

# Evaluation of Horizontal and Vertical Accuracies of SRTM and ASTER GDEMs for Topographic and Hydrological Modeling in Onitsha, South East Nigeria

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## ABSTRACT

Digital Elevation Models (DEMs) are essential in the analysis and modeling of different topographical, hydrological and ecological phenomena on the Earth surface. The Shuttle Radar Topography Mission (SRTM) DEM and Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) are the most widely available global digital elevation model (DEM) dataset. In Nigeria, due to the lack of up-to-date topographic map and high cost of obtaining elevation data using conventional techniques, Map users often resort to the use of these freely available global datasets for their topographic information. However, the vertical accuracy of these global DEM varies depending on the terrain characteristics and land cover types, and may affect the quality of products such as slope, aspect and stream channels derived from these data needed for topographic and hydrologic modeling. This study deals on a comparative analysis of SRTM and ASTER GDEM version1 and version2 in topographical and hydrological modeling of Onitsha and environs using 1:50000 topographic map of the study area as the reference DEM. The validity of the topographic map was confirmed on the ground. The contour lines of the topographic map were digitized and their equivalent values used to generate the topographic DEM. The vertical and horizontal accuracies of the global datasets were evaluated using the reference topographic DEM. The results showed that ASTER ver1 has a vertical accuracy of 13.987m while that of ASTER ver2 is 12.558m. SRTM has a vertical accuracy of 14.125m. Horizontal accuracy of 18.240m and 27.341m was obtained for ASTER ver1 and ASTER ver2 respectively. Horizontal accuracy of 27.092m was obtained for SRTM. The study recommends the use of SRTM for topographic and hydrologic modeling of Onitsha and Environs and other areas of similar topography representation.

**Keywords:** Accuracy, SRTM, ASTER GDEM, Hydrological Modeling,

## 1. INTRODUCTION

The most freely available global elevation datasets (SRTM and ASTER GDEM) provides an alternative source of obtaining elevation data for topographic mapping of urban and rural areas for various applications such as hydrology and watershed dynamics, erosion modeling, and flooding. SRTM and ASTER DEM contains elevation information of vegetation, buildings and other surface features, and only gives elevation of terrain in areas where there is little or no ground cover. The accuracy of elevation products derived from these DEMs depends on the terrain characteristics and land cover types. The implication of using inappropriate DEMs in hydrological and environmental modeling has a significant effect on the modeling results. This was evident in Datta and Schack-Kirchner (2010) where it was noted that the choice of a DEM for soil erosion modeling has a significant effect on the relevant topographic parameters (elevation, slope, aspect, and LS factor) and consequently on the modeling results. Rojas et al (2008) expressed similar results when they studied the effects of DEM grid sizes on result of modeling upland erosion and sediment yield from natural watersheds and found that using different resolution DEMs significantly reduces land surface slopes and channel network topology, resulting in varied upland erosion estimates. Users of global elevation dataset are still confused on the choice of global dataset to use for a particular application and for a particular region.

SRTM DEM is available to Africa continent at spatial resolution of 90m while ASTER GDEM is available at 30m resolution. One would expect that 30m spatial resolution ASTER GDEM will be able to provide better result for all environmental modeling applications especially gully erosion and flooding than SRTM DEM. This is not always the case for all terrain variation and land cover types. Studies (Ejikeme, 2016; Singh, 2005) have shown that highest resolution data may not perform the best as the scale of data may not effectively capture the phenomenon under investigation or to be modeled.

Although, many applications use SRTM and ASTER products around the world, there is limited scientific literature on their quality and application fitness. It is apparently not clear as to which DEMs are most suitable for a particular environmental modeling, land cover types, study area or climate zone. It is quite evident that users of SRTM DEM and ASTER GDEM in Nigeria are recklessly using these DEMs in modeling various environmental problems without knowing which of them is best suited for their particular applications. The neglect may have led to poor modeling results which have an attendant consequence on the environmental problems being modeled. For instance, in modeling areas that are prone to flooding, the use of inappropriate DEM may result to wrongly assigning land use land cover types such as buildings, farmland to flood prone areas. One wonders the attendant implication-socio economic loss, trauma or even death this may cause to the victims of this wrong modeling result.

Since, a number of applications rely solely on SRTM and/or ASTER DEM, there is need to assess their quality especially in areas like Onitsha and environs that is characterized with several environmental problems such as erosion and flooding. Nikolakopoulos et al (2006) posited that these global elevation datasets are subjected to errors, mainly due to the methodology followed to extract elevation information and the various processing steps the model have undergone (e.g interpolation). Extensive and systematic evaluation of these datasets requires substantial ground truthing. To adequately evaluate the horizontal and vertical accuracy of these DEMs, there is need to compare elevation information from these global dataset with higher accuracy elevation dataset at varying land cover types and terrain characteristics.

