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# Accuracy assessment and conflation of DEMs over Kaduna State, Nigeria

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**ABSTRACT**

Digital Elevation Models (DEMs) are a type of raster data layer in which each cell has a value corresponding to its elevation (z-values at regularly spaced intervals). This study assess the vertical accuracy of four freely available DEMs (AW3D, ASTER SRTM and ALOS-PALSAR) over two test sites (hilly and plain) with reference to ground controls available on the test sites. However, to obtain a much higher resolution DEMs, these DEMs were fussed using Multiple Linear Regression Model and the performance of the fused DEM was tested over the hilly and plain terrain. At the plain terrain, ASTER DEM is closer to those of the GCPs (ground survey) than those of the ALOS PALSAR, AW3D and SRTM. At the hilly terrain, AW3D is closer to those of the GCPs (ground survey) than those of the ALOS PALSAR, ASTER and SRTM. After conflation, the conflated DEM performed better than the whole DEMs put together in the hilly and plain terrain.

## 1. Introduction

Digital elevation models (DEMs) are evenly spaced grids which thus contain the elevations of a point on the earth surface corresponding with the position of the grid cell(Fuss, 2013). They are also known as DTMs (digital terrain models) or DSMs (digital surface models) (digital surface model)(Fuss, 2013; Poon, Fraser, Chunsun, Li, & Gruen, 2005). Traditional techniques such as ground-based surveying was used to acquire elevation data sets. Thanks to the advancements in remote sensing technology, elevation data for hard-to-reach survey locations are now available (d'Ozouville et al., 2008; Fuss, 2013; Gao, 2007).

Due to the growth and improvement of technology, there have recently been multiple creations of various types of DEMs that are extensively utilized across the world. Amongst these uses to mention a few are; terrain correction (Hirt et al., 2019), errioin risk assessment (Nitheshnirmal, Thilagaraj, Rahaman, & Jegankumar, 2019), flood susceptibility mapping (Ibrahim et al., 2021), geomorphology (Szypuła, 2017) etcetera. Among these DEMs are the Advanced Land Observing Satellite-Phased Array-Type L-Band Synthetic Aperture Radar (ALOS-PALSAR) Radiometrically Terrain Corrected (RTC) DEM, (SRTM) Shutter Radar Topographical Mapper and Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER-GDEM) models, ALOS World 3D (AW3D) to name a few. These DEMs are notable for their good horizontal resolution and nearly worldwide coverage.

Studies such as (Elkhrachy, 2018; Forkuor & Maathuis, 2012; Suwandana, Kawamura, Sakuno, Kustiyanto, & Raharjo, 2012) have demonstrated that the accuracy of DEMs varies from region to region. The very recent release of these DEMs, particularly AW3D30 and SRTM-30, calls for opportunities to conduct localized assessments of the DEM's quality and accuracy to verify their suitability and improve on these DEMs using a fusion technique for a wide range of applications in hydrology, geomorphology, archaeology, and many others.

The process of integrating information from multiple data sources into a single one, thereby resolving differences is called conflation (Samsonov, 2020). It solves misalignment issues of DEMs by adjusting the spatial relationship or transferring attributes between them. Conflation can equally mean Fusion.

For example, there is currently no freely accessible topographic map that can easily offer topographic information for different scientific purposes in Kaduna State, and it is well-known that terrestrial collecting of

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geospatial data is more tedious, time-consuming, and expensive than doing it remotely. Although several studies have been carried out on the accuracy assessment and conflation of DEMs in different parts of the world, yet there is no comprehensive study on the vertical accuracy and conflation of these freely available DEMs over Kaduna State. This Study hence addresses this problem.

## 2. Study area

The state of Kaduna, illustrated in Fig. 1, is located between Latitudes 9° 10'N and 11° 40'N and Longitudes 6° 02'E and 8° 50'E and spans an area of 44,408.3 square kilometers. The state is bordered to the south-west by Abuja – the Federal Capital Territory and Niger State, to the north-west by Katsina and Zamfara states, to the north-east by Kano and Bauchi states, as well as to the south-east by Plateau and Nasarawa states.

