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Evaluation of Prediction Methods for Elevation Determination Using SRTM Digital Elevation Model in Akure, Ondo State

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The Shuttle Radar Topography Mission (SRTM) was flown aboard the space in February 2000. The National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA) participated in an international project to acquire radar data which were used to create the first near-global set of land elevations. This paper deals with the accuracy assessment of elevation data obtained using SRTM from each of the eleven (11) selected interpolation algorithms, including Inverse Distance Weighting, Natural Neighbour, Spline Regular, Spline Tension, Universal Kriging, Empirical Bayesian Kriging, Topo to Raster, global (trend surface), local polynomial, kernel interpolation with barriers and radial basis functions in DEM surface creation. The data was compared with reference to ground control points of differential Global Positioning System (DGPS) field observations in the study area. The error statistics was generated between DGPS measurements and Extracted elevation data from each selected interpolation method and it was observed that elevation data extracted from Inverse distance weighting, Natural Neighbour, Spline R, Spline T, Topo to Raster, Universal Kriging, Empirical Bayesian Kriging, Global polynomial interpolation (GPI), local polynomial interpolation (LPI), Radial basis function and Kernel interpolation are ±8.446, ±8.648, ±9.532, ±10.707, ±10.020, ±9.795, ±8.452, ±14.565, ±9.266, ±10.802 and ±11.303 respectively when compared with elevation values from GPS with Inverse Distance weighting Interpolation method showing the best overall accuracy of ±8.446m.
Keywords: SRTM, Inverse Distance Weighting (IDW), Natural Neighbour (NN), Spline Regular, Spline Tension, Universal Kriging, Empirical Bayesian Kriging (EBK), Topo to Raster, global (trend surface)

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Introduction

Geostatistics is a class of statistics used to analyse and predict the values associated with spatial or spatiotemporal phenomena. It incorporates the spatial (and in some cases temporal) coordinates of the data within the analyses. Many geostatistical tools were originally developed as a practical means to describe spatial patterns and interpolate values for locations where samples were not taken. Those tools and methods have since evolved to not only provide interpolated values, but also measures of uncertainty for those values. The measurement of uncertainty is critical to informed decision making, as it provides information on the possible outcomes for each location rather than just one interpolated value. Geostatistical analysis has also evolved from univariate to multivariate and offers mechanisms to incorporate secondary datasets that complement a (possibly sparse) primary variable of interest, thus allowing the construction of more accurate interpolation and uncertainty models (Erdogan, 2009).

A Digital Elevation Model (DEM) can be defined as an elevation array with a (large) number of grid nodes over the domain of interest (Hengl, 2008).

$$Z=\{Z(S_J), j=1,\ldots,N\}; \quad S_j \in A \tag{1}$$

where Z is the elevation array, Z(sj) is the elevation at the grid node sj , A is the area of interest and N is the total number of grid nodes. DEMs are today increasingly produced using automated (mobile GPS) field sampling of elevations or airborne scanning devices (radar or LiDAR-based systems) [6]. In the case elevations are sampled at sparsely located points, a DEM can be generated using geostatistical techniques such as ordinary kriging (Mitas & Mitasova, 1999; Wood & Fisher, 1993).

The elevation at some grid node (s_0) of the output DEM can be interpolated using:

$$\hat{Z}(S_O)= C_O^T \times C^{-1} \times Z \tag{2}$$

where c^T_0 is the covariance vector at the prediction location, C is the covariance matrix at sampled locations s_i and z is an array of sampled points ($z(s_i)$; i = 1; . . . ; n). The covariances are determined by fitting a variogram model γ(h), where h is the distance between the point pairs of sampled elevations (Hengl *et al*., 2008).

it is feasible to obtain a DEM information for free, without financial costs, of almost every region of the earth surface. Although these DEMs are dense and generally have good spatial distributions, the accuracy of their altimetry information might not be suitable for many applications (Felgueiras *et al*., 2017). A way of alleviating this problem is to combine the available DEM data along with other information, coming from reliable sources and having better quality, in the data modelling processes.

