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Assessment Of The Impact Of Terrain Configuration And Landuse/ Landcover On The Performance Of Srtm, Aster Version1 And Version2 Gdems: A Case Study Of Onitsha And Environs, Anambra State, Nigeria

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ABSTRACT: - *The aim of this study is to evaluate the impact of terrain variation and landuse/ landcover on the performance of Shuttle Radar Topographic Mission (SRTM) and Advanced Space Borne Thermal Emission and Radiometer (ASTER) Global Digital Elevation Model (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 contour lines of the topographic map were digitized and their equivalent values used to generate the topographic DEM. The topographic DEM was reclassified into varied terrain configurations (flat, undulating, rolling, hilly and mountainous) and the profiles plotted on the different terrain categories. The profiles were used to examine the impact of terrain configuration of the different DEM. The Landsat-7ETM+ was also classified into varied landuse/ landcover types (built up area, waterbody, open space and vegetation) and the profiles of different landcover/landuse types obtained. The plotted profiles were also used to assess the influence of land cover types on the DEM. Pearson correlation test was also used to determine the strength of relationship between the global datasets and the topographic DEM at different terrain variation and landuse/ landcover types. The results of the study have been able to show that SRTM shows a close resemblance to the reference topographic DEM than ASTER ver1 and ASTER ver2 datasets under flat and undulating terrain categories. SRTM overestimated the earth surface under mountainous, rolling and hilly terrain categories while ASTER ver1 and ASTER ver2 underestimated the earth surface under the same terrain categories. Generally, SRTM overestimate elevation while ASTER ver1 and ASTER ver2 underestimate elevation. Under Built up, open space, and water body landcover types, SRTM compares favorably with the reference topographic DEM. SRTM, ASTER ver1 and ASTER ver2 overestimate elevation under vegetation influence. This study reveals that the impact of landuse/ landcover types are more pronounced in ASTER ver1 and ASTER ver2 elevation datasets than in SRTM. The Pearson correlation test for landuse/landcover assessment shows that the three datasets expresses a negative weak relationship with the topographic DEM. SRTM has a correlation value of -0.091 while ASTER ver1 and ASTER ver2 has a correlation values of -0.075 and -0.101 respectively. SRTM exhibits a positive relationship with value of 0.640 while ASTER ver1 and ASTER ver2 shows a correlation coefficients of 0.349 and 0.347 respectively for terrain assessment. The study recommends that SRTM should only be used in flat terrain while ASTER GDEMs should be used in hilly terrain. SRTM, ASTER ver1 and ASTER ver2 should not be used where there is dense vegetation.*
KEYWORDS: *DEM, Landuse/ Landcover, Terrain, Modelling*

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I. Introduction

The interaction between land cover and terrain morphologies in accuracy assessment of DEM cannot be over-emphasized. Vertical errors of DEMs propagate into various derived products, like slope, gradients, aspect, stream channel network or relief forms, and may cause unexpected artifacts putting into question the usefulness of these data for further analysis [1]. This accuracy depends on the terrain characteristics and land cover types. Land cover is a very important factor which affects the calculation of elevation when optical or radar sensors are used, where near top of canopy is measured not the bare earth [2]. [3] stated that Land cover and terrain characteristics have a major effect on the water cycle as well as on processes concerning erosion.

According to [4], some studies have suggested the accuracy of DEMs may vary depending on land cover. This suggestion is based on the assumption that any land-cover type that has a substantial canopy will inhibit a visual modification of the DEM or an automatic terrain extraction algorithm. It is not known what the accuracies are for DEMs derived over certain land cover classes or whether the errors are significantly different between land cover categories.

The implication of using inappropriate DEMs in hydrological and environmental modeling has a significant effect on the modeling results. This was evident in [5] 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. 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 *et al*, 2017; Ashraf *et al*, 2012) 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. Singh (2005) compared flood inundation mapping by hydrodynamic models using SRTM and ASTER DEM and obtained a wide difference in their result. The implication is that error in DEM can lead to inaccurate flood inundation area. Akbari (2009) suggested that it is better to use SRTM DEM than topographic DEM for terrain derivatives (slope, aspect, landscape classifications) and hydrologic modeling in areas where only topographic maps at scale above 1:25000 (ie 1:50000 and 1:100000) is available. Isioye and Yang (2013), citing the “conflict of differences in vertical datum” strongly recommended that SRTM DEM and ASTER GDEM should not be used for mapping purposes in Nigeria. This was contrary to the findings of Ozah and Kufoniyi (2008) who indicated that 90m resolution SRTM elevation data can be used as a substitute for existing 1:50000 topographic maps with the caveat that the SRTM should be processed prior to topographic information extraction for 1:25000 topographical mapping.

