Journal of Geodesy and Geomatics Engineering 2 (2016) 52-61
doi: 10.17265/2332-8223/2016.02.006

Analysis of Accuracy of Differential Global Positioning System (DGPS) and Google Earth Digital Terrain Model (DTM) Data Using Geographic Information System Techniques

Richard J. U.[1], and Chima Ogba[2]

1. *Department of Special Survey, Office of the Surveyor General, Moscow Road, Port Harcourt, Nigeria*
2. *MD. Geoid and Environmental Services Limited, Rumuomasi, Port Harcourt*

Abstract: The argument over the accuracy of DEM data from Google Earth as compared to DEM generated from field survey have created a lot of uncertainty among research communities and even in the field of geo sciences domain for various applications. To some SRTM DEM data deviation from other DEM data may not support most application areas and others suggest that the deviation of Google Earth DEM is reasonable to support most application areas including researches. This research paper give an illumination of the level of relationship between field survey DEM and Google Earth DEM carried out on a section of ADAMA farm project site located in Etche Local Government Area, Rivers State, Nigeria. The study utilized field survey elevation data obtained using Promark 3 DGPS at 50m x 50m grid interval and Google Earth elevation data obtained using KML. The KML file was first created in ArcGIS 10.1 before exporting to Google Earth and the elevation of each point was extracted using GPS visualizer. Spatial database was created from the two elevation datasets and the following DEM surfaces; TIN, and contour map were produced. The study concluded that TIN model produced from field survey and Google Earth elevation represent uniform topographic surface but the major difference is the inability of Google Earth elevation to show steep slope, a situation that was accounted for by field survey DEM. Also the linear relationship between field survey elevation and Google Earth elevation data resulted in correlation coefficient (r) 0.665 indicating perfect positive relationship as tested using Pearson's correlation algorithm. DEM data from Google Earth elevation with improvement in technology may come to a stage of no argument or if exist will be negligible for topographic modelling.

Key words: Field survey, Google Earth, DEM, correlation analysis.

1. Introduction

Spatial data acquired from field observations are very important in most urban and rural development planning and modelling. Spatial data can be acquired using different method and store in different format for specific usage. Spatial data set is divided into raster and vector data model [1] depending on how computer can display spatial data. It can also be classified as primary and secondary data type according to mode of acquisition. Elevation data is one of this spatial data representing point feature on the earth surface. Elevation data can be vector file format or raster file format depending on the method of acquisition and storage. Due to the increase in demand for elevation data and wide area of application there is need to diversified field method of acquisition with ease and more efficiently begin to emerge. Field surveys method of acquiring elevation data are level instrument, total station, and differential global positioning system [1]. Of these methods levelling, and total station approach of acquiring elevation data is more precise with very high accuracy for most engineering projects since it is directly related to known control and covering small project area [1]. Other methods of acquiring elevation data include; Aerial Photograph [2], Light Detection

Corresponding author: Chima Ogba, Dr., E-mail: geoid.environmental@gmail.com.

and Ranging satellite image (LiDAR) [3], SRTM [4] and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) [5].

LiDAR satellite as an elevation data sources for GIS modelling is fitted with active laser pulse which improved its efficiency in working day and night [3, 6]. The accuracy ranges between 30 cm to 20 cm for recent aerial LiDAR data [7], and also generate digital elevation model for large area coverage. The horizontal resolution of LiDAR of point spacing is between 1m to 2 m but higher LiDAR may have eight points per meter with a resolution of 30 cm for detail representation of the earth. ASTER data as source of DTM data has spatial resolution of 15 m to 90 m with fourteen (14) spectral bands covering the visible and near infrared region of the spectrum [8]. As earth orbiting satellite with flying altitude 438 miles, and 60 km by 60 km swath width [9], ASTER data can be applied in the following Geo sciences application areas such as geology and soil, land surface climatology, vegetation volcano monitoring, hazard monitoring carbon cycle and marine ecosystem, hydrology, and land use change to mention but a few areas [5].

