Quality Analysis of OpenStreetMap and Digital Elevation Data Based North-Western Nigeria

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SUMMARY

The quality of Open street map (OSM) was tested for Katsina Local Government area of Nigeria. The study focused on the accuracy of position, naming, type, topology and completeness of OSM roads in the area. This study also analyzed the quality DEM of Sunshine Quarry Site in Igabi Local Government Area of Kaduna State Nigeria acquired through GPS Visualizer online utility and OpenStreetMap of Katsina metropolis. This was achieved by comparing the digital elevation data with Differential GPS heights to check the accuracy of the SRTM heights. The outcomes of the study revealed that the shift of road position is within allowable limit and the accuracy of classification of the road is 98%, only 26% of the roads were labeled. The roads have no topology. OSM cannot be used for network analysis. Also the open source digital elevation achieved 90.8% accuracy and its therefore good for hydrological analysis of large area and preliminary design of engineering structures. The study recommends quality analysis of every open source data before use.

Introduction

Open Source geospatial data is an easily accessible data available to the public without any restrictions. Open source was founded by Open Source Initiative (OSI) in 1998, to promote education, awareness and public advocacy for the betterment of the society and data itself. Open source aims to create a free digital map of the world through the engagement of participants. Open source initiative save cost, time and resources for mapping projects.

OpenStreetMap, OSM (Haklay and Weber, 2008) project is a part of Open Source Project or Volunteered Geographical Information (VG1) (Goodchild 2007). The aim of the VGI is to create a free digital map of the whole world through the engagement of participants across the glove. The information is collected, collated on a central database and distributed in digital form (Mondzech and Sester 2011). OSM is used for the creation of street guide easily, efficiently, quickly, on-demand and in a cost effective manner.

The use of crowdsourcing activities to create reliable sources of information is not without difficulties. These activities are carried out by volunteers, who work independently and without co-ordination, each concentrating on their own interests. Furthermore, the participants are may not be professionals (Keen, 2007) and therefore do not follow common standards in terms of data collection, verification and use. (Tapscott and Williams, 2006; Friedman, 2006).

In the area of Geospatial data, information quality has been the essential aspect of research agenda (Goodchild, 1992). Therefore, considering issues associated with OSM such as data collection by amateurs, the distributed nature of the data collection and lack of standards. One of the significant core questions about this type of data is ‘how good is the quality of the information?

Analysis of the quality of geographical databases received the attention from mapping professionals. Van Oort, 2006 identified work on the quality of geographical information dating back to the late 1960s and early 1970s. With the emergence of GISystems in the 1980s, quality assessment witness rapid growth, receiving attention from experts including Peter Burroughs and Andrew Frank (1996), Mike Goodchild (1995), Peter Fisher (1999), Nick Chrisman (1984) and many others.

In 2002, quality aspects of geospatial data had been enshrined in the International Organisation for Standards (ISO) under the aegis of Technical Committee (Mondzech and Sester 2011). In their review Kresse and Fadaie (2004) identified completeness, logical consistency, positional accuracy, temporal accuracy, thematic accuracy, purpose, usage and lineage as aspect of data quality. this study intends to use recent map and satelite imageries to analyse the quality of an OSM of Katsina using quality parameters identified by Kresse and Fadaie (2004).

A Digital Elevation Model (DEM) is a representation of the bare ground surface in 3D without any objects. DEM is represented as raster in which the value of each pixel is associated with a topographic height. Digital Surface Model (DSM) represented the surface of the earth and all features on it (Maune, 2007 and Gold et al., 2008).

DEMs are often used in geographic information systems (GIS) and are used to produce relief maps. The DSM is applicable in landscaping, visualization, and 3D digital city modelling (Groeger et al., 2008). The DTM also is applicable for flood/drainage modeling, terrain analysis and other uses (Akeem & Aina 2013 and Elkhrachy, 2015).
Global elevation datasets are inevitably subjected to errors, due to the methodology followed to extract elevation information and the various processing steps the models have undergone (Nikolakopoulos, 2006 and Liu, 2016)

DEM can be generated from topographic maps, data collected with GPS receivers/total station levelling and photographs or satellites imageries. (Elkhrajchy, 2018) based on cost, quality, resolution and pre-processing requirements each technique has its advantages and drawbacks. Remote sensing data are frequently use to generate DEM due to cost effectiveness, large area and inaccessible area coverage with the required spatial, spectral and temporal resolutions to interpolate new DEMs (Kobrick, 2006)

In 1986, SPOT images was the first satellite data to provide basis for the extraction of DEMs. In 2003, SRTM (v3) DEM free data set released by NASA for some regions, with one arc-second resolution for the globally with vertical error of ±16 m (Miliaresis 2005). STRM is available in 5 degree 5-degree tiles, in geographic decimal degrees projection, World Geodetic System 1984 (WGS84) And Earth Gravitational Model (EGM96) geoid horizontal and vertical datum.