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.

A. 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 $06^{0}05^{1}20.89^{11}$N and $06^{0}13^{1}26.473^{11}$N and Longitude $06^{0}45^{1}20.604^{11}$E and $06^{0}52^{1}10.573^{11}$E and covers Onitsha North and South Local Government Area and part of Obosi, Nkpor and Iyiowa Odekpe 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.

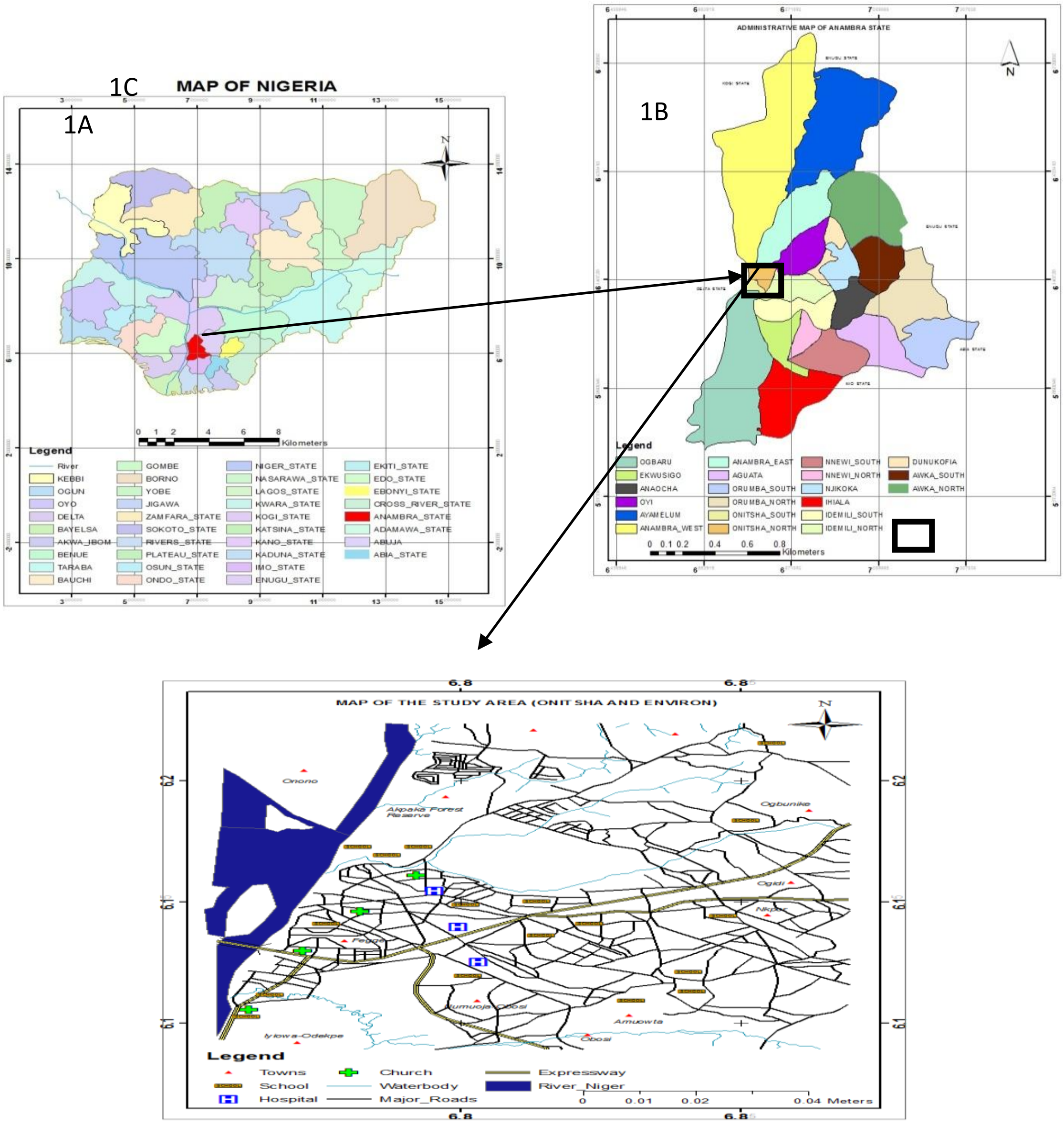


Figure 1a: *Map of Nigeria showing Location of Anambra State; Figure 1b: Map of Anambra State showing the Location of the Study Area; Fig 1c: Map of Onitsha and Environs (Study Area)*

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.

