SPOT HEIGHT DIGITAL ELEVATION MODEL OF YEWA DIVISION, OGUN STATE NIGERIA

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Abstract: Digital elevation models (DEM) are useful for estimating phenomenon on the earth surface and understanding ecological processes. Satellite imageries have been extensively used for quantitative modeling of terrain forms of the earth surface but the global nature of the model produced numerous data holes due to cloud cover, lacking the required accuracy in capturing detailed regional and small area analyses. This study explored some spatial interpolation methods on elevation data collected for a small area of Yewa Division of Ogun State Nigeria using a handheld Global Positioning System (GPS). The GPS Elevation data were compared with Google Earth Pro Lands at 8 and Shuttle Radar Topographic Mission (SRTM) satellite sources to establish accuracy levels. There were no significant differences ($F_{2,276}$ = 0.00056; p > 0.999) in the spot height data from the Ground Control Points (GCP), Google Earth Pro Landsat 8 (GOOGLE) and the Shuttle Radar Topographic Mission (SRTM). Among all the interpolation techniques that included Inverse distance weighting (IDW), Ordinary Kriging (ORK), Simple Kriging (SIK), Empirical Bayesian Kriging (EBK), Global Polynomial Interpolation (GPI), Local Polynomial Interpolation (LPI), Kernel Interpolation with Barrier (KIB) and Radial Basis Function (RBF), ordinary kriging appeared to be the most suitable spatial interpolation method (RMSE = 7.7944) that produced the most accurate digital elevation model for Yewa Division of Ogun State. It could be concluded that spot height data of GCPs of Yewa Division of Ogun State taken with a handheld GPS subjected to ordinary kriging interpolation produced reliable and suitable digital elevation model for quantitative analysis of the earth terrain forms and ecological processes of the area.

Keywords: DEM, Spot height, spatial interpolation, Yewa division, GIS

Introduction

Digital elevation models (DEMs) are computerized representations of the earth's terrain surface described by a wire frame model or an image matrix of pixels indicated by specific topographical heights (Evans, 1980; Zhang *et al.*, 2018). DEMs are important for the production of topographical maps, analysis in ecology, forestry, agriculture, climatology, geology, pedology, geomorphology, environmental modeling, hydrological modeling, landslide hazard zonation and water resources management.

Scientific researches in most disciplines require topographic data to derive ortho-image cartographic products (Hohle, 1996; Pala & Arbiol, 2002). Elevation data in digital format are also useful for quantitative modeling of slope, aspects and other terrain forms of earth surface (Burrough & McDonnell, 1998). DEM-based topography has been used to simulate models of landscape and ecosystem processes in forestry (Burrough & McDonnell, 1998) and agricultural applications (Whitney *et al*., 2001).

Satellite imageries are mostly available at global scale but their use for regional or small area mapping requires expertise skills, expensive software and time for image data processing (Maune, 2007). Although global DEMs from satellite imageries are freely available as open-source data, it is important to note that they vary significantly across the globe in accuracy and spatial resolutions as the coordinates are particularly referenced to the datum of specific countries (Verhulp, 2015). Therefore, downscaling global DEMs for regional or small area analysis often results in relatively inconsistent products with varying levels of accuracy(Farr & Kobrick, 2000). Also, cloud cover in many parts of Africa creates 'no data' holes in satellite imagery thus making elevation values unavailable, contributing to reduction in quality and accuracy of models obtained for these areas.

Several developing countries in Africa now require national DEM that are developed from a number of regional analyses to build national spatial data infrastructure that are useful for higher resolution geospatial applications (Verhulp, 2015). As such, Yewa division of Ogun State constitutes part of a regional section within the Nigerian space with spectacular soil and climatic conditions, remarkable physiographic and ecological features, and land use history of many scattered charcoal kilns (Ajadi *et al.*, 2012) that would significantly contribute to the outlook of the national spatial elevation data infrastructure.