The demand for elevation data in digital format increases day by day among researchers and the engineering professionals especially in the field of geosciences for various applications. The inclusion of elevation data in Google Earth satellite image has also helped to curb this excess demand among users. Google Earth elevation data uses Shuttle Radar Topographic Mission (STRM) as its elevation base data [10, 11]. The study conducted by Hoffmann E. (2010) showed that Google Earth elevation data produced better accuracy than SRTM data [10] and also Heywood I., Cornelius S., and Carver S. (2006) affirmed that elevation from field survey are the main source of data for the generation of digital elevation model (DEM) use in GIS applications [1]. DEM is a representation of elevation data in digital format for integration into GIS for spatial analysis and modelling. Elevation data remain the main source of Digital Elevation Model used in most GIS and remote sensing analysis [12]. The application of DEM is gaining momentum in modelling topography of the earth by the geologists, hydrologists, ecologists, geophysics, soil scientists, climatologists, and the specialists working in mineral and petroleum sectors [13]. These specialists in using DEM from various sources are concerned about the accuracy of the data for a particular application. With this, some researchers have made several efforts to ascertain this accuracy difference among DEM sources using various software and methods.

Hoffmann E. (2010) studied the hydrology of Gerhard Minnebron wetland South Africa by generating elevation from Google Earth using GIS ArcDesktop and compared the reliability with the topographic map at 1:50000 and Aerial Photography of the study area [10]. It was concluded that the deviation among the three dataset was the same. Sadeg H. A. (2010) compared the accuracy of Google Earth image DEM and topographic map at 1:50,000 in North Iraq using ArcGIS to import Google Earth KML file [14]. The software use for the analysis is ArcGIS and the study observed large shift of 330m in flat areas and small shift of 15 m in hilly and mountainous areas. Isioye O. A. and Paul J. N. (2011) assessed the accuracy of SRTM, digitized topographic map, and Google Earth Pro. with the field measured data from total station instrument in the study area using ArcGIS 9.2 [15]. The accuracy was analyzed statistically, and it was concluded that SRTM DEM does not yield satisfactory result in generating DEM. Ahmed D. A. (2010) compared accuracy of SRTM and DGPS DEM at various locations in Irag using statistical method with RMSE 5.15 m and standard deviation 3.9 m, which is higher than standard vertical accuracy of SRTM [16]. Christopher S. and Robert S. (2014) assessed the accuracy and scale dependence of the GDEM2 and SRTM DEM in developed coastal environment of New York City [17]. Yanjun S., Qinghua G., Qin M., and Wenkai L. (2015) in their studies calibrated STRM DEM over large mountainous areas using LiDAR derived DEM in Plumas and Lassen forest Califonia [18]. Endan S., Kensuke K., Yuji S., Eko K., and Beni R. (2012) also evaluate the accuracy of ASTER GDEM2, and GDEM1, SRTM, Topographic DEM, and DGPS data in Karian Dam Indonesia, and the results indicated an improvement in vertical accuracy of GDEM2 [19]. The review above illustrated the various research approach adopted to compare DEM data from different data sources. The researches reviewed above have not been carried out in any part of Etche L. G. A., and none of the researchers compared DGPS DEM and Google Earth satellite derived DEM accuracy in their study area. Hence, the specific objective of this study was to compare the accuracy of DGPS DEM and Google Earth derived DEM with a view of creating additional awareness and guide DEM users on the accuracy level of the data for different applications.

2. Methodology

2.1 Study Area

The study was carried out in Etche Local Government Area, Rivers State, Nigeria on site acquired for ADAMA farm project on 5,000 Hectares of land covering many towns and villages and includes; Obibi, Akwa, Akwa Umudimuche in the north-east, Odagwa, Okoroagu, Umuanyagu, Egwi in the south-west, and Ulakwo in the north-west. The people of Etche are predominately farmers. The site was acquired by Rivers State Government for Rivers ADAMA farm project in partnership with Israelis lr-Group of Company for the purpose of carrying out mechanize farming aimed at creating job opportunities on one hand and ensuring food security on the other hand to Rivers State. At Present, the project has commenced with the cultivation of plantain and cocoa on two separate locations. For the purpose of this study, the study was limited to 43.4 Hectares of the entire ADAMA project site for easy data analysis. The project site lies between 289375 mE-290798 mE and 550293 mN-551235 mN in a rectangular coordinate system. The elevation of the area varies from 15.04 m in the south to 28.3 m in the north. The project site is cover with light vegetation and patches of farm on the fertile soil of Etche yet to be cleared. The project is approximately 5 km from Otamiri River which may be the only source of water for irrigation and other farming activities. Otamiri River is fresh water that has its tributaries from Imo River — a major River in Eastern Region, Nigeria.