II. Research Methodology

The SRTM and ASTER ver1 and ver2 GDEMs were downloaded from the internet through the websites http://srtm.csi.cgiar.org/ and http://www.gdem.aster.ersdac.or.jp/ respectively. The 1:50000 Onitsha S.E topographic map covering the study area was obtained and the area of interest was extracted. The different coordinate systems of the datasets were reprojected to Minna UTM Zone 32N. The Minna UTM Zone 32N coordinate system was chosen because it best fit the area of interest well (Uzodinma et al, 2013). All the datasets were resampled to 20m spatial resolution using the nearest neighbor technique.

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. The topographic map was digitized. 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 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.

To examine the impact of terrain configuration, the topographic map DEM was reclassified into five classes of terrain configuration based on the Food and Agricultural Organization (FAO) categories of classification of slopes. According to Daffi and Otun (2010), the five classes are:

1. 1-40m = FLAT
2. 40-80m = UNDULATING
3. 80-120m = ROLLING
4. 120-150m = HILLY
5. 150-180m = MOUNTAINOUS

The different classes were vectorized. Cross section lines were digitized on each terrain classes and used to obtain horizontal profiles for the terrain class.

The impact of landuse/ landcover types was examined by classifying Landsat-7 ETM+ of the study area into different land cover types (built up area, waterbodies, vegetation, open space). The accuracy of the classification process was evaluated and overall accuracy of 80.16% was obtained. The different classes were vectorized and elevation points that fell on each class for the different dataset was extracted for comparison. Cross section line was digitized on each of the land cover types and used to extract the respective horizontal profiles for each DEM. The Horizontal profiles were compared to examine the influence of the land cover on the DEMs.

III. Findings

Fig (3.1a to 3.1e) shows the profiles obtained for each of the terrain class for the different DEMS. The red colour Horizontal profile represents the topographic DEM while the yellow colour profile represents SRTM. ASTER ver1 and ASTER ver2 are represented with blue and green colour respectively. The Pearson’s correlation coefficient test was conducted using SPSS Software to ascertain the strength of the linear relationship between the different global elevation datasets and the reference topographic DEM at varied terrain configurations.