The process of generating DEM is still under research in the field of remote sensing as different researchers (Isioye, 2012; Abidoye, 2019) tried to realize the possibilities of generating elevation data using Global Digital Surface Models (GDSM). There are several methods for the assessment of the quality of DEMs in terms of Digital Elevation Models and GIS applications. The accuracy of derived DEMs depends on various factors such as topographic variability (slope, curvature, aspect, gradient, skeleton, drainage network, catchment boundaries), sampling density, interpolation methods and spatial resolution (Hengl *et al*., 2008). Besides, an initial source of errors can be attributed to the data collection. When extracting elevation from Global Digital Elevation Model (GDEM), approximate values are obtained. But to derive a detailed value at any point of interest, Extrapolation/Interpolation is applied. There is a problem of determining the optimal interpolation/extrapolation algorithms used when creating the Topographic DEMs because each Interpolation/Extrapolation method gives variations in the raster surface as Liu *et al*. (2008), Erdogan (2009) and Aykut *et al*. (2013) among others has not dealt with the underlining problem. Spatial extrapolation/interpolation methods are one of the important factors which affect the accuracy of generating a Digital elevation model. Therefore, there is a need to test the performance of spatial interpolation/extrapolation techniques so as to be able to determine the technique which gives the optimal Digital elevation model.

The Shuttle Radar Topography Mission (SRTM) was flown aboard the space in February 2000. The National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA) participated in an international project to acquire radar data which were used to create the first near-global set of land elevations. Hussein (2009) further stated that the technology was modified for the SRTM mission to collect interferometry radar, which compared two radar images or signals taken at slightly different angles. This mission used single-pass interferometry, which acquired two signals at the same time by using two different radar antennas. It therefore implied that, the antenna located on board of the space shuttle collected one data set and the other data set was collected by an antenna located at the end of a 60-meter mast that extended from the shuttle. Differences between the two signals allowed for the calculation of surface elevation. SRTM thus successfully collected radar data over 80% of the Earth's land surface between 60^0 north and 56^0 south latitude with data points posted every 1 arc-second (approximately 30 metres) (Joanna *et al*., 2016).

This research assessed the disparity between the interpolation methods provided by ArcGIS in its Spatial Analyst and Geostatistical Analyst Extensions in order to determine how the varying parameter settings affect the resulting surfaces. The case study employed eleven (11) interpolation algorithms, including Inverse Distance Weighting, Natural Neighbour, Spline Regular, Spline Tension, Universal Kriging, Empirical Bayesian Kriging, Topo to Raster, global (trend surface), local polynomial, kernel interpolation with barriers and radial basis functions in DEM surface creation. Understanding the extensions differences and modifying the parameters in each interpolation algorithm result in statistically reliable elevation surfaces.

The aim of this research is to assess the relative accuracies of Spatial Prediction techniques used for ellipsoidal elevation determination in Akure South Local Government, Ondo State, to generate a better continuous surface. While the objectives of this study are to determine the optimum method of height data interpolation.

Study Area

Akure South Local Government is located in Ondo state, Nigeria and it covers an area of 331km^2 and a population of 353,211 at the 2006 National Population census. Akure has a tropical climate and has significant rainfall most months, with a short dry season. This climate is considered to be Tropical Monsoon according to the Köppen-Geiger climate classification. The average annual temperature is 26.7°C in Akure while the average rainfall is 1455mm. The study area of the research (see Figure 1) which is of varying undulation covers Akure South Local Government and it lies on the longitude and latitude 5°05’02.3’’E to 5°11’51.4’’E and 7°16’41.5’’N to 7°21’15.1’’N respectively.

