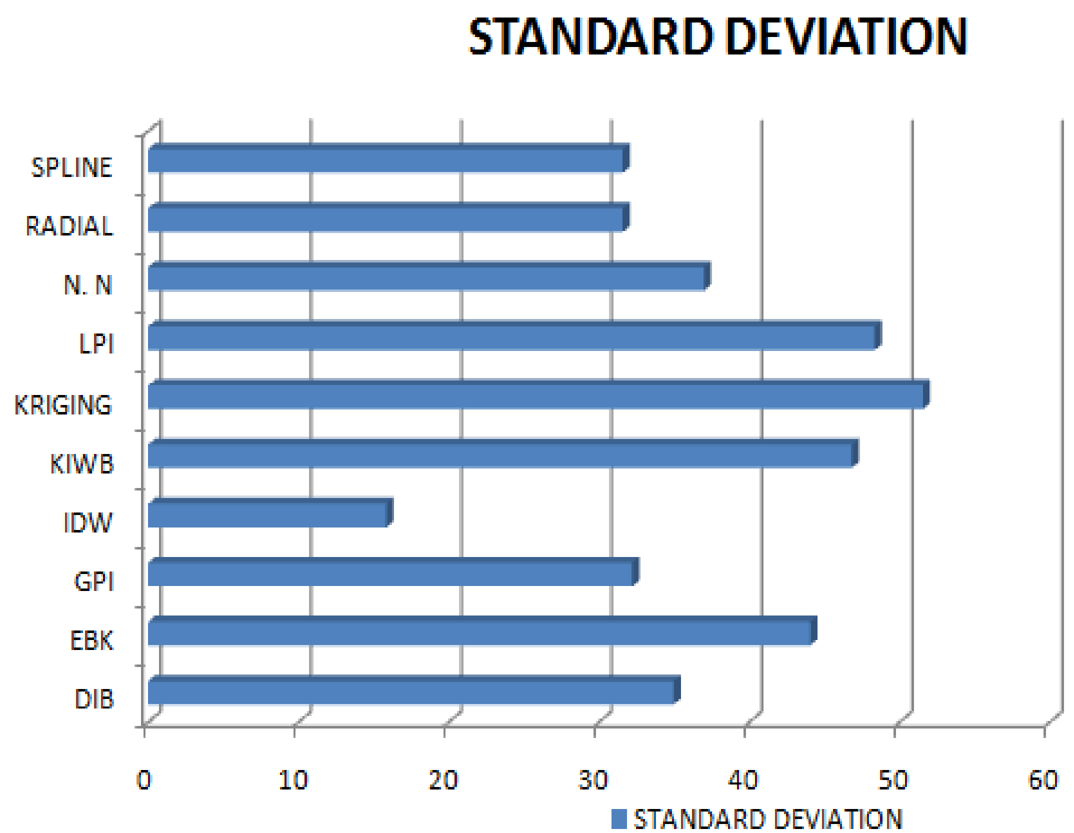

Fig 11: Bar chart of the Standard deviation

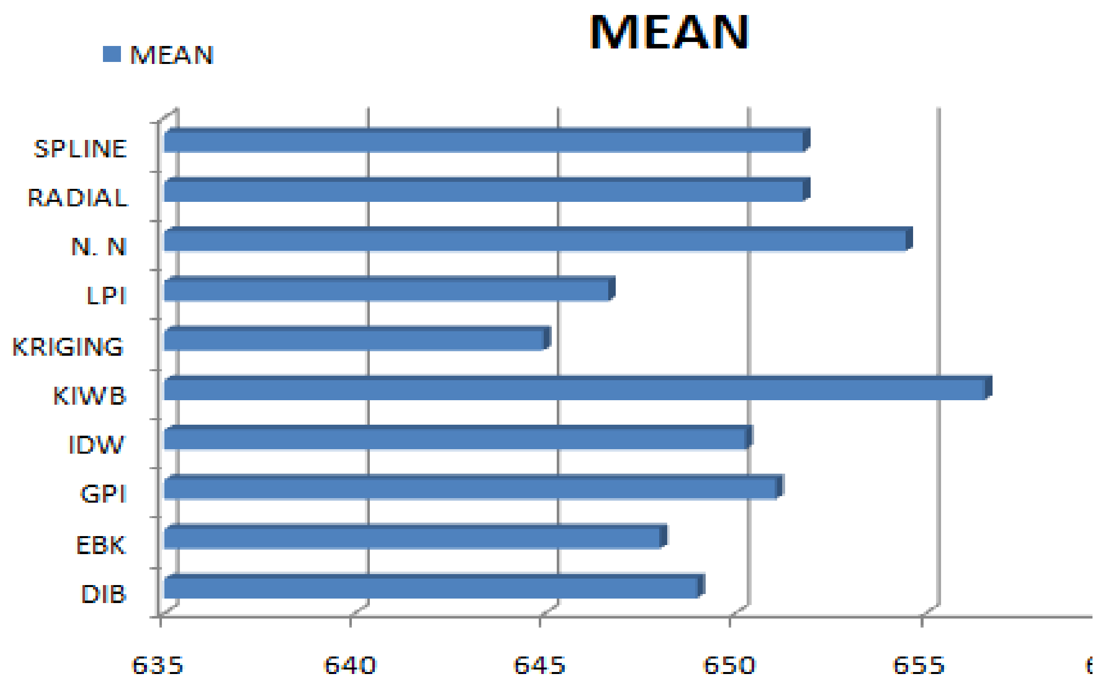

Fig 12: Bar chart of the Mean Value of the Methods of Interpolation

Conclusions

It is concluded that based on this research, the best method of interpolation is inverse distance weighting.

Recommendation

It is recommended that inverse distance weighting should be used for the production of topographic map, contour map as well as any research that involve terrain analysis in order to obtain accurate and precise results for effective and sustainable environment.

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