Regional data to be built into national geo-database for predictive modeling must be detailed and accurate to enhance model efficiency (Wechsler & Kroll, 2006). It is therefore important to ascertain the accuracy of developed models before they are used for the estimation of other parameters in order to avoid error propagation in result implementation (Heuvelink *et al*., 1989).

Raw spot heights from Ground Control Points (GCP) in field surveys with hand-held GPS have provided new, accurate and affordable data of high positional accuracy (1st and 2nd order) for the development of local digital elevation models required in detailed ecological modeling (Nwilo *et al.*, 2012). One of the most common methods of developing digital elevation models uses spatial interpolation techniques whereby estimates of spot heights at un-sampled locations are derived from values obtained at sampled locations by means of autocorrelation in spatial statistics (Wise, 1998).

Spatial interpolation is premised on the observation that points closer in space are similar than points further apart (Tobler, 1970). Spatial interpolation methods are used to create prediction surfaces for phenomenon such as rainfall, wind speed, noise level, chemical concentration and other spatial entities (Mitas & Mitasova, 1999). Optimal interpolation technique that is suitable for describing any spatial phenomenon is arrived at by comparing the results of several individual interpolation algorithms (Ikechukwu *et al.*, 2017).

The aim of this study was to develop an optimum digital elevation model from spot height data of Yewa division of Ogun State using spatial interpolation algorithms in geostatistics with the view to providing complementary data for creating accurate regional elevation geo-database that are useful for environmental applications and monitoring of ecological processes. Elevation data from SRTM, Google Earth Pro and field-based GPS were compared and the accuracy of the developed DEMs from spatial interpolation techniques was assessed.

Materials and Methods

Study area

The study area is Yewa division located in Ogun State from latitude 6°03'0" N to 7°05'0" N, and longitude 3°04'0" E to 3°06'0" E. (Fig. 1). Yewaland (formerly called Egbado) has five (5) local governments, namely: Yewa north, Yewa south, Ipokia, Imeko-Afon and Ado Odo-Ota (Adesegun *et al*., 2017). It is predominantly inhabited by the Yoruba ethnic group and a minority group from neighboring countries of Benin Republic and Togo. The inhabitants engage in occupations such as farming, hunting, artisanal trades, fishing, driving, teaching and civil services (Oduntan *et al*., 2013).

Yewa division of Ogun State comprises of a number of forest and game reserves in Nigeria purposely created to hold fortresses of the nation's sparsely populated border land with the neighbouring Benin Republic (Asiwaju, 2018). The heavily degraded savanna ecosystem of Yewa division is being rejuvenated by the Government through a Private Public Partnership (PPP) initiative to reclaim unproductive marginal land under the Land Degradation Neutrality Transformative Project "Ile dotun" (Department of Forestry, 2004).