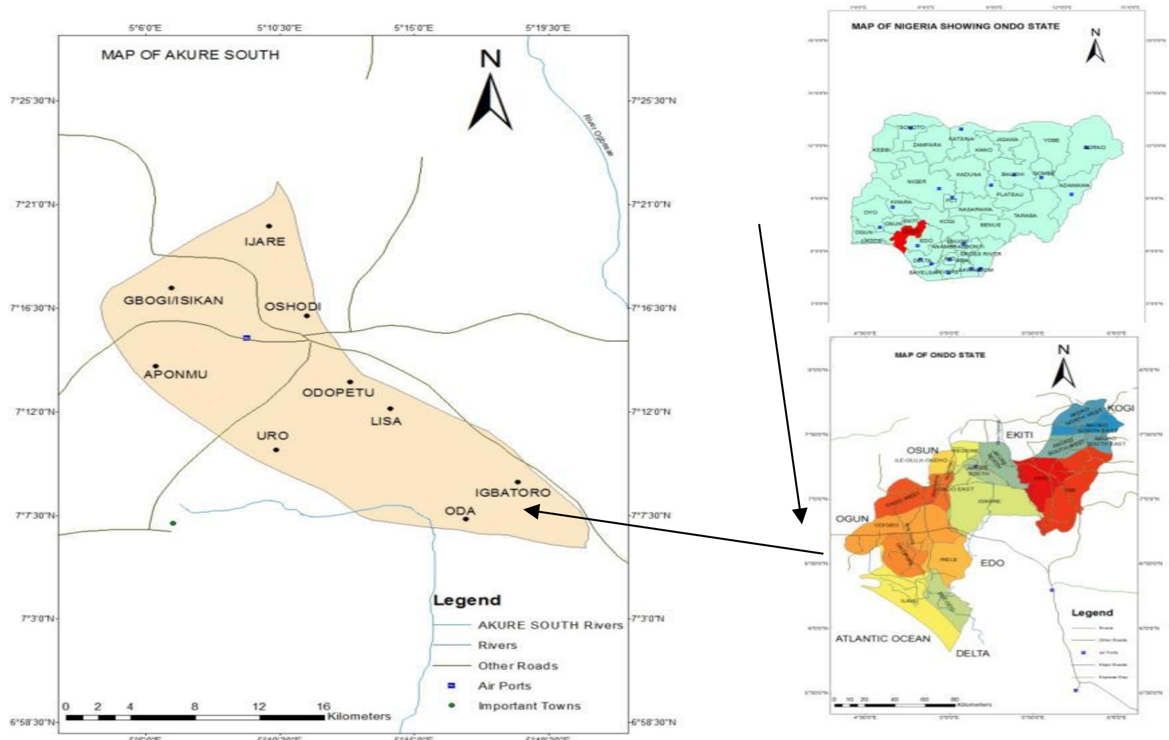

Figure 1: Map showing Akure South Local Government Area

Materials and Methods

Data acquisition

The data set acquired in the study were secondary data of both point positioning (DGPS) and Digital Elevation Model (DEM) of the study area. SRTM Digital Elevation Model resolution of the study area was obtained from the USGS website for the purpose of ellipsoidal height extraction. The field was visited so as to pre-plan the random ground control points (GCP) and identifying the positions of important features to be used for ground truthing. The established GCP served as the project controls as well as the test stations on which the accuracy of height values from adopted approaches was based.