## **1.2 Study Area**

The study area selected for this study (Onitsha and environs) is located within Anambra State in South-eastern Nigeria. The geographic location is approximately between Latitudes  $06^{\circ}05'20.89''N$  and  $06^{\circ}13'26.473''N$  and Longitude  $06^{\circ}45'20.604''E$  and  $06^{\circ}52'10.573''E$  and covers Onitsha North and South Local Government Area and part of Obosi, Nkpor and Iyiowa Odeke of Anambra State (See figure 1a, 1b & 1c). It is bounded by Anambra West/East L.G.A. and Oyi in the North, Idemili-North/South in the East, Ogbaru L.G.A in the South and in the West by the River Niger.

Onitsha and environs was selected for this study because of the peculiar nature of its terrain and associated environmental problems. The South-east region of Nigeria lies within Awka-Orlu uplands and Enugu-Awgu-Okigwe escarpment where gully erosion is a general problem which reduces the land resource of the area. Onitsha and environs being located within the South-eastern Nigeria is found on the dip section of the east facing scarp slopes of the Awka-Orlu landscape. It is underlain by flood plain deposits, and coarse to fine grained Nanka sands of the Bende-Ameki formation of the Eocene era (Orajaka, 1975). Onitsha stands at about 50 meters above sea level (Ofomata, 1975). Onitsha to Nsugbe is between 150-200 meters above mean sea level. There are east west trending hills from Nsugbe (near Onitsha) to Awka which constitutes the most prominent topographic feature. It provides a stretch of well drained, healthy site in the flood plains of River Niger. Thus, leaving a favourable site at the meeting point of two contrasting regions east and west of the Niger, and the Niger itself.

## **2. MATERIALS AND METHOD**

The data that was used in this study were obtained from the following sources:

- The SRTM and ASTER image were downloaded from the internet through the websites <http://srtm.csi.cgiar.org/> and <http://www.gdem.aster.ersdac.or.jp/> respectively.
- The 20m spatial resolution SPOT-5 DEM was acquired from the Office of the Surveyor General of the Federation (OSGoF).
- The 1:50000 Onitsha S.E topographic map was obtained from the Survey Department of the Ministry of Lands, Survey and Town Planning, Awka, Anambra State.
- Field data needed for accuracy assessment and validation of the topographical and hydrological model was obtained through GPS observations

Transforming the different coordinate system of the datasets to a common coordinate system is one of the major tasks needed to achieve a comparable result. The datasets were in different coordinate system as can be seen in table 1.1. The characteristic of Minna UTM Zone 32N projected coordinate system is given in table 1.2.