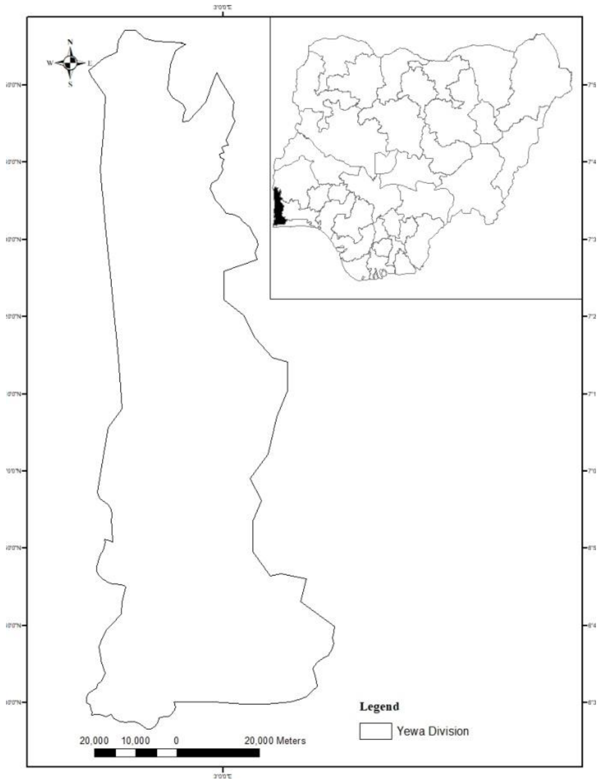


Fig. 1: Map of the Yewa Division, Ogun State; Inset: Federal Republic of Nigeria

The study area has an annual rainfall of between 100 and 200 mm spreads over eight months from April to November with a bi-modal pattern having peaks in May-June and September-October which drains into Yewa River which runs from North to South with its tributaries as Rivers Oyan and Oba. The average relative humidity is generally high, usually above 80%, during the rainy seasons, and ranges from between 60 and 80% in the dry season with average maximum daily temperature varies from 28 to 32^{o}C in wet and dry seasons, respectively (Adedeji & Aiyeloja, 2014).

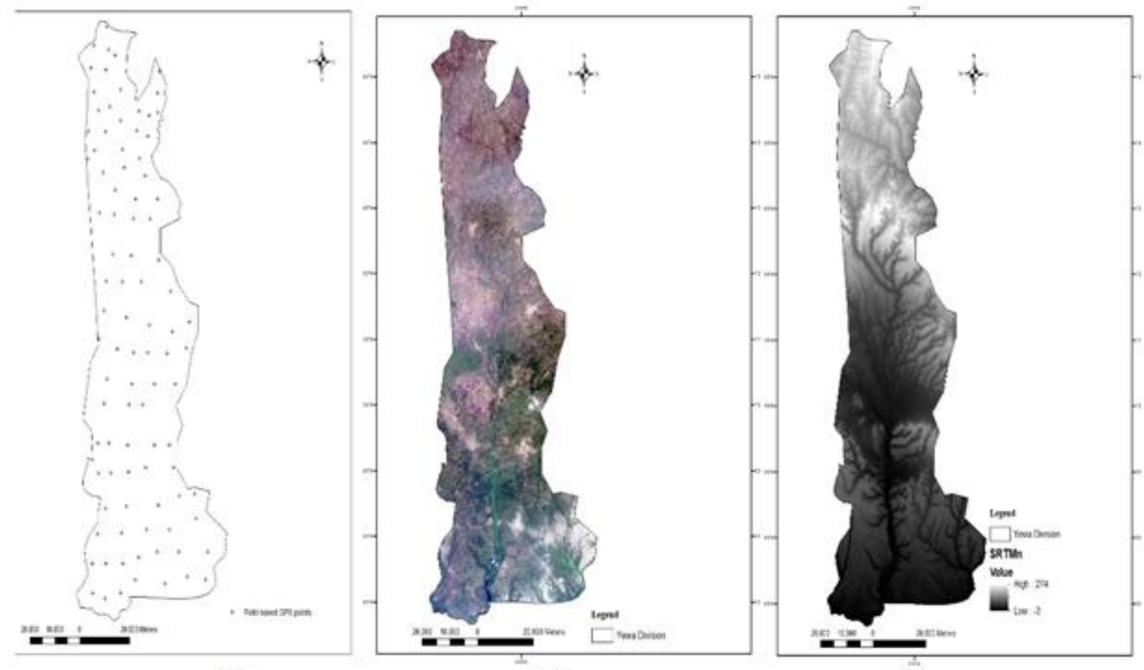
The vegetation structure is dominated by flora species that include *Hymenocardiaacida, Anogeissusleiocarpus, Lophiralanceolata, Zanthoxylumzanthoxyloides, Cassia siamea, Isoberliniadoka, Uapacatogoensis, Brideliaferruginea, Danielliaoliveri* and declining populations of wildlife species such as *Tragelaphus scriptus.*

Sampling design, data collection and processing

The study area was delineated into 1 km x 1 km grids to randomly select 250 square grids. Each of the 250 square-grid was divided into 500 m x 500 m grid out of which 100 grids were selected using a table of random numbers. Within each of the 100 square-grid, random spots were located where spot height data were collected using e-trex 20 Garmin handheld Global Positioning System (GPS). The operational vertical accuracy of the handheld e-trex 20 GPS was ± 5.0 cm (Dawod & Al-Ghamdi, 2017). A total of ninety-three (93) random points were located during the field survey and their geographic coordinates and respective spot heights recorded (Fig. 2a).