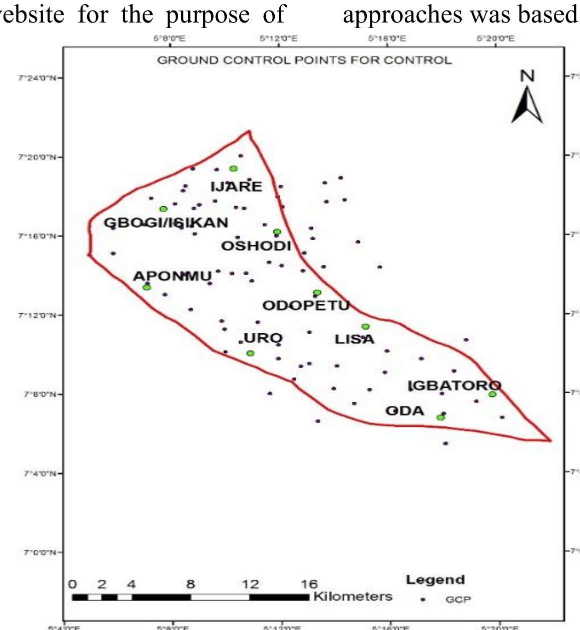

Figure 2: Selected GCP within the study area

A total of One ninety-five (195) Disperse Ground Control Points (GCP) was established within the study area using DGPS with positional values determined in 3-dimension (X, Y, Z) and also GCP's obtained from the Ondo State ministry of Lands. Eighty-two (82) GCP was established in the study area using Trimble R8 and Sokkia Differential GPS with reference to Minna Datum Zone 31 while One Hundred and Thirteen GCP (113) coordinates was obtained from the Ministry of Lands. Due to the vastness of the study area, Akure South Local Government was divided into 15 units of which at least 3 GCP was established within each unit. The units include: Aponmu, Gbogi, Isikan, Ijomu, Obanla, Oda, Odopetu, Aro, Uro, Oke-Aro, Oshodi, Owode, Isolo, Imuagan and Lisa (Figure 2). The coordinate system/datum transformation process from WGS84 (GPS) to Minna Datum Zone 31 entails using ArcGIS 10.3 project tool in the Arc Toolbox. The SRTM data that covered Akure-South LGA, Ondo State was downloaded from the website that belongs to United State Geological Survey (USGS) which is www.earthexplorer.usgs.gov.The height values of the study area was extracted from SRTM digital elevation model. The established GCP served as the project controls as well as the test stations on which the accuracy of height values from adopted approaches were based.

Methodological approach for the assessment interpolation methods using the SRTM data and DGPS measurements is shown in Figure 3. The details of which are summarised below.

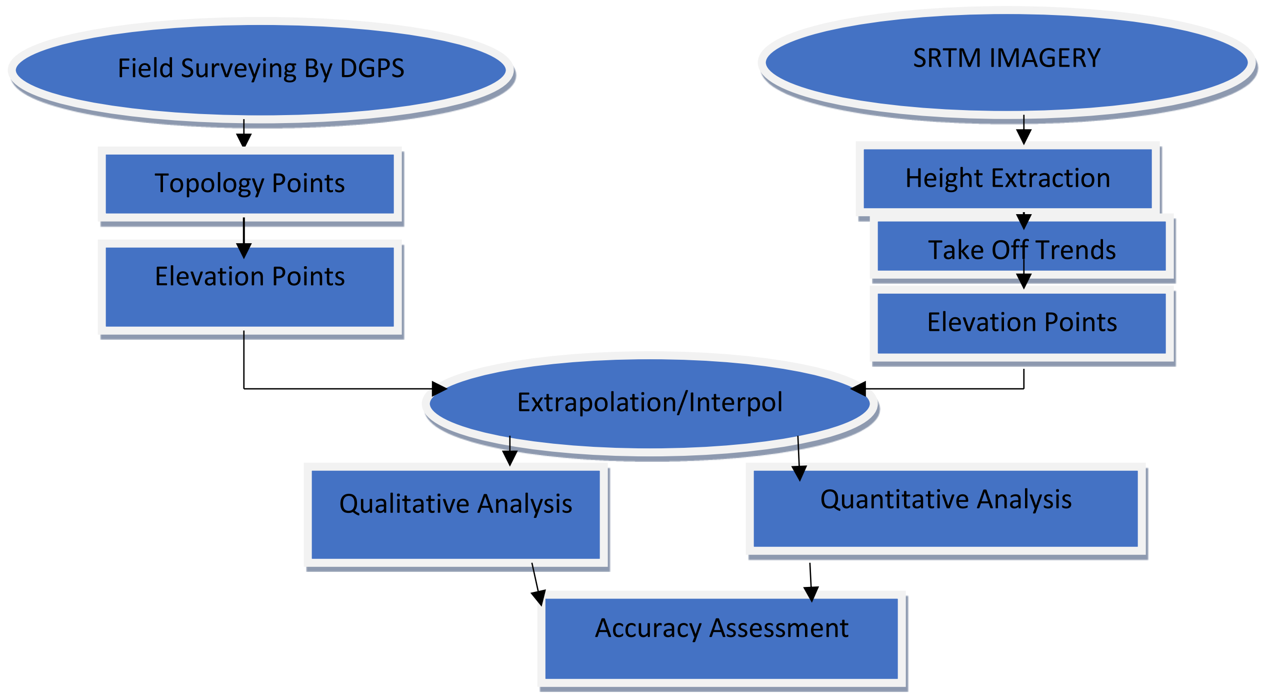

Figure 3: Flowchart for methodology of the Accuracy Assessment of the selected interpolation methods