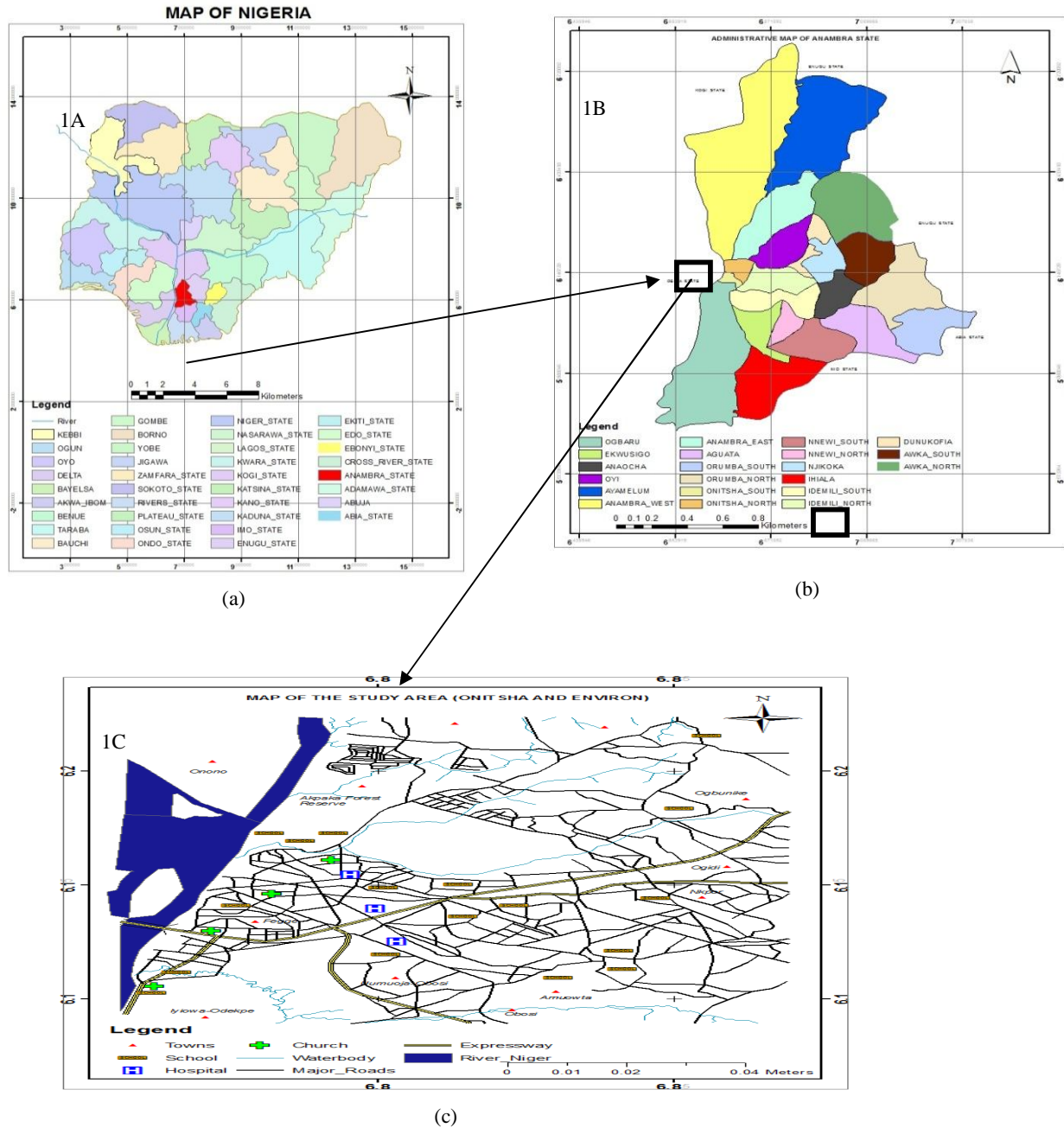


Figure 1(a): Map of Nigeria showing Location of Anambra State; Figure 1(b) Map of Anambra State showing the Location of the Study Area; Fig 1(c) Map of Onitsha and Environs (Study Area)

**Evaluation of Horizontal and Vertical Accuracies of SRTM and ASTER GDEMs for Topographic and Hydrological Modeling in Onitsha, South East Nigeria**

Table 1: Characteristics of the different coordinate system of the datasets

|                           | <b>ASTER_V1</b>                               | <b>ASTER_V2</b>                               | <b>SRTM</b>                                   | <b>SPOT 5 ELEVATION</b>        | <b>TOPO MAP</b>     |
|---------------------------|---|---|---|--------------------------------|---------------------|
| <b>Coordinate system</b>  | Geographic Coordinate System:<br>GCS_WGS_1984 | Geographic Coordinate System:<br>GCS_WGS_1984 | Geographic Coordinate System:<br>GCS_WGS_1984 | WGS_1984_UTM_ZON<br>E 32N      | Minna               |
| <b>Angular unit</b>       | Degree<br>(0.0174532925199433)                | Degree<br>(0.0174532925199433)                | Degree<br>(0.0174532925199433)                | Degree<br>(0.0174532925199433) |                     |
| <b>Prime meridian</b>     | Greenwich (0.0)                               | Greenwich (0.0)                               | Greenwich (0.0)                               | Greenwich (0.0)                |                     |
| <b>Horizontal (Datum)</b> | D_WGS_1984                                    | D_WGS_1984                                    | D_WGS_1984                                    | D_WGS_1984                     |                     |
| <b>Vertical (Datum)</b>   | WGS_1984                                      | WGS_1984                                      | WGS_1984                                      | WGS_1984                       | Clarke 1880         |
| <b>Semi major axis</b>    | 6378137.0                                     | 6378137.0                                     | 6378137.0                                     | 6378137.0                      |                     |
| <b>Semi minor axis</b>    | 6356752.314245179                             | 6356752.314245179                             | 6356752.314245179                             | 6356752.314245179              |                     |
| <b>Inverse flattening</b> | 298.257223563                                 | 298.257223563                                 | 298.257223563                                 | 298.257223563                  |                     |
| <b>Projection</b>         |   |   |   | Transverse Mercator            | Transverse Mercator |
| <b>False Easting</b>      |   |   |   | 500000.0                       |                     |
| <b>False Northing</b>     |   |   |   | 0.0                            |                     |
| <b>Central meridian</b>   |   |   |   | 9.0                            | 8°30 E<br>Greenwich |

|                           |     |     |     |             |                   |
|---------------------------|-----|-----|-----|-------------|-------------------|
| <b>Scale factor</b>       |     |     |     | 0.9996      | 0.99975           |
| <b>Latitude of origin</b> |     |     |     | 0.0         | 4 <sup>00</sup> N |
| <b>Linear unit</b>        |     |     |     | Meter (1.0) | Foot              |
| <b>Spatial Resolution</b> | 30m | 30m | 90m | 20m         | 1/50,000<br>Scale |