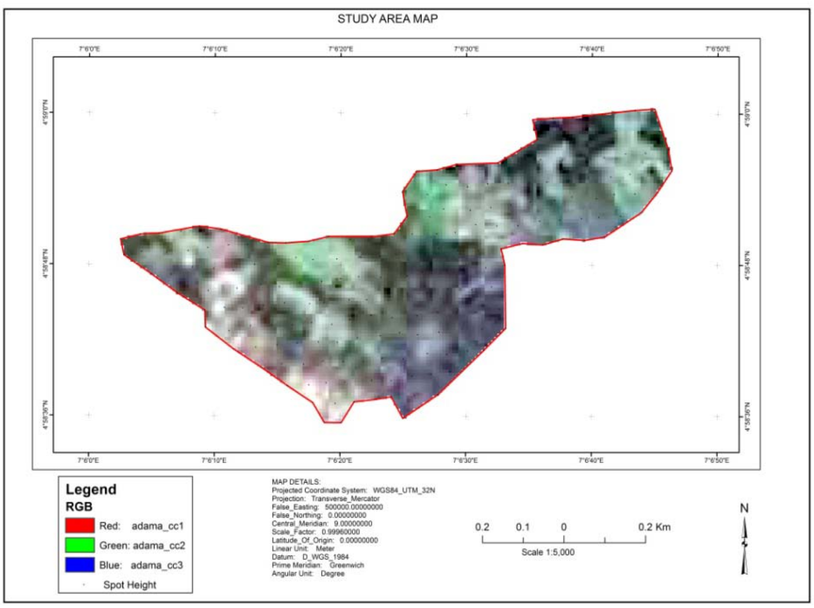

Fig. 1 Study area location map with overlay spot heights point data.

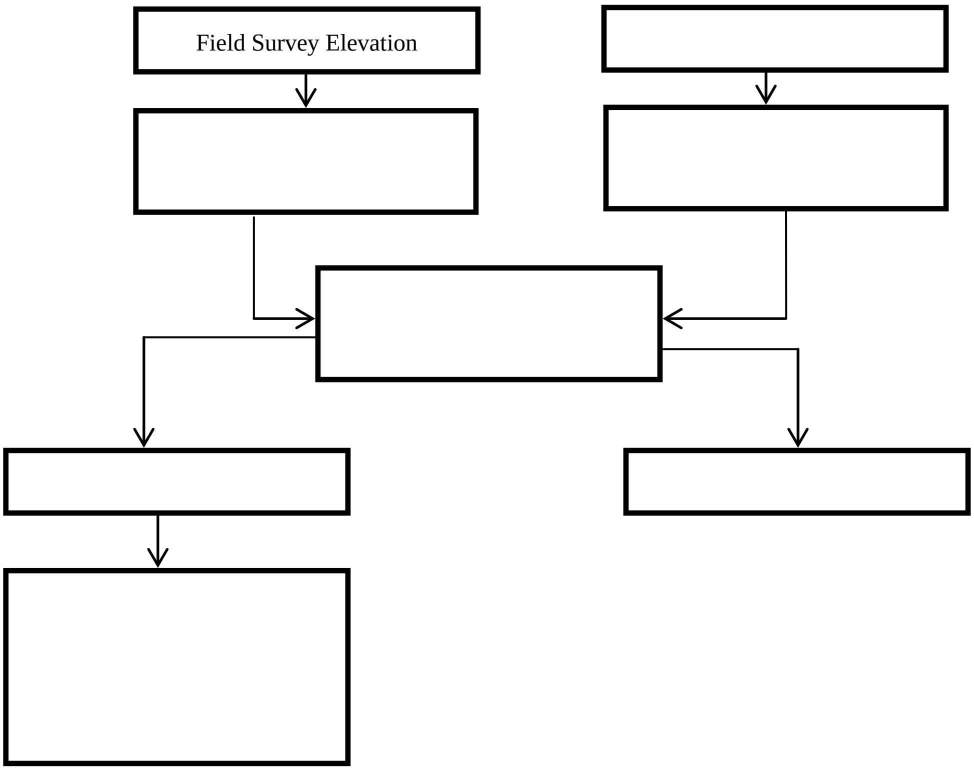

Fig. 2 Flow chart methodology.

2.2 Dataset

The dataset used for this study are elevation data obtained from field observation (Nigerian Army field reports) and Google Earth elevation extracted through Keyhole Markup Language (KML). The field observation was carried out using Promark 3 RTK DGPS [16] in stop and go to acquire elevation at 50 m × 50 m grid interval making a total of 201 points covering the study area [4]. The coordinates (field observation and Google Earth) were acquired in grid coordinate system, WGS84 zone 32N.

The software applied for this analysis is ESRI ArcGIS 10.1 [14, 15], because of it ability in modelling surfaces including digital terrain model and computer with MS excel 2010 install for correlation analysis [12]. Other researchers used SPSS for statistical analysis.