Google Earth Pro image data were derived from Lands at 8 satellite imagery. Planimetric geographic coordinates of the random GPS points from field survey were uploaded onto Google Earth Pro imagery as 'kml file' and their corresponding spot heights were read and recorded online (Fig. 2b).

Shuttle Radar Topography Mission (SRTM) data provided as 90 m spatial resolution imagery were downloaded in GeoTiff formats from the National Aeronautic and Space Administration's (NASA's) data repository (Fig. 2c). Elevation values provided in the SRTM DEM GeoTiff raster file were extracted to the field-based GPS points using the extraction mask tool in ArcGIS.



(a) (b) (c)

Fig. 2: (a) GCPs taken with GPS (b) Google Earth Pro Landsat Imagery (c) SRTM Elevation model

Ellipsoidal heights of the GPS device were referenced to the geoid heights (Mean Sea Level – MSL) of the local area as computed in (Rapp, 1997) in order to ensure height consistency from the three data sources and maintain the positional vertical accuracy of first-order spot heights from hand-held GPS device (ellipsoidal heights).

The horizontal datum of the spatial data (i.e. the two satellite imagery and the field-based data) wasreferenced toWorld Geodetic Survey (WGS) 84 Universal Transverse Mercator (UTM) Zone 31 coordinate system for GIS analysis.

Statistical and GIS analyses

Descriptive statistics were first used to obtain a general description of the spot height data, followed by analysis of variance for testing the significant differences in the elevation data from the SRTM, Google Earth Pro and field-based GPS. Priori expectation was that there would be no significant differences in elevation data from the three (3) different sources. The GPS spot heights were partitioned into two sets of data, eighty (80%) training data and twenty (20%) test data. The training data were subjected to spatial interpolation techniques in geo-statistics to create continuous surface models of spot heights for the study area while the test data were used to evaluate the performance of the models.

Inverse distance weighting (IDW), Ordinary Kriging (ORK), Simple Kriging (SIK), Empirical Bayesian Kriging (EBK), Global Polynomial Interpolation (GPI), Local Polynomial Interpolation (LPI), Kernel Interpolation with Barrier (KIB) and Radial Basis Function (RBF) algorithms were explored to assess the optimum interpolation methods suitable for developing spot height digital elevation model of the study area. Residuals and Root Mean Square Error (RMSE) were used to evaluate the performance of the interpolation methods in developing the spot height digital elevation model for the study area (Westphalen *et al.*, 2004; Wise, 1998; Wilson *et al.*, 2005) whereby lower RMSE implies better model.

Results and Discussion

Table 1 shows the statistical evaluation for comparison among the elevation data sources, namely: Google's Earth Pro Lands at elevation data, Shuttle Radar Topographic Mission elevation data and hand-held GPS spot height data.

Table 1: Statistical evaluation for comparison among elevation data sources

	Google	SRTM	GPS
Mean	103.2494624	102.9785	103.2968
Standard Error	7.258678548	7.256874	7.252296
Median	79.5	78	79.5
Mode	14	21	22
Standard Deviation	70.00016091	69.98276	69.93861
Sample Variance	4900.022527	4897.586	4891.409
Kurtosis	-1.50975725	-1.50991	-1.51236
Skewness	0.270071696	0.268319	0.265804
Range	224.7	224	223.8
Minimum	9.2	9	9.5
Maximum	233.9	233	233.3
Sum	9602.2	9577	9606.6
Count	93	93	93
Confidence Level(95%)	14.41636214	14.41278	14.40369

Table 2 shows the Analysis of Variance (ANOVA) table for the test of means among the different elevation data sources. Table 3 shows the statistical measures of the interpolation methods which the elevation data were modeled in order to determine the most suitable digital elevation modeling method for Yewa Division of Ogun State.