Table 2: Characteristics of Minna UTM Zone 32N

|                           | <b>Minna UTM Zone 32N</b>               |
|---------------------------|---|
| <b>Coordinate system</b>  | Geographic Coordinate System: GCS_Minna |
| <b>Angular unit</b>       | Degree (0.0174532925199433)             |
| <b>Prime meridian</b>     | Greenwich (0.0)                         |
| <b>Horizontal (Datum)</b> | D_Minna                                 |
| <b>Vertical (Datum)</b>   | Clarke_1880_RGS                         |
| <b>Semi major axis</b>    | 6378249.145                             |
| <b>Semi minor axis</b>    | 6356514.869549776                       |
| <b>Inverse flattening</b> | 293.465                                 |
| <b>Projection</b>         | Transverse Mercator                     |
| <b>False Easting</b>      | 500000.0                                |
| <b>False Northing</b>     | 0.0                                     |
| <b>Central meridian</b>   | 9.0                                     |
| <b>Scale factor</b>       | 0.9996                                  |
| <b>Latitude of origin</b> | 0.0                                     |
| <b>Linear unit</b>        | Meter (1.0)                             |

The shape of an ellipsoid is determined by three parameters; semi major axis (a), semi minor axis (b) and Inverse flattening (1/f). It was obvious from Table 1 and 1.2 that these parameters differ for the global ellipsoid-WGS\_1984\_UTM\_Zone 32N and the local ellipsoid- Minna UTM Zone 32N. Hence, the coordinate system of the global ellipsoid was transformed to the local ellipsoid.

The different coordinate systems of the datasets which were not in geographic coordinate system- GCS\_WGS\_1984 were transformed first to GCS\_WGS\_1984 by editing the spatial reference system to GCS\_WGS\_1984 in Arc Catalogue. The aim of transforming the data to WGS84 coordinate frame was to position the data in an easy-to-convert coordinate system. WGS84 is the most popular reference frame in the world today and transformation parameters between it and other reference frames are readily available (Chukwuocha, 2012). All the datasets which were now in GCS\_WGS\_1984 were transformed to Minna Geographic coordinate system- GCS\_Minna by using the transformation dialog box in the data frame properties dialog coordinate system tab. Molodensky method was chosen and the 7 parameters modified by editing X Axis Translation to 93.809786, Y Axis Translation to 89.748672, and Z Axis Translation to -118.83766, Rotation X-0.000010827829, Rotation Y-0.0000018504213, Rotation Z-0.0000021194542 and scale factor-0.99999393. These values are the 7 transformation parameters of Clarke 1880 ellipsoid of the Minna datum (OSGOF, 2013). The four bounding coordinates of the area of study were plotted into the Arc Map window. Draw rectangle tool was used to define the boundary and used to clip the area of interest of each dataset using image analysis of the window menu. The coordinate system of the datasets which were now in GCS\_Minna were re-projected to Minna UTM Zone 32N using the edit spatial reference box of each dataset in Arc Catalogue window. The bounding coordinates which are the common points in all the datasets were transformed manually from GCS\_Minna to Minna UTM Zone 32N projected coordinate system using the indirect approach of coordinate transformation. In order to ensure that accurate results were obtained using manual process, the bounding coordinates were also transformed to Minna UTM Zone 32N using the Eye4Software Coordinate Calculator and the result compared with that of the manual computation. This software was chosen among various coordinate transformation software because it has the capability of modifying its transformation parameters. Hence, the conversion properties were modified to the parameters of Minna datum. That is (Translation X = -92, Translation Y= -93, and Translation Z = 122). This coordinate system was chosen because it best fit the area of interest well (Uzodinma et al, 2013). Since, there was no significant difference between the coordinate obtained using the manual method and the Eye4Software, the coordinate obtained using the manual method was adopted and used to georeference each of the datasets.

The topographic map which was produced using aerial photogrammetric process in 1964 was used as the reference data. This data was used despite the difference in the date of production and present study because a sample survey carried out by Ejikeme (2013) revealed that there was no significant change in the elevation of the study area except where there are possibly gully erosion, sand excavation or developmental project. This was further validated by the 20m spatial resolution

SPOT-5 DEM, obtained from the Office of the Surveyor General of Federation, Nigeria.