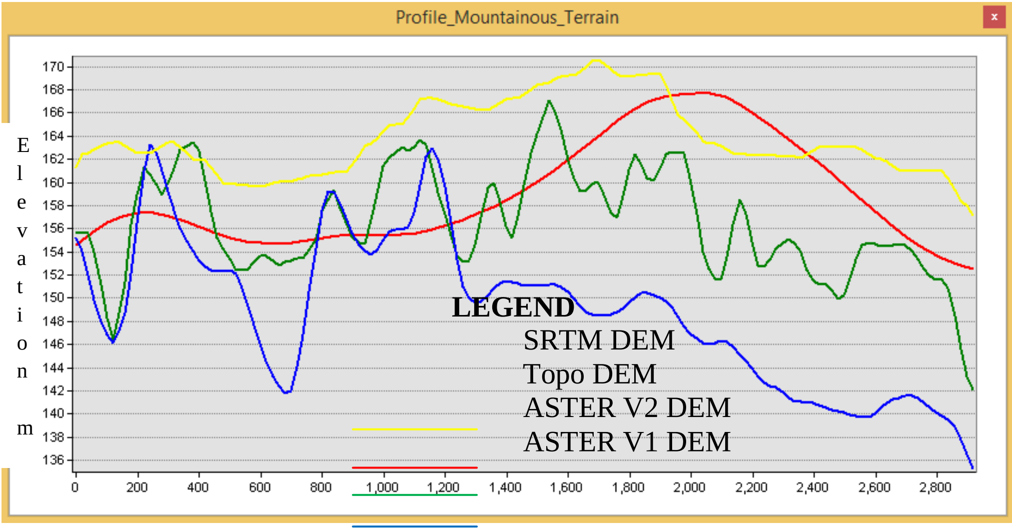


Fig (3.1a) Horizontal Profile for Mountainous Terrain

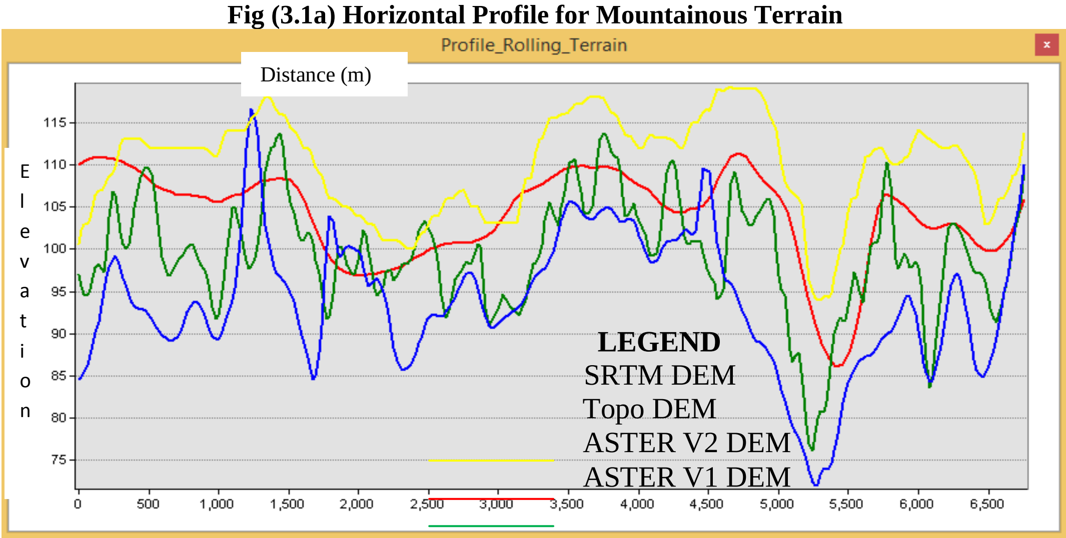


Fig (3.1b) Horizontal Profile for Rolling Terrain

Distance (m)

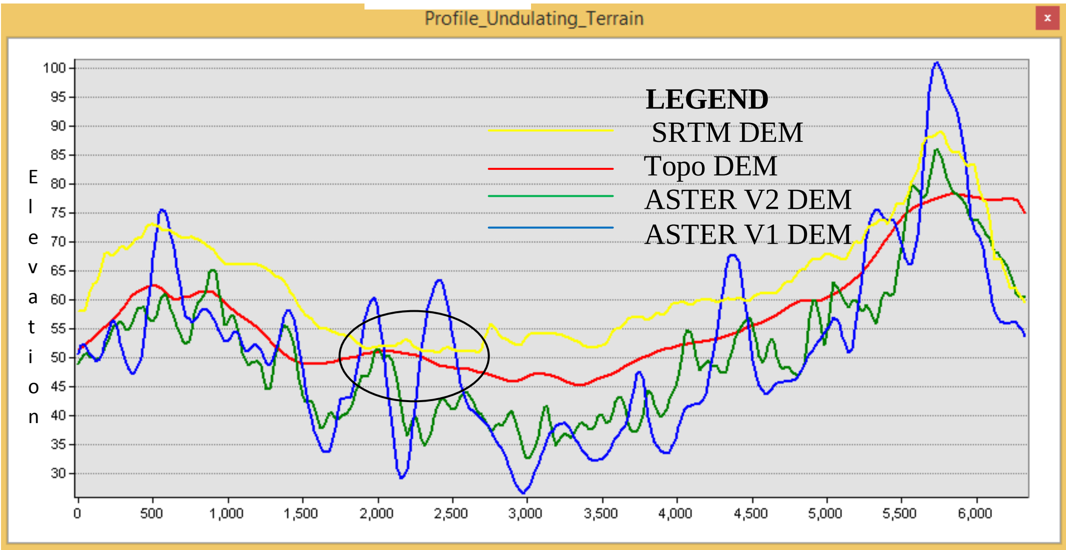
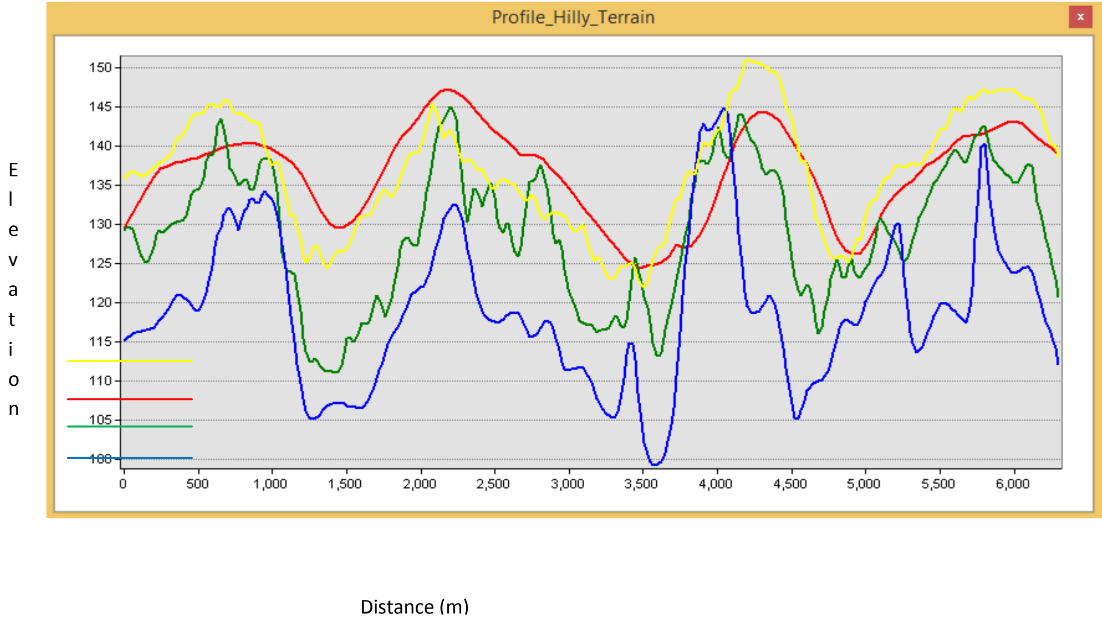