The methodology of this Study has the following steps:

a) Performing spatial data exploratory analysis of the basic information.
b) Take-off trends of the basic information creating residual stationary information.
c) Assess the spatial variation of the residuals through direct and cross semi-variograms, empirical and conceptual.
d) Assess the SRTM collocated elevation values related to the spatial position of the sample set of elevations. This will be performed using bilinear interpolation over the SRTM grid cells.
e) Apply the Inverse Distance Weighting procedures using the SRTM and the sample set of elevations.
f) Using an independent sample set of elevation points, perform validations and analyses of the resulting maps using statistics and root mean square deviation metrics.
g) Repeat steps for other interpolation methods.

Results and Discussion

The results of this study provide the difference between the Spatial Interpolation methods (Spatial Analyst and the Geostatistical Analyst Extensions). These can also help GIS Professionals to make an informed choice when tasked with creating an interpolated surface.

The elevation data of the over one thousand points was used in creating the extrapolation /interpolation models and these models namely Inverse Distance Weighting, Natural Neighbour, Spline Regular, Spline Tension, Universal Kriging, Empirical Bayesian Kriging, Topo to Raster, global (trend surface), local polynomial, kernel interpolation with barriers and radial basis functions models were compared with one another based on their uncertainty values and processing speeds. Table 1 depicts the descriptive statistics of the elevation data. It is clear that the calculated statistic indicator like mean error, standard deviation, sample variance, maximum and minimum values from the approaches adopted are relatively closer to one another; values from SRTM data source are relatively same using geospatial method of interpolation (Kriging) with the exception of the spatial interpolation methods (Natural, Spline and Topo to Raster) which doesn't have errors associated with the predicted points.

It was observed that Global Polynomial Interpolation (GPI) and Kernel Interpolation with Barriers (KIB) has relatively the lowest mean errors among the adopted methods while using SRTM data. ME (mean error) for an unbiased model should be approximately zero. While RMSE (root mean squared error) which refers to the Model precision should be as small as possible.

Table 1: Descriptive Statistics of adopted methods of determining elevation value (SRTM)

Method used	Minimum (m)	Maximum (m)	Mean Error (m)	Root Mean Square (RMSE) (m)	Mean Standard ized (m)	RMSS (m)	Processing Speed (Seconds)	Average Standard Error(m)
IDW	262	495	0.376	14.304	-	-	1.320	32.048
NATURAL	263.164	493.726	-	-	-	-	2.010	29.488
SPLINE R	-1073.930	1318.710	-	-	-	-	3.450	184.938
SPLINE T	214.081	516.475	-	-	-	-	2.950	34.492
TOPO_RASTER	259.853	495.662	-	-	-	-	15.190	31.237
KRIGING	264.022	489.716	0.061	13.212	0.003	0.956	3.860	14.251
EBK	266.074	484.635	-0.064	13.186	-0.002	0.942	11.780	14.193
GPI	304.371	393.796	0.004	27.266	-	-	0.580	17.307
LPI	268.995	451.874	-0.268	14.819	-	-	1.240	27.833
RBF	262	495	0.124	13.584	-	-	1.370	341.221
KERNEL	265.676	470.808	-0.004	13.375	-0.00001	1.001	3.510	13.305