The topographic map was digitized using ArcGIS 10.1 software. The following feature classes of interest were digitized; Contour as a line feature, Spot heights as a point feature and water body as a line feature. The contour lines were digitized and allocated a value equal to its recorded height above datum as written on the topographic sheet. The contour values were written in feet measurement in the topographic map and were converted to metric measurement by multiplying it with 0.3048m. This is the conversion factor used by Shell-BP Nigeria and Federal Survey Department of Nigeria to convert foot to meter ((Uzodinma and Ezenwere (1993) citing Agajelu (1987) and Oyeneye (1985)). The converted metric values were recorded in the attribute table of the Contour feature class.

The contour values were used to create the Triangular Irregular Network (TIN) using the 'Topo to Raster' tool available in raster interpolation tool of the Arc Tool box. The TIN was used to create a topographic map DEM at 20m spatial resolution. Elevation data were extracted from the DEM using the Raster to Point tool in the conversion tool of the Arc tool box. The equivalent Northing and Easting coordinate of each of the elevation point were extracted from the point elevation attribute table. A total of 70782 points were extracted. The northing and easting coordinate field were added in the attribute table and their geometry calculated by clicking on the field created. The northing, easting, and height were exported to Excel using dbase file format.

Similarly, the northing, easting, and height coordinate of the SRTM, ASTER version1, and ASTER version 2 were extracted and exported to Excel. Voids were noticed in the original ASTER ver1 and ASTER ver2 image. The minimum value (representing the voids) was -153 and the maximum value was 231 for ASTER ver1 while the minimum value was -64 and the maximum value was 171 for ASTER ver2. The focal statistics tool was used to calculate for each cell location a statistics of the value within a specified neighborhood around it. This was done using the rectangle neighborhood option with default neighborhood setting of the cell unit of height-3 and width-3. The result is DEMs with less noise and homogenous voids with the minimum value of ASTER ver1 as -152.222 and the maximum 227.333 while that of ASTER ver2 is 61.3333-minimum and 168-maximum. A total of 433149, 432482,432299, 432383 points were extracted for SRTM, ASTER version1 and ASTER version2 respectively.

## **2.1 Vertical and Horizontal Accuracy Assessment**

The accepted quantifiable measure of DEM accuracy is the root mean square error (RMSE) (Federal Geographic Data Committee, 1998). RMSE is used to assess DEM products by comparing them with elevation points that reflect the "most probable" elevations at specific locations. For each observation of a phenomenon, a variation can be computed between the actual observation and a calculated value. Each variation is then squared. The sum of these squared values is divided by the number of observations and the square root is taken to obtain the RMSE value.

RMSE for DEM vertical accuracy is defined by the USGS as:

$$RMSE = \sqrt{\frac{\sum (Z_i - Z_t)^2}{n}} \quad \dots (1)$$

Where  $Z_i$  is the interpolated DEM elevation of a test point,  $Z_t$  is the true elevation of a test point and  $n$  is the number of test points. RMSE quantifies the validity of a predictive model (USGS, 1998).

To quantify the horizontal accuracy of a DEM, a linear accuracy test can be performed along a well defined topographic feature (Gameth, 2010). A horizontal ridgeline accuracy assessment was used to evaluate the horizontal accuracy of ASTER ver1, ASTER ver2 and SRTM DEM datasets. According to Gameth, (2010), when using this technique it is important to use terrain with relief significant enough to accurately digitize ridgelines and allow for adequate detail in the test DEM delineations. Well defined visible ridgelines were digitized from the topographic map to represent portions of watershed boundaries. Nkisi river

boundary was digitized from the topographic map and compared to similar river boundary derived from the other DEMs to calculate the accuracy of those delineations. "Horizontal accuracy was tested by comparing the planimetric coordinates of well defined points in the dataset with coordinates of the points from an independent source of higher accuracy" (Federal Geographic Data Committee, 1998). Well defined point locations were digitized along the Nkisi river boundary obtained from the topographic map to act as a control dataset. These points were then used as references to compare against similar points obtained from delineating Nkisi river from ASTER ver1, ASTER ver2 and SRTM DEM. The planimetric coordinates of these sample point features can then be utilized for the purpose of calculating an error offset between the control stream and the drainage networks delineated from a respective DEM (Tveite and Langaas, 1995).

Figure (2.0) shows the delineated Nkisi river boundary from the topographic map and the different DEMs.