Fig (3.1c) Horizontal Profile for Undulating Terrain

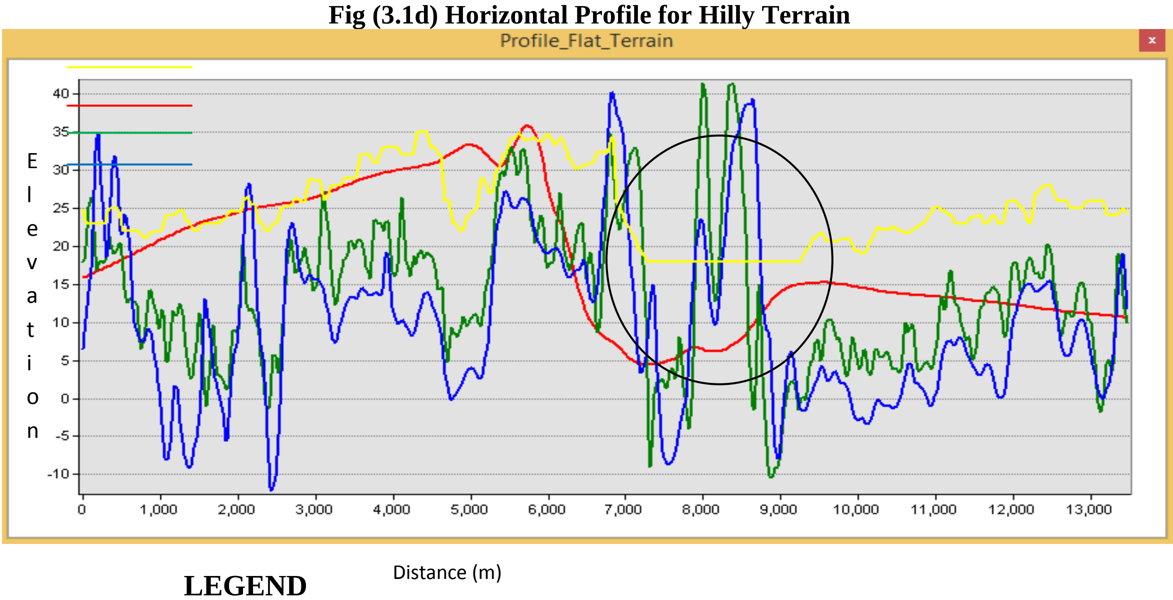
Distance (m)