Positional accuracy of X and Y, accuracy of the attribute (heights) or both are the three errors of DEM. It is very essential to analyze error sources to calculate the quality of DEMs derived from SRTM (Elkhrajchy, 2018).

Data acquisition, baseline length and orientation, phase, slant range and position of the antenna. data processing steps, and the influences of vegetation and land cover are factors introducing uncertainties of SRTM DEM. For both products (DEMs from SRTM), it is important to examine the quality of the dataset before usage carefully. Several researchers have checked the accuracy of SRTM in many places by using Ground Control Points (GCP) measured by differential GPS or by using elevations from topographic maps (Bolkos et al., 2016).

The quality of an open source geospatial data has been studied extensively and generally (Mondzech and Sester 2011, Elkhrachy, 2015, Bolkos et al., 2016, Bawa et al., 2021). However, each area has its peculiarity - different local conditions and influence, terrain and the rate at which open source community updates its information. Thus, there is need to continue validating open source data and particularly where such studies were not done intensively before, such as the Sun shine quarry site and Katsina metropolis.

In this paper, the quality of SRTM DEMs for sunshine quarry site in Igabi LGA of Kaduna State examined by using GCPs measured with GPS receiver and are differentially corrected using the GPS base station.

Study Area

Two sites were selected for this study, First, Sunshine quarry site Sunshine Quarry is a commercial quarry owned by the Chinese (Sunshine Quarry Nig. Ltd). The quarry is located between latitudes 10^0 53′ 40.36" to 10^0 52′ 48.06"N and longitude 07^0 38′ 16.73" to 07^0 39′ 47.11"E in Igabi LGA of Kaduna State. And the second, Katsina metropolis is the capital of Katsina State; it is located between Latitudes 120 55’ 30” N – 130 03’0” N of the Equator and Longitudes 70 33’ 0” E – 70 40’0” E of the Greenwich meridian.

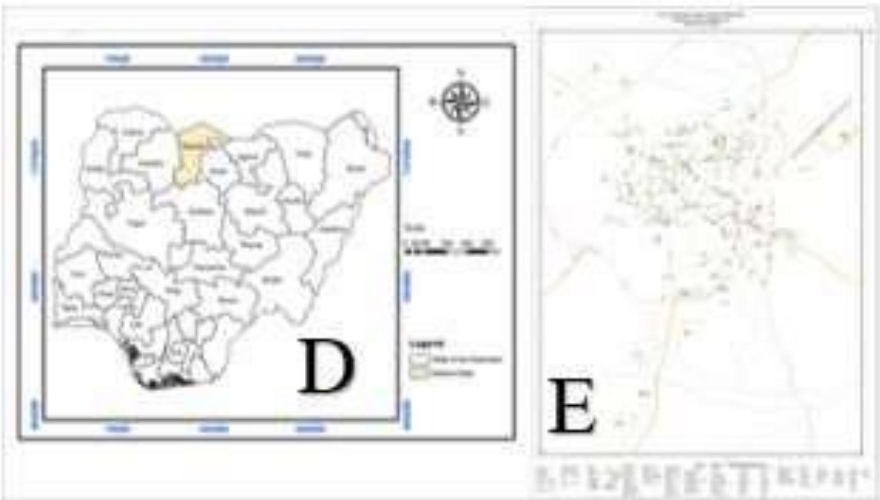

Figure 1 (A) Nigeria (B) Kaduna state (C) Igabi (D) Katsina State (E) Katsina LGA

2. **MATERIALS AND METHODS**

2.1 Materials

2.1.1 Software used and the application

a. ArcGIS version 10.4.1 for data pre-processing and analysis
b. GPS Visualizer for the extraction of position and heights of a corresponding GPS coordinates
c. SPSS for statistical analysis