2.3 Data Processing

The field elevation data which was acquired using DGPS was downloaded into computer via data downloader. The data was re-saved in MS excel spread sheet 2010 by creating two separate files one with easting, northing and elevation and the other with only easting and northing coordinates. The later was use for extracting elevation data in Google Earth. Similarly, for the generation of elevation data from Google Earth, the easting and northing coordinate created in MS excel was plotted in ArcGIS 10.1 and converted to KML [14] data file recognized by Google Earth. In the Google Earth image the loaded point data was re-saved in KML format and the X, Y, Z coordinates of all the points was extracted using GPS Visualizer. GPS visualizer allows for quick extraction of bulk elevation data from Google Earth and the data was saved in MS excel. The elevation data for the field survey and Google Earth extracted was combine in one MS excel spread sheet in separate columns each having the same ground coordinate.

2.4 Generation of DEM

The X, Y, Z coordinates created in MS excel is plotted in ArcGIS 10.1 and Triangular Irregular Network (TIN) was created from the data. The TIN model was created using Mass point since the elevation is to be imported as node for both field survey and Google Earth data. TIN surface is digital elevation model [13] with the triangular vertices representing terrain features such as peaks, depressions, and passes, and the edges represents ridges and valleys [1]. Accordingly, the surface of the triangle provides area, slope, and aspect that are stored as TIN attributes. TIN model was converted to raster for the production of contour map and other surfaces. The TIN model produced was reclassified from the default nine classes to five classes of equal interval and was rated as very high, high, moderately high, low, and very low to aid analysis. In ArcGIS all elevation data must be converted to raster before it can be used for DEM generation.

The raster model created from TIN was used to create contour map for both the field survey and Google Earth data. The contour was created at 0.5m interval in cordovan brown colour for comparison. The volume in form of void between these dataset was also computed from the cut and fill tool in ArcGIS 10.1. The purpose of this analysis was to ascertain the separation between field survey and Google Earth elevation data because it is believed that by overlaying these data and impression of opening exist between them.

2.5 Correlation Analysis

The concept of correlation analysis provides a means of measuring relationship between variables (dependent and independent) that are quantitative. This relationship is tested by correlation coefficient (r) which provides standardized measure of linear association between variables [20]. The correlation between two sets of measured variables may be positive or negative depending on variables relationship. It is said to be positive when an increase (or decrease) in one variable corresponds to an increase (or decrease) in the other variable and it is negative when increase in one variable corresponds to decrease in the other variable and decrease corresponds with increase in the other variable [22]. The degree of relationship is expressed by the coefficient of correlation whose values range between -1 (indicating perfect negative correlation) to +1(indicating perfect positive correlation) [22]. The correlation analysis was performed using MS excel, where the independent variable was the field survey elevation data and the dependent variable was the Google Earth data. This research adopted Pearson's correlation coefficient [15], [12] to analyze the relationship. The Pearson's correlation model according to [22] is given by;

$$r = \sum(x - \bar{x})(y - \bar{y}) / (n - 1)SxSy \qquad (1)$$

Where, x is the independent variable, y is the dependent variable, n is the number of sample, Sx and Sy are the sample standard deviation of measured variable x and y.

3. Results and Discussion

Assessing Fig. 3 showing the TIN model generated from Google Earth elevation data of the study area the highest elevation value is recorded in the North-East of the map with a range 35.28-38.00 m, representing very high elevation as shown in the TIN model in ash colour. This very high elevation value covers an approximate area 49,087 square meters of the total study area. Below this area lies region of elevation in the range 32.56-35.28 m, representing high elevation as shown in the legend with area coverage 75,220 square meters. In going down the map is a region of moderately high elevation which traverses west-east in the range 29.84-32.56 m as represented in the legend with map area 175,450 square meters. Just immediately below the moderately high elevation is the low elevation region in the range 27.12-29.84 m, represented in the map with map area 85,473 square meters. It lies in the upper south location of the map. The very low elevation lies in the south location of the map in the range 24.40-27.12 m with map area 29,861 square meters.