LEGEND

SRTM DEM
Topo DEM
ASTER V2 DEM
ASTER V1 DEM

Fig (3.1d) Horizontal Profile for Hilly Terrain



LEGEND

SRTM DEM
Topo DEM
ASTER V2 DEM
ASTER V1 DEM

Fig (3.1e) Horizontal Profile for Flat Terrain

From the mountainous terrain profile, it can be seen that SRTM overestimated the elevation while ASTER ver1 and ASTER ver2 underestimated the elevation. The behavior of this datasets is not reliable on mountainous terrain. This is confirmed by the result of the correlation test. The three global datasets shows a weak relationship to the topographic DEM on mountainous terrain. The same effect was also noticed on the rolling terrain. Under undulating terrain, there is a positive relationship with ASTER ver2 having a correlation coefficient of 0.720 while SRTM and ASTER ver1 have a value of 0.681 and 0.661 respectively. ASTER ver2 and ASTERver1 shows a strong positive relationship with the topographic DEM with ASTER ver2 having a correlation value of 0.956 and ASTER ver1 having a value of 0.934. SRTM expresses a weak relationship with a value of 0.135. Under flat terrain configuration profile, SRTM expresses a close terrain resemblance with the topographic DEM whereas ASTER ver1 and ASTER ver2 shows a fluctuating elevations as can be seen in circle diagram in fig (3.1e). SRTM exhibits a positive relationship with value of 0.640 while ASTER ver1 and ASTER ver2 shows a correlation coefficients of 0.349 and 0.347 respectively.

Fig (3.2a to 3.2d) shows the Horizontal profile obtained for each DEM for a particular land cover type. Pearson correlation test was also used to determine the strength of relationship between the global datasets and the topographic DEM at different landuse/ landcover types.