2.1.2 Data used

a. SRTM Digital elevation of sunshine quarry site
b. OSM and Street guide of Katsina Local Government Area
c. 0.6 meters resolution image of Katsina metropolis
d. GPS coordinates of sampled locations in sunshine quarry site

2.2 Method

OSM was converted to shapefiles file extension to enable spatial analysis on the data. The extend of the study area was clipped to save time and storage. Then, it was projected from Geographic coordinate to WGS84 Zone 32N to pave the way for data overlaid. The street guide of the study area was scanned, georeferenced, vectorized and buffered to 6 meters buffer zone for proper comparison and overlay analysis. The total length of trunk, primary, secondary and tertiary roads in both OSM and street guide were computed using ArcGIS attribute table tools. The completeness was analyse using equation 1. Intersection analysis was carried out between 6 meters buffer zone and OSM roads to check positional accuracy. Identity tool was used to check the attribute information of both the maps. Street on the OSM with attribute information were counted. Also, streets with correct and wrong attribute were taken care off. Katsina state government renamed about fifty roads within the metropolis this was also checked in the attribute information of the OSM to analyse how often the attribute information is updated by the open source community. This study also analysed the classification of roads to check consistency between the map and the image of the study area. Finally, connectivity was analyse using the following rules must be larger than cluster tolerance, features must not overlap, features, must not have dangles, features must not Intersect or touch Interior to check the topology of the OSM.

$$\sum \text{(OSM roads length)} - \sum \text{(Street guide roads length)} \qquad (1)$$

As for the analysis of the accuracy of SRTM Digital and GPS elevation. Topcon GPS receiver in static mode was used to capture 23 coordinates and heights of selected points. These coordinates were converted to KMZ file extension using ArcGIS software. The KMZ file, was uploaded to GPS visualizer online utility. The coordinates and heights of the corresponding GPS positions were extracted by the visualizer and download. GeodEval online calculator was used to compute the Geod heights (EGM96) of each position. The equation 2 the ellipsoidal height of each position was computed.

$$h = H + N \qquad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad 2$$

where h is an ellipsoidal height, H is the optometric heights and N geod undulation.

The 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), and Count(C), of both GPS and DEM heights were computed and compared. Longitudinal profile of both the GPS and DEM heights were drawn and compared.

Results and Analysis

Positional accuracy – From figure 2 and plate 1 the result of the analysis of positional accuracy reveals the roads are within 6 meters butter zones around the digitized roads from the street guide map. The average shift distance is 3 meters.

Completeness –The total length of Trunk, Primary, Secondary and Tertiary roads (see plate 2) on both the street guide and OSM are the same (319624 meters)

Logical consistency – Analysis of connectivity (on figure 3) among the roads revealed 447 dangle (disconnection) and 7551 intersections and 0 overlap

Attribute accuracy – Comparison between OSM and street guide of Katsina metropolis in terms of attribute or name of the roads shows only 37 out of 140 roads on OSM were named (see table 3 and 4).

Temporal quality – the rate at which the database and geometrical information change with time is very slow because Katsina state government rename about fifty roads in town and some single lane roads were dualized since 2016. These changes were not shown on the map as shown on figure 5 and 6.

Semantic accuracy – OSM is Katsina metropolis were captured completely including footpath and even as low as track and were represented correctly.