Table 2: Analysis of Variance for the spot height data sources

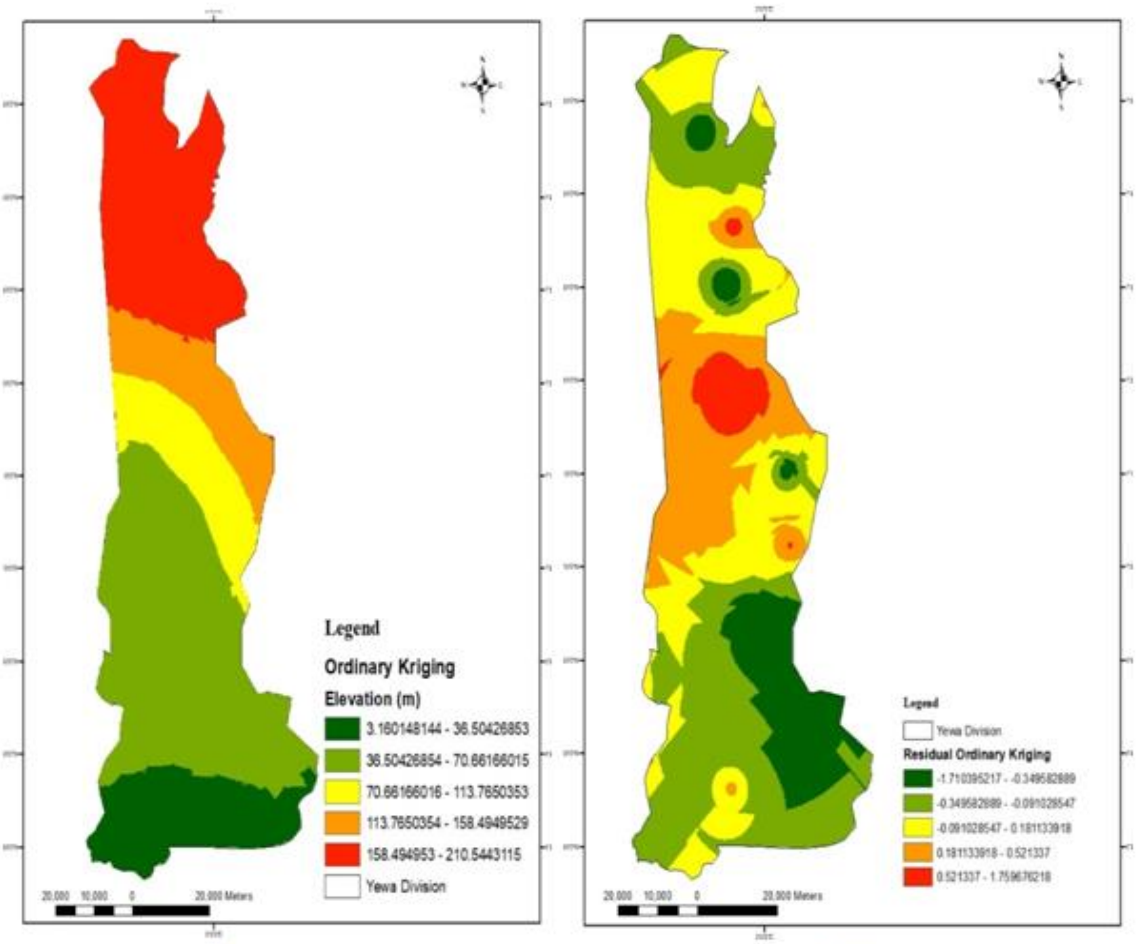
Source Variation	Sum square	df	Mean square	F-value	P-value	F-critical
Between sources	5.485878	2	2.742939	0.00056	0.99944	3.028485
Within sources	1351390	276	4896.339			
Total	1351395	278				