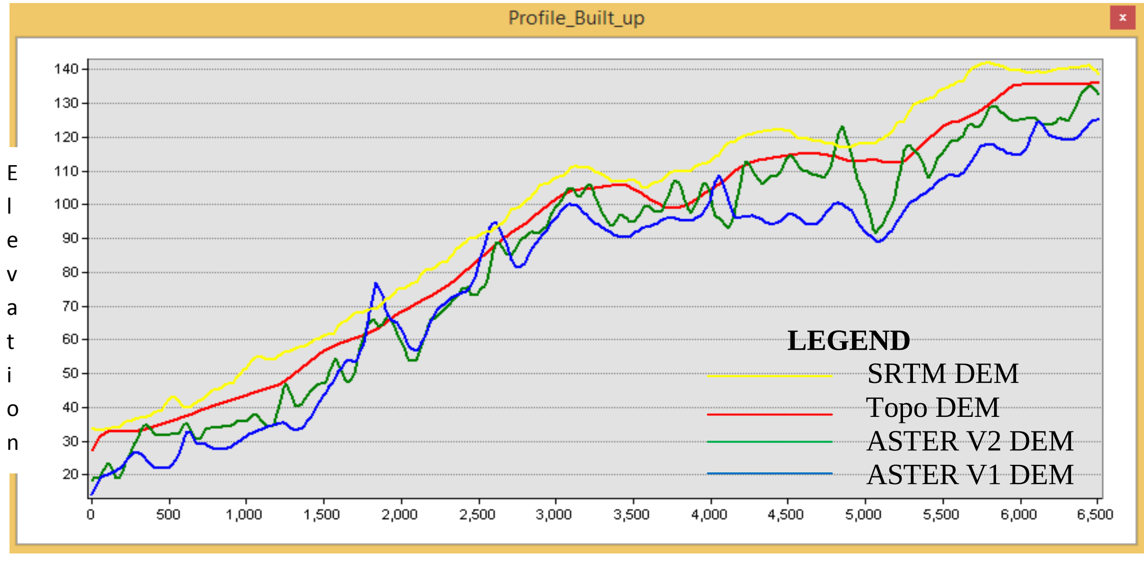


Fig (3.2a) Horizont ained for Built up land cover type

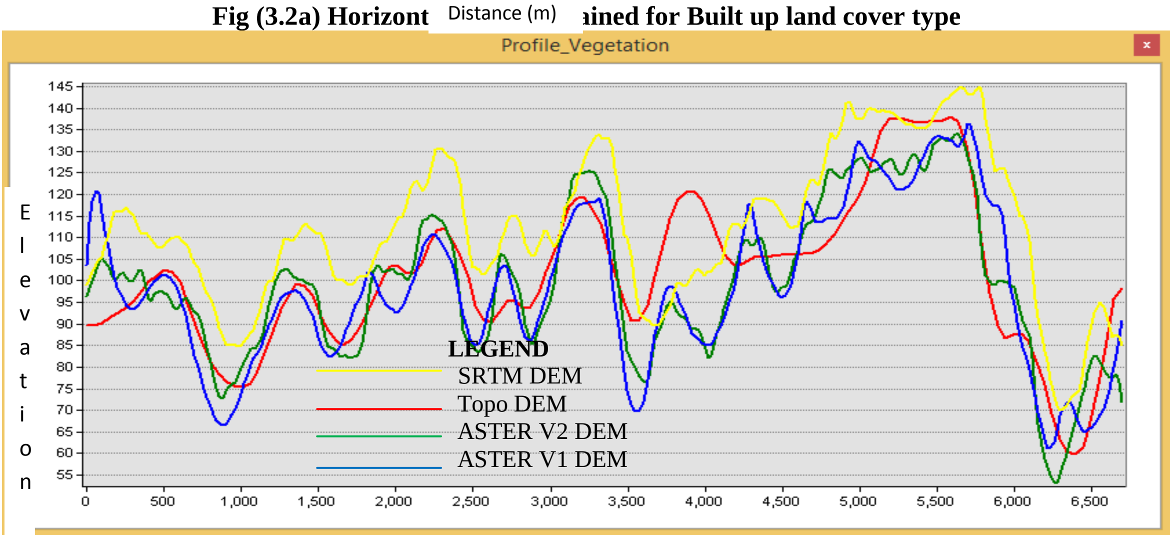


Fig (3.2b) Horizontal Profile obtained for vegetation land cover type

Distance (m)