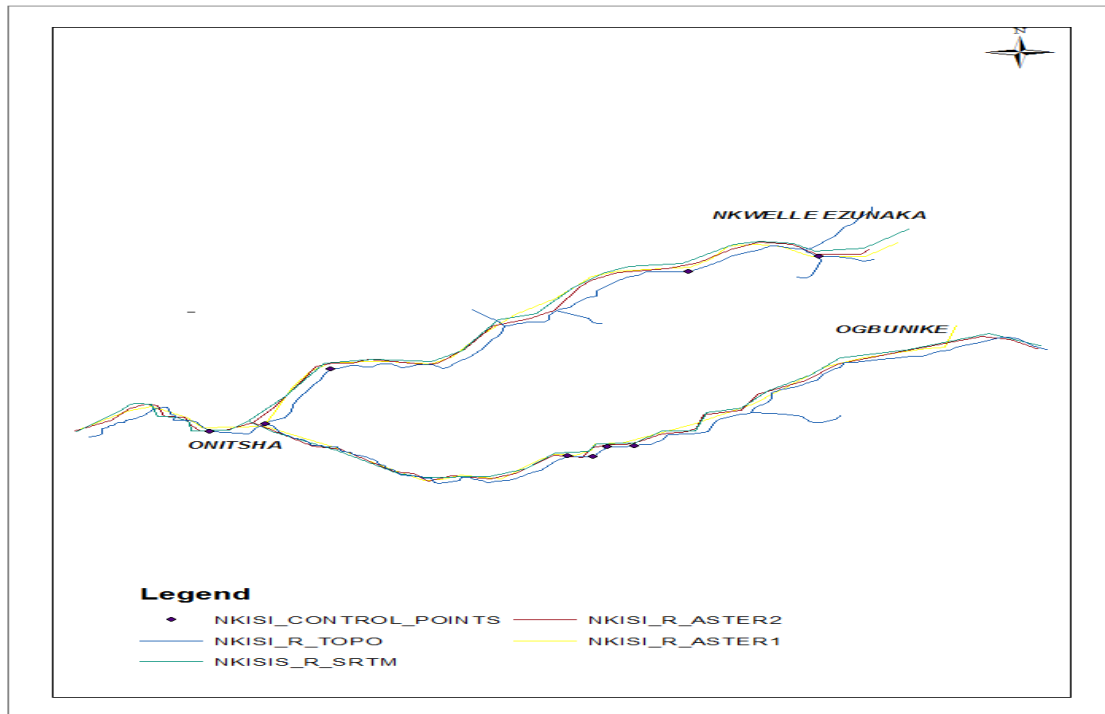


Figure 2: Delineated Nkisi river boundary from different elevation datasets

### 3. ANALYSIS AND RESULTS

#### 3.1 Analysis of Vertical Accuracy of Digital Elevation Models

The extract sample tool of the spatial analyst tool of Arc GIS 10.1 software was used to extract common points among the elevation

datasets. The topographic map point was selected as the input point file while the different elevation dataset was selected as the input raster data. The nearest neighbor interpolation technique was used to extract the common points and the data saved as Excel. dbf format. A total of 70782 elevation common points were extracted for all the datasets. These points were exported to SPSS software. The data were analyzed for outliers. The outliers were detected and removed. An outlier is an extremely high or an extremely low data value when compared with rest of the data

values (Bluman, 2012). An outlier can strongly affect the mean and standard deviation of a variable. Outliers can also have an effect on other statistics if not detected and removed. A total of 63363 points were remaining after removing the outliers using SPSS.

The sample size was determined using the Taro Yamane (1967) formula for determining sample size at 95% confidence level and P=0.05, as cited in Obasi et al (2015) and Onwuka et al (2015):

$$n = \frac{N}{1 + N(e)^2} \quad \dots (2)$$

Where  $n$  = sample size  
 N= population size  
 e= the level of precision (0.05)  
 1 = Theoretical constant

Therefore,

$$n = \frac{63363}{1 + 63363(0.05)^2} = 397.491 = 397 \quad (\text{to the}$$

nearest whole number)

The population size (that is 63363) was determined after removing the outliers. This value represents points that are common to all the elevation datasets. Three hundred and ninety-seven (397) sample points were selected out of the total population size of 63363 for each of the elevation datasets. The stratified random sampling technique was used to select the samples. The first stratum was done on the basis of elevation values while the second stratification was based on location of the elevations.

### 3.2 Calculation of Root Mean Square Error (RMSE)

RMSE for DEM vertical accuracy is defined as:

$$RMSE = \sqrt{\frac{\sum (Z_i - Z_t)^2}{n}} \quad \dots (3)$$

where  $Z_i$  is the interpolated DEM elevation of a test point (That is, the elevation of SRTM, ASTER ver1, or ASTER ver2)  $Z_t$  is the true elevation of a test point (That is, the elevation of the topographic map) and  $n$  is the number of test points (which is 397).