Plate 1 Overlaid OSM and Image of the area depicting OSM shift from the center

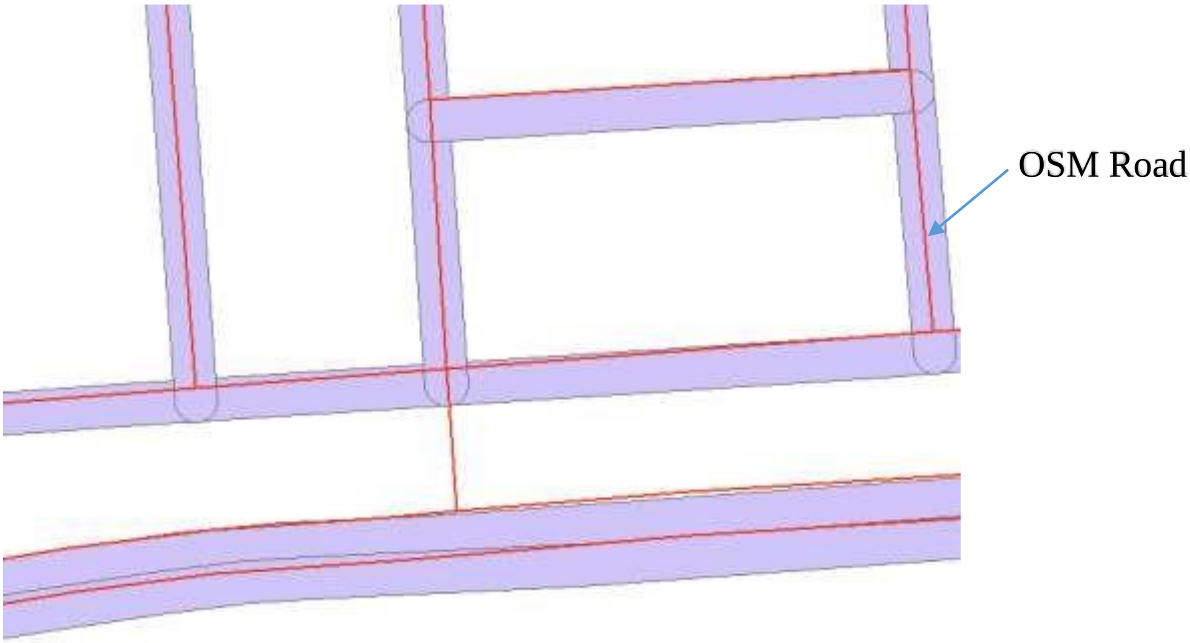

Figure 2 Overlaid OSM and 6 meters bufferzone

Plate 2 overlaid satelite image of the study area and OSM depicting completeness

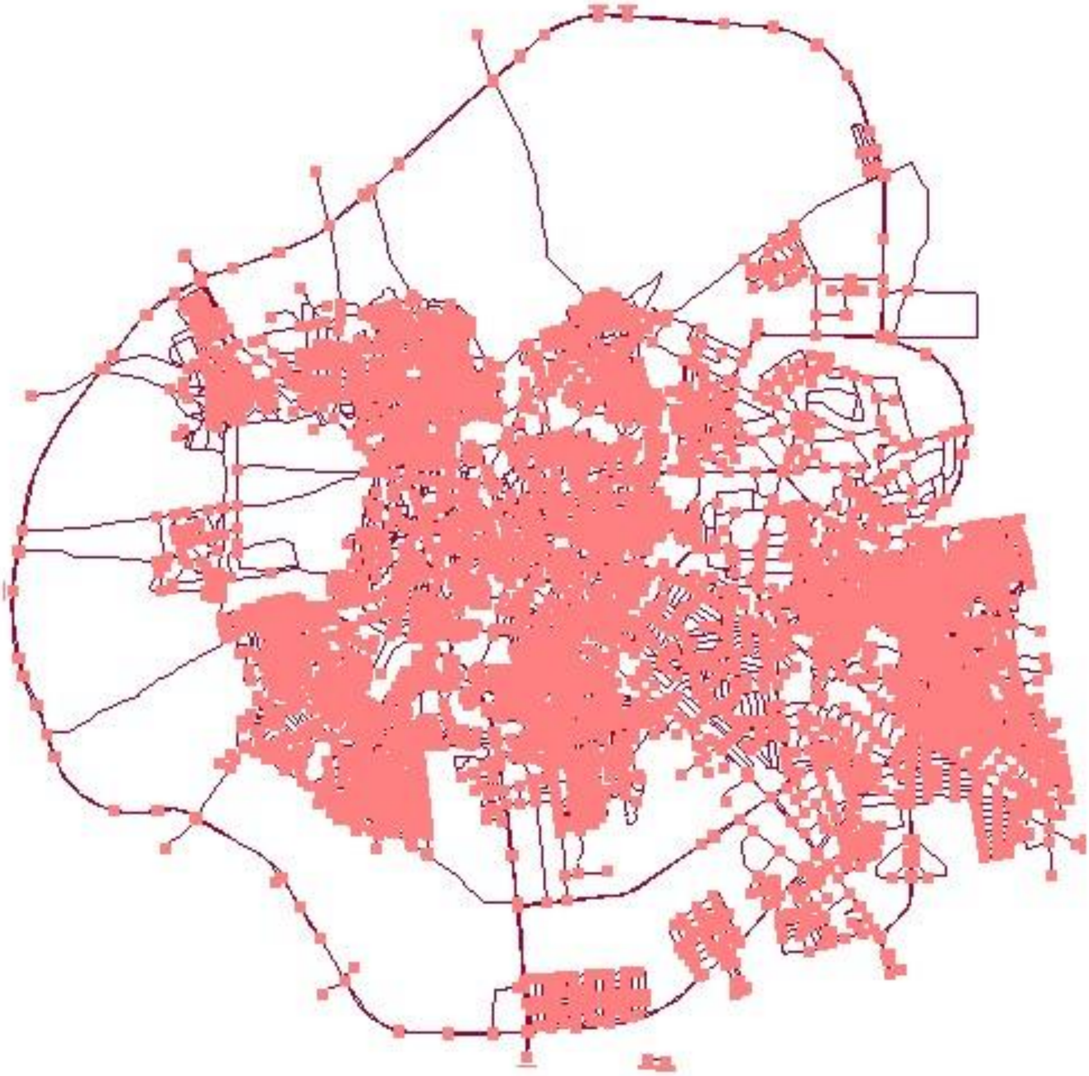

Figure 3 Result of topological analysis depicting point errors

The results of the closeness of SRTM Digital elevation and GPS heights is presented in Table 1, 2 and Figure 4. From table 1 the accuracy of SRTM compared with GPS is about 90.8%. also figure 4 depicted the graph of GPS and SRTM heights, from the graph the relationship two heights are is very strong (R^2 Linear = 0.825). The standard deviation and standard error of both SRTM and GPS on table are closer. The relationship is given by Equation 3

$$GPS_{reading} = 0.71DEM_{SRTM} + 1400 \quad 3$$

Table 1 Correlation between DEM AND GPS Heights

		DEM Heights	GPS Heights
DEM Heights	Pearson Correlation	1	.908**
	Sig. (2-tailed)		<.001
	N	23	23
GPS Heights	Pearson Correlation	.908**	1
	Sig. (2-tailed)	<.001	
	N	23	23

**. Correlation is significant at the 0.01 level (2-tailed).

Table 2 Descriptive statistics SRTM and GPS Heights

		DEM Heights	GPS Heights
N	Valid	23	23
	Missing	0	0
Mean		651.237783	720.4983
Std. Error of Mean		1.3766396	1.76116
Median		651.143000	719.9333
Mode		640.3080	706.04
Std. Deviation		6.6021314	8.44621
Variance		43.588	71.338
Skewness		0.235	0.205
Std. Error of Skewness		0.481	0.481