Table 2 shows a summary of the regression analysis for the SRTM imagery using the adopted prediction techniques. Although, the regression model predicted that all method investigated are good fit for GPS data. Furthermore, the positional accuracy of each adopted method was also determined using the United National Standard for Spatial Data Accuracy of 2016. Horizontal and vertical accuracy is determined based on the distributed data points reported at the 95% confidence level. As horizontal accuracy is of little importance to this study, only vertical accuracy of adopted methods was investigated. The vertical accuracy (V.A) is given as

$$RMSEz = SQRT\left[\Sigma(Zobsi-Zstandi)^2/n\right] \quad (3)$$

Where Z_{obsi} are the coordinates of the ith check point in the dataset, and Z_{standi} are the coordinates of the ith check point in the independent source of higher accuracy. Where n is the number of check points tested and i is the integer ranging from 1 to n. Vertical accuracy at the 95-percent confidence level is as expressed as

$$Accuracy_Z = 1.9600 * RMSE_Z \quad (4)$$

Table 2: Model Summary for Adopted Techniques

Methods	*R*	*R^2*	*Adjusted R^2*	*Significance value in ANOVA*	*Standard deviation of Error of estimate*	*Unstandardized coefficient (B)*		*Remarks on F-ratio*
						Constant	coefficient	
IDW	0.923	0.851	0.847	P = 0.0000 <0.05	3.925	76.245	0.672	Good fit for GPS data
TOPO TO RASTER	0.883	0.779	0.773	*P* = 0.0000 <0.05	4.755	69.931	0.802	Good fit for GPS data
Kriging	0.894	0.800	0.794	*P* = 0.0000 <0.05	4.149	90.997	0.744	Good fit for GPS data
KIB	0.866	0.751	0.744	*P* = 0.0000 <0.05	4.768	92.495	0.743	Good fit for GPS

								data
GPI	0.756	0.572	0.561	*P* = 0.0000 <0.05	5.592	145.528	0.580	Good fit for GPS data
LPI	0.905	0.819	0.814	*P* = 0.0000 <0.05	4.259	66.600	0.814	Good fit for GPS data
SPLINE_T	0.868	0.754	0.748	*P* = 0.0000 <0.05	5.227	63.186	0.821	Good fit for GPS data
SPLINE_R	0.907	0.822	0.817	*P* = 0.000 <0.05	4.325	60.061	0.834	Good fit for GPS data
EBK	0.920	0.847	0.843	*P* = 0.0000 <0.05	3.846	66.558	0.813	Good fit for GPS data
NATURAL	0.917	0.841	0.837	*P* = 0.0000 <0.05	3.897	69.642	0.804	Good fit for GPS data
RBF	0.866	0.750	0.743	*P* = 0.0000 <0.05	4.877	85.966	0.758	Good fit for GPS data

Figure 4 shows the line graph of the residuals (difference between each elevation values and the GPS elevation values) prediction techniques IDW, Topo to Raster, Kriging, KIB, GPI, LPI, Spline_T, Spline_R, EBK, Natural and RBF. They are colour coded to highlight their surface distribution. Further to this, the distribution of the residual of elevation data in terms of collinearity (see figure 2) shows that the elevation values extracted using the adopted techniques are of close variance with Topo to Raster Interpolation method and Spline Regular having the highest magnitude of residuals.