**RMSE for ASTER ver1 vertical accuracy is given as:**

$$\sum (Z_{A1} - Z_t)^2 = 77670.78512$$

where

$Z_{A1}$  = elevation points of ASTER ver1

$Z_t$  = elevation points of Topographic map

$$\frac{\sum (Z_{A1} - Z_t)^2}{n} = \frac{77670.78512}{397} = 195.644295$$

$$RMSE = \sqrt{\frac{\sum (Z_{A1} - Z_t)^2}{n}} = \sqrt{195.644295} = 13.987m$$

**RMSE for ASTER ver2 vertical accuracy is given as:**

$$\sum (Z_{A2} - Z_t)^2 = 62611.3216$$

where

$Z_{A2}$  = elevation points of ASTER ver2

$Z_t$  = elevation points of Topographic map

$$\frac{\sum (Z_{A2} - Z_t)^2}{n} = \frac{62611.3216}{397} = 157.7111375$$

$$RMSE = \sqrt{\frac{\sum (Z_{A2} - Z_t)^2}{n}} = \sqrt{157.7111375} = 12.558m$$

**RMSE for SRTM vertical accuracy is given as:**

$$\sum (Z_{SR} - Z_t)^2 = 79202.47501$$

where

$Z_{SR}$  = elevation points of SRTM

$Z_t$  = elevation points of Topographic map

$$\frac{\sum (Z_{SR} - Z_t)^2}{n} = \frac{79202.47501}{397} = 199.5024559$$

$$RMSE = \sqrt{\frac{\sum (Z_{SR} - Z_t)^2}{n}} = \sqrt{199.5024559} = 14.125m$$



The reported absolute vertical accuracy of SRTM 90m elevation revolves around  $\pm 16m$  depending on terrain characteristics of slope and aspect (Ozah and Kufoniyi 2008, citing Koch et al 2000, Milicuesis et al 2005). The RMSE obtained for ASTER ver1, ASTER ver2, and SRTM were compared. Table 3 shows the summary of vertical accuracy for the three elevation datasets under study.

Table 3: Summary of vertical accuracy of the DEMs

| S/N | DEM        | VERTICAL RMSE (m) |
|-----|------------|-------------------|
| 1   | ASTER ver1 | 13.987            |
| 2   | ASTER ver2 | 12.558            |
| 3   | SRTM       | 14.125            |

The larger the value of the RMSE, the greater the discrepancy between the two datasets. The result showed that SRTM exhibit a larger discrepancy from the topographic map elevation, followed by ASTER ver1, and then ASTER ver2.

### 3.3 Analysis of Horizontal Accuracy of Digital Elevation Models

According to the Federal Geographic Data Committee (FGDC), horizontal accuracy is determined through the calculation of RMSE with the following formula:

Let:

Horizontal RMSE is:

$$\left. \begin{aligned} RMSEr &= \sqrt{\sum ((x \text{ data}, i - x \text{ check}, i)^2 + (y \text{ data}, i - y \text{ check}, i)^2) / n} \\ &= \sqrt{RMSE_x^2 + RMSE_y^2} \\ RMSE_x &= \sqrt{\sum (x \text{ data}, i - x \text{ check}, i)^2 / n} \\ RMSE_y &= \sqrt{\sum (y \text{ data}, i - y \text{ check}, i)^2 / n} \end{aligned} \right\} (4)$$

where:

$x \text{ data}, i$ ,  $y \text{ data}, i$  are the coordinates of the  $i$ th check point in the dataset,  $x \text{ check}, i$ ,  $y \text{ check}, i$  are the coordinates of the  $i$ th check point in the independent source of higher accuracy,  $n$  is the number of check points tested and  $i$  is an integer ranging from 1 to  $n$ .

Horizontal error at point  $i$  is defined as  $\sqrt{(x \text{ data}, i - x \text{ check}, i)^2 + (y \text{ data}, i - y \text{ check}, i)^2}$ .

Horizontal RMSE for delineated drainage networks is thus figured using the preceding formula.

The X- and Y-coordinate of the topographic map which is the independent source of higher accuracy is given as  $(X_t)$  and  $(Y_t)$  respectively. Similarly, the X-and Y-coordinate of the ASTER ver1 is given as  $(X_{a1})$  and  $(Y_{a1})$ , ASTER ver2 as  $(X_{a2})$  and  $(Y_{a2})$ , and SRTM as  $(X_s)$  and  $(Y_s)$  respectively.