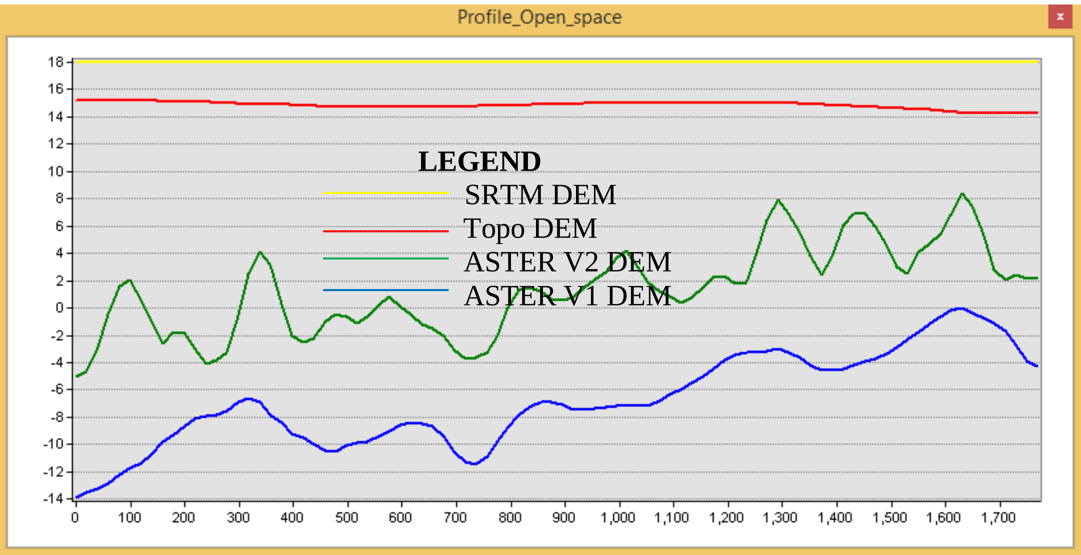


Fig (3.2c) Horizontal Profile obtained for Open space land cover type

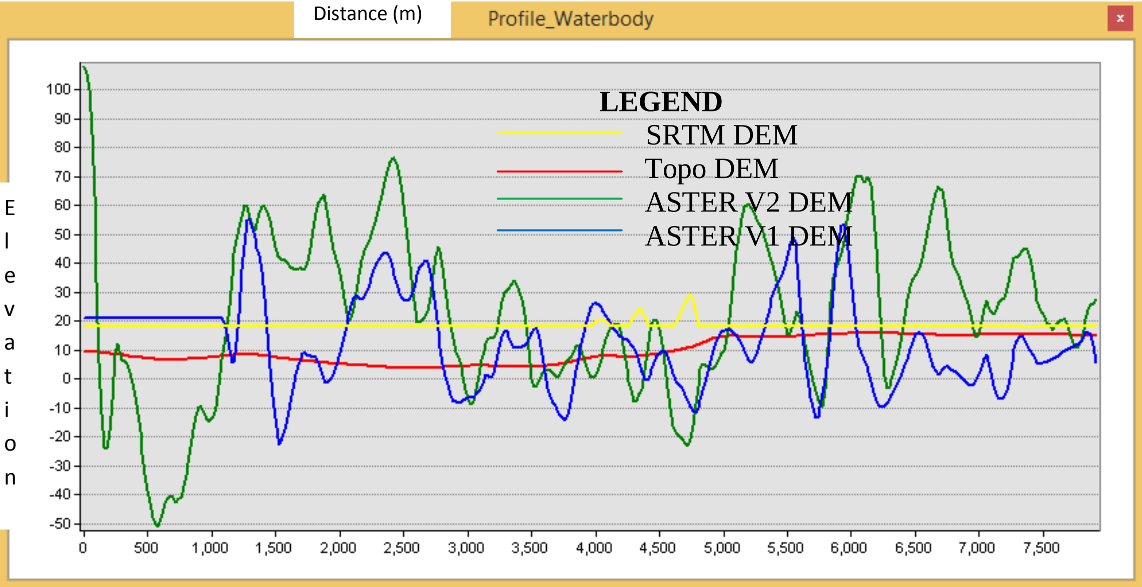


Fig (3.2d) Horizontal Profile obtained for waterbody land cover type

Distance (m)

The topographic DEM is represented in Red colour while ASTER ver2 is represented in Green colour. Also, ASTER ver1 and SRTM are represented in Blue and Yellow colour respectively. From the Built up profile in fig (3.2a), it can be seen that SRTM overestimated the elevation when compared to the Topographic DEM as the reference DEM. ASTER ver1 and ASTER ver2 underestimated the elevation under built up influence. The Pearson correlation test shows that the three datasets expresses a negative weak relationship with the topographic DEM. SRTM has a correlation value of -0.091 while ASTER ver1 and ASTER ver2 has a correlation values of -0.075 and -0.101 respectively.

Also, it can be seen from vegetation cover profile in fig (3.2b) that SRTM overestimated the elevation under vegetation influence. The same applies to ASTER ver1 and ASTER ver2 respectively. A weak relationship was also noticed here. SRTM has a correlation value of 0.05, ASTER ver1- 0.043, and ASTER ver2- 0.029. SRTM seem to overestimate elevation in an open space while ASTER ver1 and ASTER ver2 underestimate elevation in open space. SRTM follows the same linear topographic pattern with that of the reference topographic DEM as is evident in the profile in fig (3.2c). This is not the case with ASTER ver1 and ASTER ver2. The correlation result shows a weak relationship with ASTER ver1 having a value of -0.068 while ASTER ver2 and SRTM have a value of -0.052 and -0.034 respectively.

For water body land cover type, SRTM shows a close resemblance to the reference Topographic DEM. It shows a flat profile. ASTER ver1 and ASTER ver2 overestimate elevation in water body. The correlation test shows that SRTM have a positive correlation value of 0.115 while ASTER ver1 and ASTER ver2 have a negative correlation value of -0.348 and -0.171 respectively.

IV. Conclusion And Recommendations

Most of the related literature works reviewed in this study failed to examine the impact of varied terrain configuration on the performance of the global elevation datasets. The study area was classified into five terrain categories-Flat, Undulating, Rolling, Hilly, and Mountainous terrain. This study have been able to show that SRTM shows a close resemblance to the reference topographic DEM than ASTER ver1 and ASTER ver2 datasets under flat and undulating terrain categories.

SRTM overestimated the earth surface under mountainous, rolling and hilly terrain categories while ASTER ver1 and ASTER ver2 underestimated the earth surface under the same terrain categories. Generally, SRTM overestimate elevation while ASTER ver1 and ASTER ver2 underestimate elevation.

Landuse/ landcover types affect the elevation values obtained from DEMs and subsequently on the performance of the DEM for hydrological modeling. This was evident in the results of the investigation of impact of landuse/ landcover on the performance of the DEMs. Under Built up, open space, and water body landcover types, SRTM compares favorably with the reference topographic DEM. SRTM, ASTER ver1 and ASTER ver2 overestimate elevation under vegetation influence. This study reveals that the impact of landuse/ landcover types are more pronounced in ASTER ver1 and ASTER ver2 elevation datasets than in SRTM.

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:

1. Further studies should be carried out on the evaluation of these global elevation datasets as new version of them are released for public use.
2. 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.
3. Despite the fact that SRTM is recommended for topographic and hydrological modeling in Onitsha and Environs, care should be taken when using this dataset in mountainous terrain.
4. SRTM should only be used in flat terrain while ASTER GDEMs should be used in hilly terrain. SRTM, ASTER ver1 and ASTER ver2 should not be used where there is dense vegetation.
5. SRTM and ASTER GDEM should be validated in other locations in Nigeria.
6. 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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