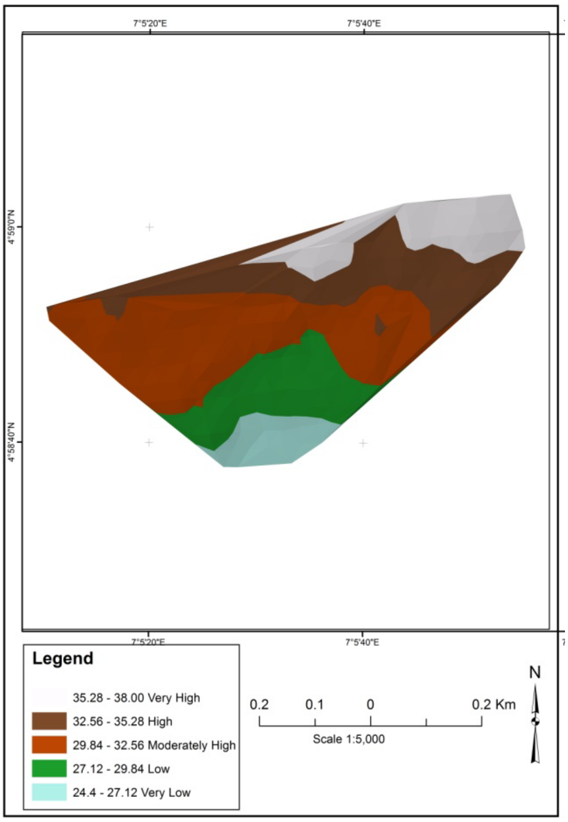

Fig. 3 TIN DEM from Google Earth.

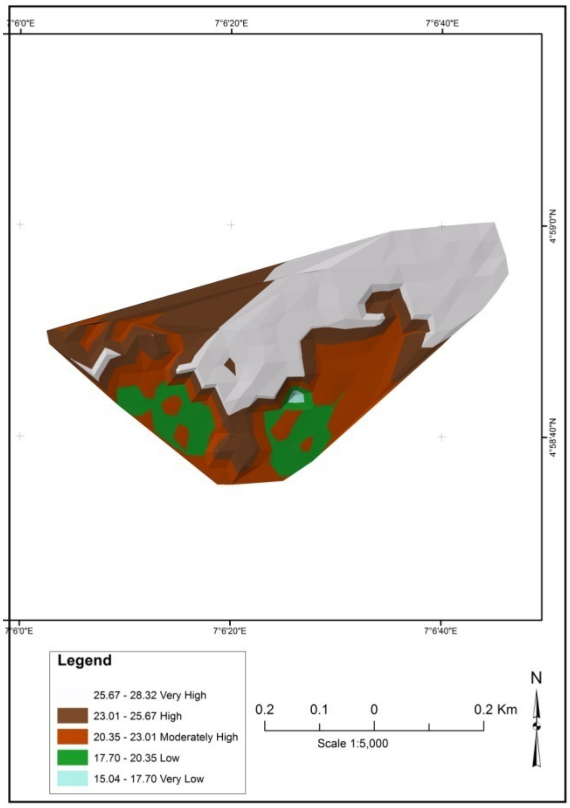

Fig. 4 TIN DEM from field survey.

Fig. 4 is TIN model generated from field survey data and was reclassified into five classes rated very high, high, moderately high, low, and very low elevation region in the legend. The very high elevation region emanate from north-east with range 25.67-28.32 m and extend to the middle south of map location covering an area 187,945 square meters. The next is the high elevation region in the range 23.01-25.67 m traversing west-east with map area 82,465 square meters. Down the map is the moderately high region in the range 20.35-23.01 m with map approximate area 83,274 square meters. It appears little in the west and extends south-east of the TIN model. The region of low elevation values lies south of the map with range 17.70-20.35 m and covering approximate area 56,815 square meters. The very low region have a range 15.04-17.70 m with approximate area 1,304 square meters, lying in an isolated location up south.

Comparing the two TIN models from Google Earth and field survey as explained above it will be observed that the pattern of terrain representation is the same. In Fig. 3 the very high elevation region emanate from north-east and extend to south similar to Fig. 4, except in the size of the area cover by the region. Similar terrain pattern is equally followed for all other classes; the major difference will be in the size of each region under investigation. For the Google Earth TIN model the variation of terrain elevation is not rapid compare to field survey TIN model indicating by the gap between class boundaries. Because for a rapid and close class boundary the topography is steep while for a gentle and wide boundary the topography is flat. These can be explained using contour map of the study area.

The field survey contour map in Fig. 6 shows the steepness of the terrain clearly, especially in the east and upper south position of the map. This is represented by the close contour lines of 0.5 m interval around contour 17 m and 23 m [10]. But on the Google Earth contour model in Fig. 5 the contour line are evenly spaced throughout the map surface, excluding steep slope of the area and suggest that is a flat surface.