Kurtosis		-0.910	-0.813
Std. Error of Kurtosis		0.935	0.935
Range		23.3640	30.79
Minimum		640.3080	706.04
Maximum		663.6720	736.83
Sum		14978.4690	16571.46
Confidence level		0.793	0.961

Table 3 Attribute table of Street guide complete attribute

Table

Street guide of Katsina Metropolis

FID	Shape *	Id	Distance	Code	Type
0	Polyline	0	9390.24	1	Ibrahim Shehu Shema Way
1	Polyline	0	7932.27	1	Aminu Bello Masari Way
2	Polyline	0	4722.89	1	Abu Gidado Way
3	Polyline	0	3908.48	1	Abba Musa Rimi Way
4	Polyline	0	1783.94	1	Lawal Kaita Way
5	Polyline	0	2121.6	1	Saidu Barda Way
6	Polyline	0	2911.7	1	Umaru Musa Yar' adua Way
7	Polyline	0	1795.97	1	Aminu Zayyad Crescent
8	Polyline	0	2900.37	2	Murtala Muhd Way
9	Polyline	0	1697.95	2	Yahaya Madaki Road

(0 out of 581 Selected)

Table 4 Attribute table of OpenStreetMap with incomplete attributes

Table

OpenStreetMap of Katsina metropolis

FID	Shape *	osm_id	code	fclass	name
58	Polyline	213163419	5114	secondary	Kaita Road
59	Polyline	213163420	5115	tertiary	
60	Polyline	213163421	5115	tertiary	
61	Polyline	213163422	5114	secondary	
62	Polyline	213163423	5114	secondary	
63	Polyline	213163424	5114	secondary	
64	Polyline	213163425	5115	tertiary	
65	Polyline	213163426	5114	secondary	
66	Polyline	213163429	5114	secondary	
67	Polyline	213163430	5121	unclassified	

(0 out of 6323 Selected)

Table 5 Attribute table of street guide showing current attribute

Table

OpenStreetMap of Katsina metropolis.