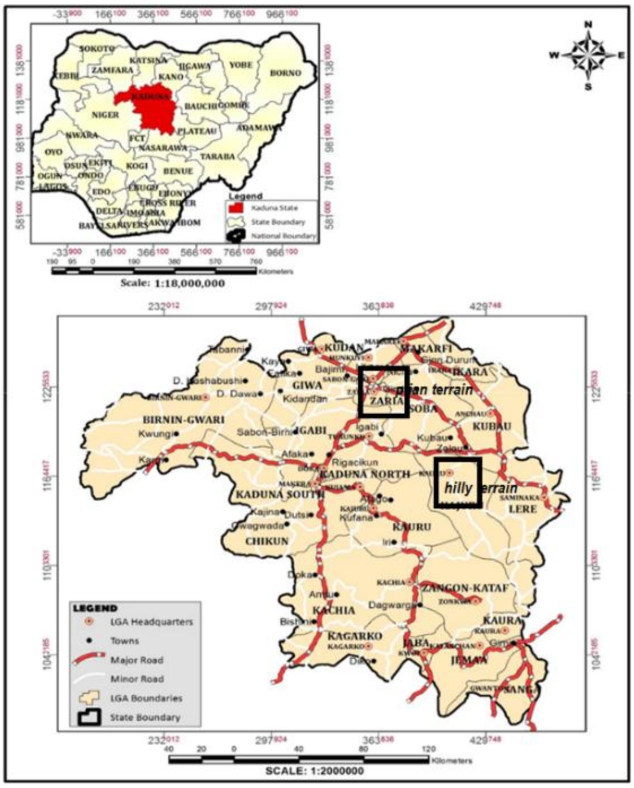


**Figure 1.** Inset map of the Study area.

## 3. METHOD

### 3.1. Datasets and source

Table 1 presents the data set and their sources adopted for the study. Ground control point height for two different terrain which is the plain terrain at Ahmadu Bello university campus, Zaria and hilly terrain at Kajuru local government all located at Kaduna state. 15 ground control points were established for plain terrain and 12 Ground control points were established for the hilly terrain. The corresponding ground control points (GCP) at the plain and hilly terrain were used for assessment.

**Table 1.** Dataset and source adopted for the study

| S/N | Data | Resolution | Sources |
|---|---|---|---|
| 1 | SRTM | 30m | * |
| 2 | ALOS PALSAR | 12.5 m | ** |
| 3 | AW3D | 30m | * |
| 4 | ASTER | 30m | * |

* http://eaerthexplorer.usgs.gov/
**http://asf.alaska.edu.com

### 3.2. Data manipulation

Downloaded DEMs were mosaicked and clipped. Unlike the ALOS PALSAR 12.5m DEM having its projected coordinate system already in WGS 1984 ZONE 32N. The other DEMs like ASTER, SRTM and AW3D projection system were the GCS (Geographic Coordinate System) 1984. So, in other to avoid errors due to the varying projection systems, all the DEMs were re-projected to WGS 1984 zone 32N. Thereafter, corresponding spot height were extracted using the fish netting tool in ArcGIS 10.6.

### 3.3. Conflation of DEMs using multiple linear regression (MLR)

When it comes to merging different variables, regression analysis is crucial. By combining DEMs from many sources, the purpose of employing multiple regression models in elevation models is to achieve a reduced height error probability and improved dependability. The MLR model, as represented in Equation 1, is used.

$$\mathrm{Y}=Ax1 + Bx2 + Cx3 + Dx3 + k \qquad (1)$$

Where a, b, c, d are the respective coefficient and k is the constant and Y is the fussed DEM.

## 4. Results and discussions

### 4.1. Overall spot heights estimation performance

Corresponding heights for 15 points for plain terrain and 12 points for hilly terrain were obtained from the different DEMs spatial data generated from (SRTM 30, ALOS PALSAR, ASTER and AW3D.) and were compared with GCPs. Table 2 depicts the descriptive statistics for spot heights for plain terrain from which it is obvious that the calculated standard error, standard deviation and sample variance from the ASTER DEM is closer to those of the GCPs (ground survey) than those of the ALOS PALSAR, AW3D and SRTM. The descriptive statistics for the spot heights as presented in Table 2 clearly show the poor relationship of the ALOS PALSAR, AW3D and SRTM DEM data source when compared to the GCPs (ground survey) sources under investigation.

Fig. 2 presents the variations of spot height for plain terrain from the various sources of DEMs and it is clear that the ASTER and AW3D DEM tends to be closer to the reference source more than any other.