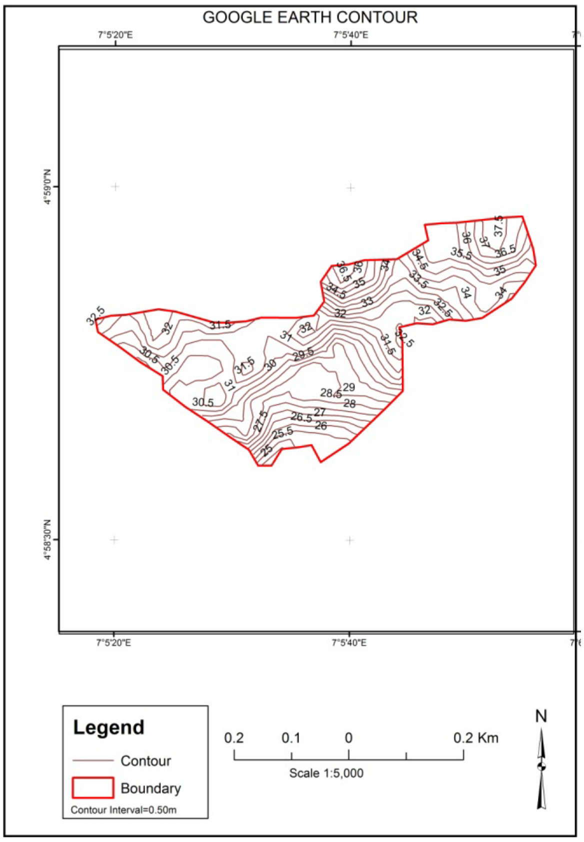

Fig. 5 Contour surface from Google Earth.

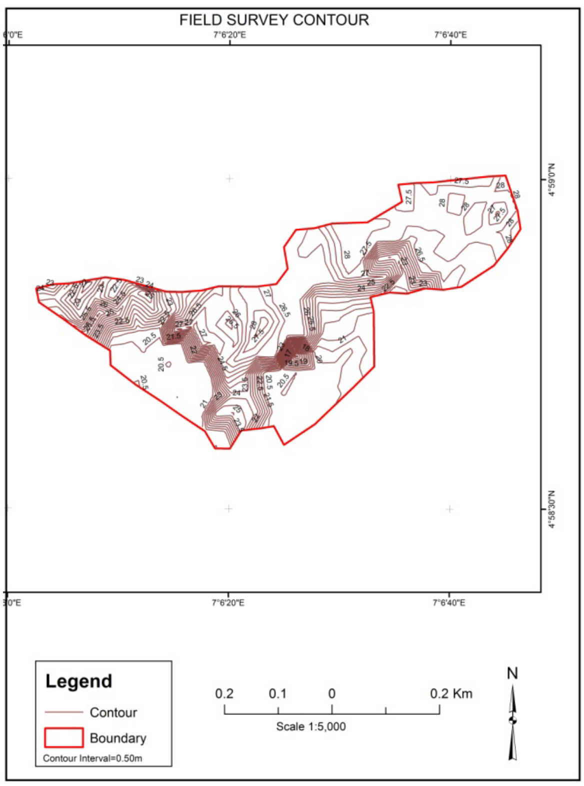

Fig. 6 Contour surface from field survey.

This justified study that Google Earth DEM is good for generating DEM for areas with flat terrain [10]. Other important point to note is that Google Earth DEM cannot represent small area very precisely since undulating surfaces will be missing in the DEM, a situation that can be addressed using field survey methods such as; GPS, Levelling instrument, and total station that is accurate [1].

In Fig. 7 the net loss between field survey and Google Earth elevation calculated as volume is 3,164,830 cubic metres. This volume is the void between the dataset and is a function of height difference as shown in blue colour on the map. The scatter plot of the dataset shown in Fig. 8 also proved that separation exists between the dataset. This can also be explained using correlation analysis of the variables [15].

Table 1 shows the Pearson's correlation from the measured variables with correlation coefficient (r) as 0.665 indicating strong positive correlation between the variables [23]. It is therefore concluded that strong linear relationship exist between field survey elevation and Google Earth elevation data [15]. But Arabinda S. and Dheeraj G. (2014) uses root mean square, mean error, and absolute mean error to evaluate accuracy of Google Earth DEM and topographic map of Bahal Region [11]. This linear relationship suggests that an increase in field survey elevation correspond to increase in Google Earth elevation as indicated by (r) value 0.665 over the study area. This uniform increase is what produced the volume between the two surfaces as shown by net loss over the entire map.