FID	Shape *	Id	Distance	Code	Name
0	Polyline	0	9390.24	1	Ibrahim Shehu Shema Way
1	Polyline	0	7932.27	1	Aminu Bello Masari Way
2	Polyline	0	4722.89	1	Abu Gidado Way
3	Polyline	0	3908.48	1	Abba Musa Rimi Way
4	Polyline	0	1783.94	1	Lawal Kaita Way
5	Polyline	0	2121.6	1	Saidu Barda Way
6	Polyline	0	2911.7	1	Umaru Musa Yar' adua Way
7	Polyline	0	1795.97	1	Aminu Zayyad Crescent
8	Polyline	0	2900.37	2	Murtala Muhd Way

(0 out of 581 Selected)

Table 6 Attribute table of OpenStreetMap with previous name

Table

features

osm_id	code	fclass	name	ref	oneway	maxs
213163368	5113	primary			F	
213163369	5113	primary			F	
213163370	5113	primary			F	
213163371	5113	primary	Ring Road		F	
213163372	5113	primary	Ring Road		F	
213163373	5113	primary	Ring Road		F	
213163374	5113	primary	Ring Road		F	
213163375	5115	tertiary			F	

(0 out of 6323 Selected)

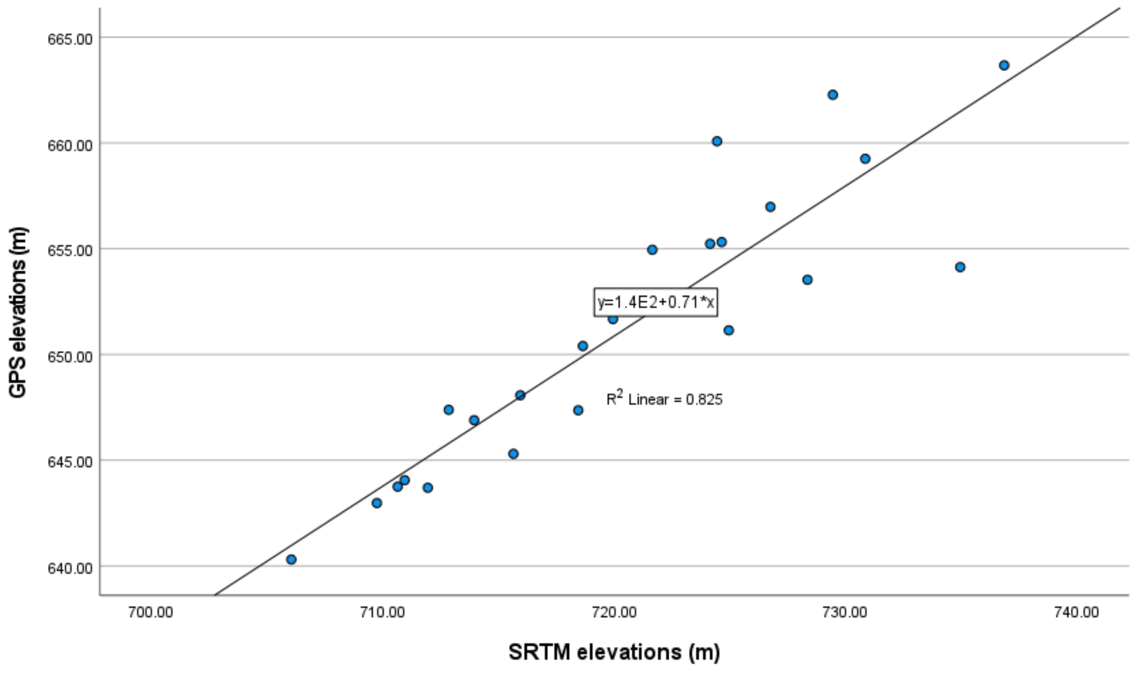

Figure 4 Scattered plot for SRTM and GPS heights

Conclusion

OpenStreetMap has a general shift of 3 meters, its 100% complete, only 26% of the OSM in Katsina metropolis were identified labelled and it has no topology. OSM is good for street guide mapping of an area. It cannot be used for geodetic network analysis as there is no connectivity among the nodes and edges of the roads. The correlation between SRTM and GPS heights is 90.8%. Descriptive statistics indicate the standard deviation, standard error and confidence measure of SRTM is closer to GPS heights. SRTM is suitable for terrain analysis of large area and preliminary design of engineering structures. This study recommends quality analysis of each open source data before use

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