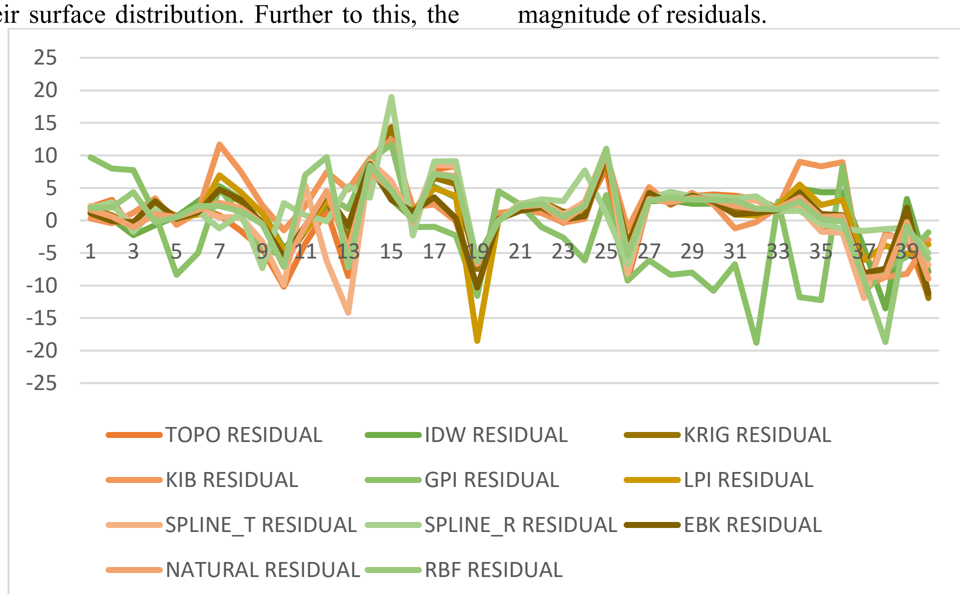

Figure 4: Surface distribution of residuals (SRTM)

Table 3 shows the accuracy assessment of the shown that the absolute vertical accuracy of the selected interpolation methods using the SRTM data was within the allowable limit values of ±16m as for GDSM data specification using GPS elevations as a reference. From Table 3, vertical accuracy degree with respect to the United Nation spatial standard revealed that elevation data extracted from SRTM using the Inverse distance weighting, Natural Neighbour, Spline R, Spline T, Topo to Raster, Universal Kriging, Empirical Bayesian kriging, Global polynomial interpolation (GPI), local polynomial interpolation(LPI), Radial basis function and Kernel interpolation are ±8.446, ±8.648, ±9.532, ±10.707, ±10.020, ±9.795, ±8.452, ±14.565, ±9.266, ±10.802 and ±11.303 respectively when compared with elevation values from GPS. Table 3 shows the accuracy estimation of residuals for each prediction technique using the SRTM with Inverse Distance weighting giving the best accuracy degree.

Table 3: Accuracy Estimation of Residuals

Method	Minimum residual (m)	Maximum Residual (m)	Mean Residual (m)	RMSE(m)	Accuracy degree(m)	Accuracy allowable limit (m)
IDW	2.977	81.592	3.885	4.309	8.446	± 16.00
NATURAL	-8.958	11.074	0.717	4.412	8.648	± 16.00
SPLINE R	-7.326	18.98	1.6214	4.863	9.532	± 16.00
SPLINE T	-14.170	10.984	0.360	5.462	10.707	± 16.00
TOPO_RASTER	-11.575	8.350	0.155	5.112	10.020	± 16.00
KRIGG	-11.915	14.37	0.947	4.997	9.795	± 16.00
EBK	-11.162	9.972	0.637	4.312	8.452	± 16.00
GPI	-18.80	11.690	-2.1773	7.431	14.565	± 16.00
LPI	-18.510	9.607	1.010	4.728	9.266	± 16.00
RBF	-18.680	11.029	0.949	5.511	10.802	± 16.00
KIB	-10.986	12.418	1.963	5.767	11.303	± 16.00

The standard deviation, average, minimum and maximum height values were extracted and mathematically proved which prediction model has received the lowest error and uncertainties. From table 4, Standard deviation (which is a measure of precision) for Digital Elevation models created from SRTM using the Topo to Raster, Inverse distance weighting (IDW), Universal Kriging, Kernel interpolation with Barrier (KIB), Global polynomial interpolation (GPI), local polynomial interpolation(LPI), Spline Tension, Spline Regular, Empirical Bayesian kriging, Natural Neighbour and Radial basis function are 9.987, 10.048, 9.149, 9.426, 8.436, 9.884, 10.402, 10.114, 9.708, 9.642 and 9.628respectively when compared with elevation values from GPS. Table 4 shows mathematically which prediction model has the lowest error and uncertainties through the standard deviation, average, minimum and maximum height values. GPI has the highest overall precision with 8.436m. Inverse Distance Weight method proves to be the most optimal interpolation method for elevation determination using SRTM with a root mean square error (RMSE) of ±4.309 degrees accuracy thereby giving the best accuracy degree using Ground control points elevations as a reference.