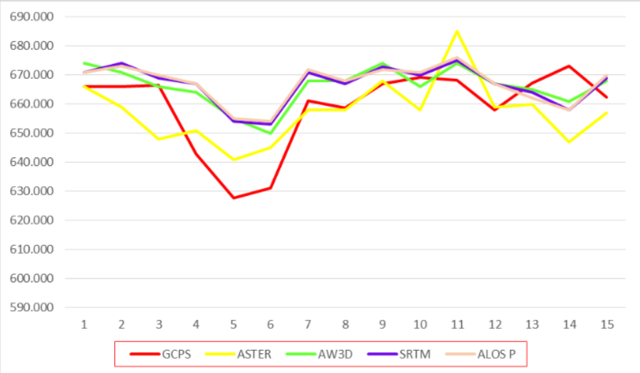


**Figure 2.** Scattered plot for spot height of the various DEMs for plain terrain

Table 3 depicts the descriptive statistics for spot heights for hilly terrain from which it is obvious that the calculated standard error, standard deviation and sample variance from the AW3D is closer to those of the GCPs (ground survey) than those of the ALOS PALSAR, ASTER and SRTM. This clearly shows the poor relationship of ALOS-PALSAR, ASTER and SRTM DEM data sources when compared to other data sources under investigation.

**Table 2.** Descriptive statistics of the various spot height for plain areas

| S/N | Statistics | GCPS | ALOS-PALSAR | ASTER | AW3D | SRTM |
|---|---|---|---|---|---|---|
| 1 | M | 659.07 | 667.09 | 657.33 | 666.07 | 666.80 |
| 2 | SE | 3.60 | 1.74 | 2.78 | 1.74 | 1.76 |
| 3 | MD | 666.15 | 670.02 | 658.00 | 667.00 | 669.00 |
| 4 | SD | 13.93 | 6.75 | 10.76 | 6.75 | 6.83 |
| 5 | SV | 194.11 | 45.58 | 115.81 | 45.50 | 46.60 |
| 6 | KU | 1.25 | -0.20 | 2.13 | 1.27 | 0.21 |
| 7 | SK | -1.52 | -0.95 | 0.97 | -1.07 | -1.05 |
| 8 | R | 45.45 | 22.03 | 44.00 | 24.00 | 22.00 |
| 9 | MI | 627.68 | 653.99 | 641.00 | 650.00 | 653.00 |
| 10 | MA | 673.13 | 676.03 | 685.00 | 674.00 | 675.00 |
| 11 | S | 9886.06 | 10006.29 | 9860.00 | 9991.00 | 10002.00 |
| 12 | C | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 |
| 13 | CL | 7.72 | 3.74 | 5.96 | 3.74 | 3.78 |

**Mean (M), Standard Error (SE), Median(MD), Standard Deviation (SD), Sample Variance (SV), Kurtosis (KU), Skewness (SK), Range (R) Minimum(MI), Maximum(MA), Sum(S), Count(C), Confidence Level(CL)( (95.0%)

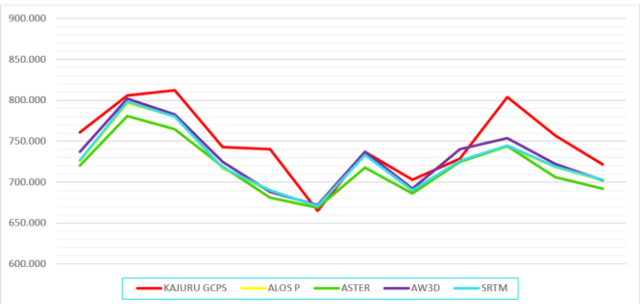


**Figure 3.** Scattered plot for spot heights for hilly terrain of the various

**Table 3.** Descriptive statistics of the various spot height for hilly areas

| S/No | Statistics | GCPS | ALOS-PALSAR | ASTER | AW3D | SRTM |
|---|---|---|---|---|---|---|
| 1 | M | 748.10 | 724.32 | 717.17 | 729.50 | 725.00 |
| 2 | SE | 12.64 | 10.56 | 9.74 | 11.08 | 10.57 |
| 3 | MD | 741.42 | 721.48 | 718.50 | 731.00 | 722.50 |
| 4 | SD | 43.78 | 36.59 | 33.73 | 38.39 | 36.63 |
| 5 | SV | 1917.12 | 1338.80 | 1137.61 | 1473.55 | 1341.64 |
| 6 | KU | -0.15 | 0.25 | -0.28 | -0.21 | 0.30 |
| 7 | SK | -0.09 | 0.69 | 0.52 | 0.42 | 0.69 |
| 8 | R | 147.30 | 125.97 | 112.00 | 130.00 | 127.00 |
| 9 | MI | 664.81 | 670.51 | 669.00 | 672.00 | 671.00 |
| 10 | MA | 812.11 | 796.48 | 781.00 | 802.00 | 798.00 |
| 11 | S | 8977.23 | 8691.89 | 8606.00 | 8754.00 | 8700.00 |
| 12 | C | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 |
| 13 | CL | 27.82 | 23.25 | 21.43 | 24.39 | 23.27 |