4. Conclusion

Elevation data from various sources are mostly used to produce DEM which are applied in many engineering projects. Although some of the users were concern about the reliability of these data and their sources. Previous researchers have combine two to four DEM sources to assessed accuracy in their study areas. In this paper, two elevation data sources one from field

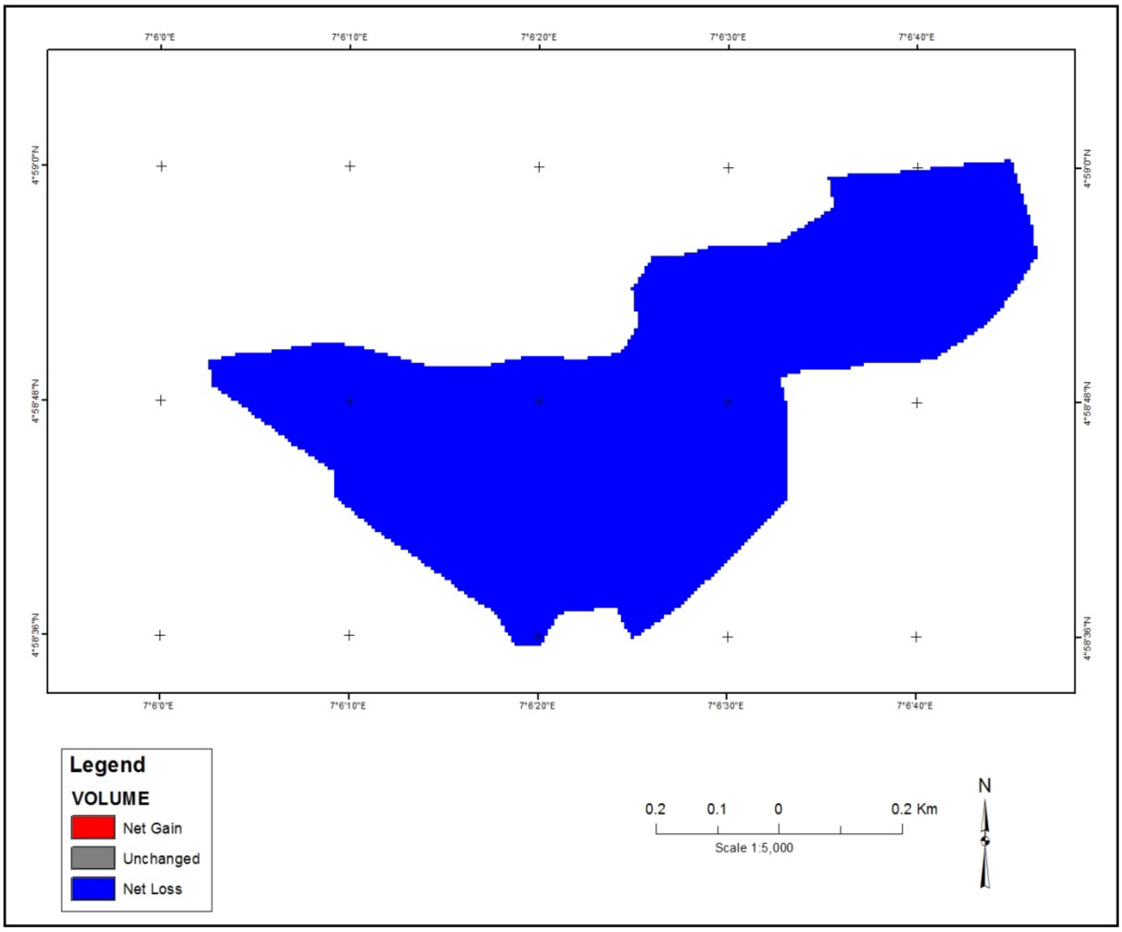

Fig. 7 Cut and Fill volume from Google Earth and field survey.