Table 4: Precision estimation of extracted elevation data

Method	Minimum	Maximum	Mean	Std. Deviation
TOPO_RASTER	331.808	368.392	352.006	9.987
IDW	331.815	369.798	352.872	10.048
KRIGING	331.688	367.462	352.799	9.149
KIB	332.816	368.525	353.816	9.426
GPI	332.254	369.686	349.675	8.436
LPI	331.922	367.808	352.863	9.884
SPLINE_T	330.000	368.142	352.212	10.402
SPLINE_R	331.554	370.741	353.474	10.114
EBK	331.891	368.462	352.489	9.708
NATURAL	331.707	366.871	352.570	9.642
RBF	331.633	367.318	352.801	9.628

Conclusion

This study revealed the possibility of generating elevation data from any global digital surface models that exhibits continuous characteristics of physical surfaces at large, medium and small scale. All analyses were empirically based and gives the allowance for a deep insight into quantifying the magnitude, the direction and general behaviour of errors incurred in the process. The adopted techniques have been proven to be reliable for quick integration determination of elevation data in the study area with the Inverse Distance Weight method proving to be the most optimal interpolation method for elevation determination using SRTM with a root mean square error (RMSE) of ±4.309 degrees accuracy.

References

Abidoye, A.I (2019). Analysis of elevation models for Nigerian 2D cadastre height. *African Journal of Land Policy and Geospatial Sciences, 2*(3). https://doi.org/10.22004/ag.eccon.334216

Aykut, N. O., Akpinar B., & Aydin O. (2013). Hydrographic data modelling methods for developing precise seafloor topography. *Computer Geosci 17*, 661-669 https://doi.org/10.1007/s10596-013-9347-1

Erdogan, S. (2009). A comparison of interpolation methods for producing digital elevation models at the field scale: *Earth Surface Processes and Landforms 34*, 366-376. https://doi.org/10.1002/esp.1731

Felgueiras, C. A., Camargo, E. C. G., & Ortiz, J. O. (2017). Exploring Geostatistical Methods to Improve the Altimetry Accuracies of Digital Elevation Models. http://www.geocomputation.org/2017/papers/45.pdf

Hengl, T., Bajat, B., Blagojevic, D., & Reuter, H. I. (2008). Geostatistical modelling of topography using auxiliary maps. *Computers & Geosciences, 34*(12), 1886 - 1899. https://doi.org/10.1016/j.cageo.2008.01.005

Hussein, A. (2009). Evaluation of the EGM2008 Geopotential Model in Egypt. *Newton's Bulletin, 4*(6), 185-199. https://www.researchgate.net/publication/258255636_Evaluation_of_the_EGM2008_geopotential_model_for_Egypt

Isioye, O. A. (2012). An assessment of digital elevation models (DEMs) from different spatial data sources. https://www.fig.net/resources/proceedings/fig2011/papers/ts05i/ts05i_isioye_jobin_4911.pdf

Joanna, K., Adam, L., & Monika, B., (2016). Geoid Determination for The Area of Poland by The Least Squares Modification of Stokes' Formula. *Acta Geodynamica et Geomaterialla*, 13(1),181. https://doi.org/10.13168/AGG.2015.0041

Liu, X., Z. Zhang, & J. Peterson. (2008). Evaluation of the performance of DEM interpolation algorithms for LiDAR data. *Proceedings of the Surveying & Spatial Sciences Institute Biennial International Conference.* Surveying & Spatial Sciences Institute. 771-780. https://research.usq.edu.au/item/9z65v/evaluation-of-the-performance-ofdem-interpolation-alagorithms-for-lidar-data

Mitas, L., & Mitasova, H., (1999). Spatial Interpolation. In: P. Longley, M. F. Goodchild, D. J. Maguire, D. W. Rhind (Eds.), *Geographical Information Systems: Principles Techniques Management and Applications* (481-492), GeoInformation International, Wiley.

Wood, J., & Fisher, P.F., (1993). Assessing interpolation accuracy in elevation models. *IEEE Computer Graphics and Applications*, 13(2), 48–56. https://doi.org/10.1109/38.204967