df = degree freedom

Table 3: Statistical measures of interpolation methods

Interpolation Method	Mini.	Max.	Mean	RMSE
Ordinary kriging	3.18	210.54	93.79	7.7944
Inverse Distance Weighting	10.03	223.99	106.44	7.9112
Global Polynomial Interpolation	-6.89	225.59	109.35	8.0108
Empirical Bayesian Kriging	7.10	221.73	110.89	8.0261
Radial Basis Function	5.70	224.34	108.11	8.0372
Kernel Interpolation with Barrier	3.32	224.36	100.36	8.0608
Simple kriging	12.06	206.22	92.22	8.1212
Local Polynomial Interpolation	-1.25	238.25	113.18	8.1281

Figures 3a & 3b show the continuous surface for the elevation values and the residuals, respectively created by ordinary kriging interpolation technique.



(a) (b)

Fig. 3(a): DEM of Yewa Division by Ordinary Kriging; 3(b) –Residuals of Ordinary Kriging DEM of Yewa Division

Priori expectation was that Ground Control Point (GCP) elevation data measured on a handheld-held GPS would be of better accuracy or at least similar to elevation data from satellite sources (i.e. GOOGLE Earth Pro and SRTM). Statistically, there appeared to be no significant differences (Table 2: $F_{2,276} = 0.00056$; $p > 0.999$) in the elevation data obtained from three different sources examined for this study. Table 1 shows the descriptive statistics of spot height data indicating mean elevations of 103.2, 102.9 and 103.2 m for Google Earth Pro Lands at imagery (GOOGLE), Shuttle Radar Topographic Mission (SRTM) and Ground Control Point (GPS) respectively. Ground Control Point elevation data measured on the GPS device have often been used as reference values due to their relatively high level of positional accuracy (Gorokhovich & Voustianiouk, 2006). It could be inferred from the result that spot heights from SRTM were underestimated when compared with the values obtained for the GOOGLE and GPS. This result also showed that localized field-based GPS data produced digital elevation models of similar accuracy to global satellite sources as found in (Isioye & Jobin, 2011) where it was found that the spot height data of GCPs from total station were similar in accuracy to elevation data derived from topographic and satellite sources.

Several spatial interpolation techniques of spot heights of GCPs taken with the GPS were explored and the results are as presented in Table 3. The result showed that Ordinary Kriging which had the lowest RMSE appeared to be the most suitable interpolation method for creating digital elevation outlook for the study area. This result conforms with the position of (Isaaks & Srivastava, 1989) who reported that minimal error variances were observed in ordinary kriging when compared with other kriging interpolation methods. Therefore, Ordinary Kriging interpolation method produced the optimum digital elevation model for the study area. Residuals of the optimum interpolation method as presented in Figure 3b showed that substantial parts of the study area had lower residuals of between -1.71 and 0.18, i.e. minimal error variances, as against the middle portion of the study area that had relatively high residuals of between 0.18 and 1.78.

Conclusion

Due to the uniqueness of Yewa division of Ogun State comprising of marginal lands on which a number of forest and games reserves have been established to serve as fortresses for holding the sparsely populated border land with the neighbouring Republic of Benin, precise local digital elevation model of Yewa division of Ogun State is required for detailed monitoring of ecological and environmental processes within the area. This study concludes that elevation data from satellite sources such as Landsat Google Earth Pro and Shuttle Radar Topographic Mission are as suitable as the Ground Control Points elevation data from a handheld GPS device subjected to ordinary kriging interpolation method for creating localized DEM of Yewa Division of Ogun State. Therefore, the application of ordinary kriging interpolation technique on elevation data of Yewa Division of Ogun State taken with a hand-held GPS would provide as accurately reliable digital elevation model as those obtained from satellite sources such as Landsat Google Earth Pro and Shuttle Radar Topographic Mission.

Conflict of Interest

The authors declare that there is no conflict of interest reported in this work.

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