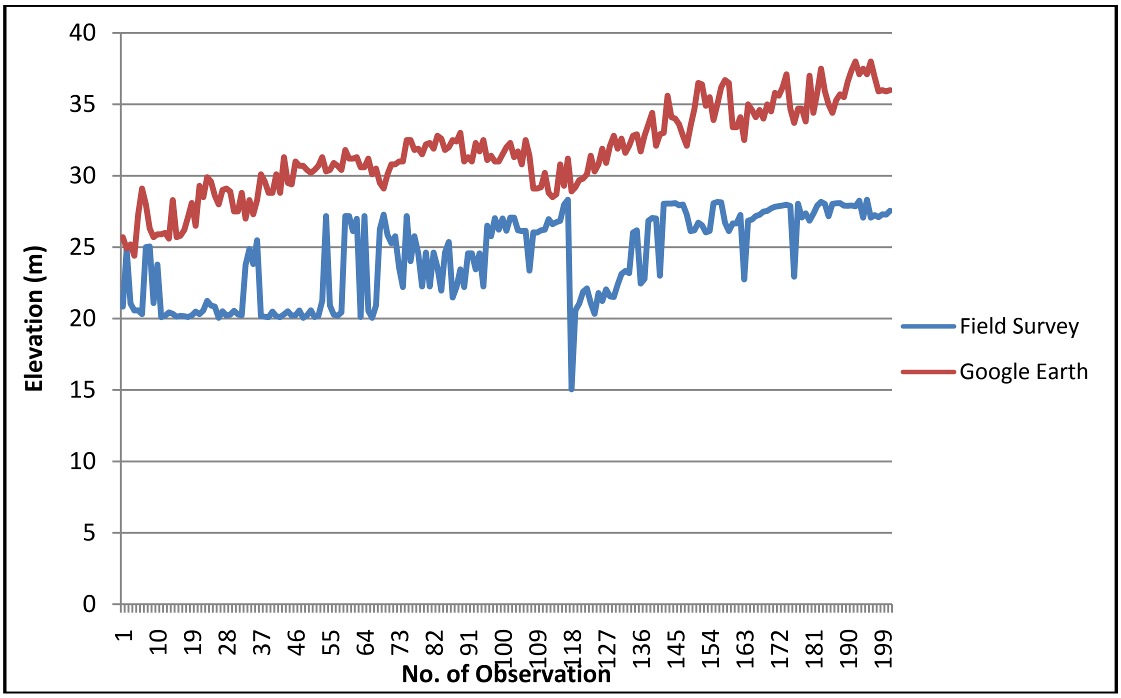

Fig. 8 Scatter plot of field survey and Google Earth elevation data.

Table 1 Correlation analysis between field survey and Google Earth elevation data.

	Field survey (Variable 1)	Google Earth (Variable 2)
Mean	24.278 m	31.640 m
Variance	9.416	9.244
Observations	201	201
Pearson's Correlation	0.665	
Mean Diff	7.362 m	

survey and the other from Google Earth was used to compared accuracy for topographic representation. The field survey elevation data was acquired on a grid interval of 50 m × 50 m using Promark 3 DGPS and the Google Earth elevation data was generated from Google Earth image using KML file created in ArcGIS 10.1. The spatial data created in ArcGIS database was used to create TIN and contour surfaces. The study concluded that Google Earth DEM is not perfect in representing steep slope and also, the correlation analysis using Pearson's correlation coefficient is 0.665 indicating linear relationship in the data. The study also recorded mean difference of elevation as 7.362 m which by assumption if subtracted from Google Earth elevation will modify it to equivalent field survey elevation. Although, Hoffmann E. (2010) discovered that Google Earth contour lines display 5 m lower elevation with contour map from Chief Directorate: Surveys Mapping (CDSM) and suggested that 5 m to be subtracted from contour map in the Google Earth [10]. We hope and believe that in the near future new technology will emerge where DEM generated from Google Earth will meet the expectation of many users and one will not think of correcting DEM data before use.

For further study, Google Earth DEM should be corrected first before use and compare the accuracy with ground survey DEM. Also, on hilly topography when using Google Earth DEM the contour interval should be small to accommodate the slope. This is because if the contour interval is large slope terrain will not be capture in the contour map. Finally, Google Earth digital terrain model (DTM) because of it positive correlation with field survey DTM could be applied in the following areas: (1) preliminary road, railway tracks, pipeline, and electric power alignment design; (2) movement of water, ice and glaciers on the earth surface; (3) analysis of groundwater potential; (4) planning location for sitting communication masts; (5) plant nutrient distribution and mass animal burial; (6) mapping potential mineral deposit; (7) modelling 3D surfaces such as wire frame, slope, hill shade and aspect; (8) airline operational safety; (9) Hazard assessments and inundation modelling of coastal areas [17].

Acknowledgement

We appreciate the cooperation of the Nigeria Army that allows free access to its data especially during field observation we all work as a team to achieve this goal. We also thank the Surveyor General of the State, Surv. Gaius Assor who deployed us to site to work with the Nigeria Army.

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