**For ASTER ver1**, the horizontal RMSE was calculated as follows:

$$RMSE_x = \sqrt{\sum (X_{a1} - X_t)^2 / n} = \sqrt{1459.913/9} = \sqrt{162.2125556} = 12.736m$$

$n$ =the number of check points tested = 9

$$RMSE_y = \sqrt{\sum (Y_{a1} - Y_t)^2 / n} = \sqrt{1534.368/9} = \sqrt{170.4853333} = 13.057m$$

$$\begin{aligned} \text{Horizontal RMSE} &= RMSEr = \sqrt{RMSE_x^2 + RMSE_y^2} \\ &= \sqrt{(12.736)^2 + (13.057)^2} = 18.240m \end{aligned}$$

**For ASTER ver2**, the horizontal RMSE was calculated as follows:

$$RMSE_x = \sqrt{\sum (X_{a2} - X_t)^2 / n} = \sqrt{3278.946/9} = \sqrt{364.3273333} = 19.087m$$

$n$ =the number of check points tested = 9

$$RMSE_y = \sqrt{\sum (Y_{a2} - Y_t)^2 / n} = \sqrt{3448.677/9} = \sqrt{383.1863333} = 19.575m$$

$$\begin{aligned} \text{Horizontal RMSE} &= RMSEr = \sqrt{RMSE_x^2 + RMSE_y^2} \\ &= \sqrt{(19.087)^2 + (19.575)^2} = 27.341m \end{aligned}$$

**For SRTM**, the horizontal RMSE was calculated as follows:

$$RMSE_x = \sqrt{\sum (X_s - X_t)^2 / n} = \sqrt{2560.422/9} = \sqrt{284.4913333} = 16.867m$$

$n$ =the number of check points tested = 9

$$RMSE_y = \sqrt{\sum (Y_s - Y_t)^2 / n} = \sqrt{4045.428/9} = \sqrt{449.492} = 21.201m$$

$$\begin{aligned} \text{Horizontal RMSE} &= RMSEr = \sqrt{RMSE_x^2 + RMSE_y^2} \\ &= \sqrt{(16.867)^2 + (21.201)^2} = 27.092m \end{aligned}$$

The results of horizontal accuracy is summarized in table 4

Table 4: Summary of horizontal accuracy of the DEMs

| S/N | DEM        | HORIZONTAL RMSE (m) |
|-----|------------|---------------------|
| 1   | ASTER ver1 | 18.240              |
| 2   | ASTER ver2 | 27.341              |
| 3   | SRTM       | 27.092              |

The horizontal accuracy of ASTER version1 is better than that of ASTER version2. This may be attributed to the process of removing the imperfections in ASTER version1 which led to the improved ASTER version2. In other words, in the process of improving the vertical accuracy of ASTER version1 to obtain ASTER version2, the horizontal accuracy of ASTER version2 may have been affected.

The acceptability of hydrologic delineations depends greatly on the user's need. Delineation accuracy values cannot be expected to be much greater than the cell resolution of the DEM they were produced from. Gamett (2010) stated that an accuracy threshold of 30 meters for quantitative comparison of ASTER, NED and SRTM DEMs is deemed acceptable. Once DEM accuracy meets an acceptable tolerance, hydrologic data derived from the model can also be assumed to be more accurate (Srivastava, 2000).

## 4. CONCLUSION AND RECOMMENDATIONS

### 4.1 Conclusion

SRTM DEM and ASTER GDEM provides alternative source of elevation data needed for environmental modeling applications such as in hydrology and erosion studies. Before this global data can be used for any specific application, there is need to evaluate their performance. Otherwise, one may be using an inappropriate DEM for an environmental modeling application.

## Evaluation of Horizontal and Vertical Accuracies of SRTM and ASTER GDEMs for Topographic and Hydrological Modeling in Onitsha, South East Nigeria

This work has been able to show that the performance of DEM does not only rely on its quoted spatial resolution but also on the inherent properties of the DEM. For example, SRTM has a 90m spatial resolution while ASTER has a 30m resolution. The result of this study shows that ASTER ver2 has a vertical accuracy of 12.558m, ASTER ver1 13.987m while SRTM has 14.125m. The horizontal accuracy of ASTER ver1 is 18.240m, ASTER ver2 is 27.341m while SRTM is 27.092m. A horizontal accuracy threshold of 30m is deemed acceptable and any hydrologic data derived from the DEM is assumed to be accurate (Gamett, 2010; Srivastava, 2000). Therefore, SRTM, ASTER ver1, and ASTER ver2 are good and acceptable for hydrological modeling.

### 4.2 Recommendations

The use of these global elevation datasets in environmental modeling cannot be completely discouraged especially in a country like Nigeria that has no up-to-date topographic map. Based on the result of the findings from this study, the following recommendations were made:

- Further studies should be carried out on the evaluation of these global elevation datasets as new version of them are released for public use.
- SRTM should be used for topographic and hydrological modeling in Onitsha and environs or other areas that have similar topographic configuration like the study area. Also, SRTM should be used where higher accurate elevation data are not readily available since they can be obtained freely online.
- SRTM and ASTER GDEM should be validated in other locations in Nigeria.
- The result of this study should be adopted and used for accelerated action to provide the Country with accurate and up-to-date topographic Maps of scales 1:50000, 1:25000 and 1:10000. This will ensure that needed topographic data at various scales are available to serve the various needs of our National planning and development.

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