**Mean (M), Standard Error (SE), Median(MD), Standard Deviation (SD), Sample Variance (SV), Kurtosis (KU), Skewness (SK), Range (R) Minimum(MI), Maximum(MA), Sum(S), Count(C), Confidence Level(CL)( (95.0%)

Fig. 3 represents the variations of spot height for hilly terrain from the various sources of DEMs and it is clear that the AW3D and SRTM DEM tends to be closer to the reference source more than any other.

### 4.2. Overall spot heights estimation performance of the fussed DEM

The DEM for the study area were fussed and subsequently tested for the hilly and plain test sites, while considering ALOS-PALSAR as the reference DEM. To test the accuracy of the fused DEM, corresponding spot heights for the 15 points for plain terrain and 12 points for hilly terrain were extracted respectively. Table 4 depicts the descriptive statistics for spot heights for the fussed plain terrain from which it is obvious that the calculated standard error, standard deviation and sample variance from the FUSSED DEM is closer to those of the GCPs (ground survey) than those of the ALOS-PALSAR, ASTER, AW3D and SRTM.

**Table 4.** Descriptive statistics plain terrain

| S/N | Statistics | ABU GCPS | ALOS-PALSAR | ASTER | AW3D | SRTM | FUSSED DEM |
|---|---|---|---|---|---|---|---|
| 1 | M | 659.07 | 667.09 | 657.33 | 666.07 | 666.80 | 661.03 |
| 2 | SE | 3.60 | 1.74 | 2.78 | 1.74 | 1.76 | 2.75 |
| 3 | SD | 13.93 | 6.75 | 10.76 | 6.75 | 6.83 | 10.63 |
| 4 | SV | 194.11 | 45.58 | 115.81 | 45.50 | 46.60 | 113.04 |
| 5 | MI | 627.68 | 653.99 | 641.00 | 650.00 | 653.00 | 634.32 |
| 6 | MA | 673.13 | 676.03 | 685.00 | 674.00 | 675.00 | 675.04 |
| 7 | CL | 7.72 | 3.74 | 5.96 | 3.74 | 3.78 | 5.89 |

Table 5 depicts the descriptive statistics for spot heights for hilly terrain from which it is obvious that the calculated standard error, standard deviation and sample variance from the FUSSED DEM is closer to those of the GCPs (ground survey) than those of the ALOS PALSAR, ASTER, AW3D and SRTM.

**Table 5.** Descriptive statistics hilly terrain

| S/No | Statistics | KAJURU GCPS | ALOS-PALSA | ASTER | AW3D | SRTM | FUSSED DEM |
|---|---|---|---|---|---|---|---|
| 1 | M | 748.10 | 724.32 | 717.17 | 717.17 | 725.00 | 748.10 |
| 2 | SE | 12.64 | 10.56 | 9.74 | 9.74 | 10.57 | 11.36 |
| 3 | SD | 43.78 | 36.59 | 33.73 | 33.73 | 36.63 | 39.34 |
| 4 | SV | 1917.12 | 1338.80 | 1137.61 | 1137.61 | 1341.64 | 1547.87 |
| 5 | MI | 664.81 | 670.51 | 669.00 | 669.00 | 671.00 | 692.33 |
| 6 | MA | 812.11 | 796.48 | 781.00 | 781.00 | 798.00 | 832.56 |
| 7 | CL | 27.82 | 23.25 | 21.43 | 21.43 | 23.27 | 25.00 |

## 5. Conclusion

DEM are models used for the creation of relief maps, rendering of 3D visualizations, modelling of water flow for hydrology or mass movement, etcetera. In this study, we assessed the reliability and fusion of four freely available elevation data (ALOS-PALSAR, AW3D, ASTER AND SRTM) for public use. Using the multiple linear regression model technique, the four DEMs were fussed and tested over two different terrain (hilly and plain). The fussed DEM tend to have an improvement with respect to referenced GCP of the terrain. Finally, it is important to point out that accuracy of DEMs be properly understood before they are utilized in varying applications.

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