Journal of Scientific Research & Reports
3(1): 170-184, 2014; Article no. JSRR.2014.008

SCIENCEDOMAIN *international*
www.sciencedomain.org

Attributes of Topographic Mapping of a Fast Urbanising Area in Nigeria, Using Remote Sensing and GIS

Olarewaju O. Ifatimehin[1], Fanan Ujoh[2*] and Patrick S. U. Eneche[1]

[1]Department of Geography and Planning, Kogi State University, Anyigba, Nigeria.
[2]Department of Urban and Regional Planning, Benue State University, Makurdi, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author OOI designed the study, performed the statistical analysis, and wrote the protocol. Authors FU and PSUE managed the literature searches and analyses of the study wrote the first draft of the manuscript. All authors read and approved the final manuscript.

Research Article

Received 23rd March 2013
Accepted 31st July 2013
Published 9th October 2013

ABSTRACT

Aims: To produce an updated 1:25,000 topographic map of Anyigba through the application of geospatial technologies – GIS techniques, Remote Sensing data, GPS and other ancillary hardware and software.
Study Design: Application of satellite imageries and GIS software for the production of updated topographic map of Anyigba Town in Nigeria.
Place and Duration of Study: GIS Laboratory, Department of Geography and Planning, Kogi State University, Anyigba, Nigeria, between April and July 2012.
Methodology: Satellite image processing, classification and vectorization, visually-aided interpretation, digitization and geocoding of features, using ArcGIS 9.2, ILWIS 3.3 Academia, AutoCAD 2010 and Microsoft Excel 2010 software.
Results: Topographic map created through the integration of point map, contour line map, land use classification map, planimetric map, digital elevation model (DEM) and digital terrain model (DTM). The built-up area has grown in an omni-directional pattern, annexing most surrounding villages. It was discovered that Anyigba is characterized by a gentle undulating landscape architecture, with some areas of marked elevation and depression as against what was reflected in the old toposheets (248 NW and 268 SW)

**Corresponding author: E-mail: fananujoh@gmail.com;*

produced in 1973. The DEM and DTM generated from the 1973 toposheets and the satellite imageries of 2001, 2005 and 2008 showed that changes in the topography is a direct result of unplanned expansion of the built-up area.
Conclusion: The method is considered relatively cheaper and time-effective for updating topographic maps in Developing Countries where resources are scarce. The study suggests periodic research to update the topographic map of Anyigba as part of contributions towards building the much required National Elevation Dataset (NED) and Geospatial Data Infrastructure (GDI) in Nigeria for updating environmental planning and management.

Keywords: Topographic map; remote sensing and GIS; DEM; DTM; contour line map; planimetric map; point map; Anyigba.

1. INTRODUCTION

The issue of topographic mapping is of paramount concern to many nations, map users and cartographers. To the developing economies, topographic mapping heralds national efforts and programmes towards sustainable development [1]. While many developed nations have topographic sheets covering the whole area of their countries, developing nations are, till today, faced with the dearth of comprehensive topographic maps. The state of topographic mapping in Nigeria has not been quite efficient both in accuracy and in coverage as revealed by [2], [3] and [4]. However, during the last period of colonial mapping in Nigeria (i.e. the period of aerial photography), an adequate foundation had been laid for accurate topographic mapping, which started after the World War II [5]. Following this period, Nigeria adopted the 1:50,000 scale as the National topographic mapping scale in 1962. It had coverage of about 68.8% in 1979 and as at 1997 it had improved to over 83% coverage [2,6]. This shows clearly that the 1:50,000 topographic maps have not fully covered the entire country and even those that did in 1979 needed review in 1997. The 1991 Census in Nigeria was faced poor coverage due to the 1:50,000 topographic mapping and this led to the production of a new 1:50,000 planimetric line map to compensate for areas of the country where base maps were not available. As such, these un-contoured and incorrect planimetric maps produced in 1990 cannot adequately compensate for the absence of a topographic map of those areas in need [2,7].

The entire Nigeria has not been covered by 1:25,000 topographic maps [3,6,8]. This implies that Anyigba which appears on both Sheets 248 S.W and 268 N.W on the Index Map of Nigeria have not been mapped [6]. However, in recent times, the use of Remote Sensing (RS) and Geographic Information Systems (GIS) techniques in map production and revision has revolutionized the map-making processes. Apart from just getting a topographic map, the rapidity and magnitude of change of population size, expansion in development and resource exploitation, etc. in relation to the slow rate of traditional mapping programmes in Nigeria, pose an enigmatic dialect for planning as stressed by [2]. Consequently, several Nigerian authors have propagated the use of geospatial techniques to revise maps in Nigeria [9,10,11,12,13,14].

While many authors used high resolution satellite imageries (SPOT, QUICKBIRD, IKONOS etc.), others used medium resolution imageries (Landsat, Nigeriasat-1 etc.) for recent mapping efforts. For the purpose of third dimension mapping (i.e. altitude), many authors [3,4,14] have adopted the use of the NASA provided Shuttle Radar Topographic Mission (SRTM) elevation data, some applied the use of LiDAR elevation dataset, while others

[15,16], for the purpose of accuracy, adopted the use of detailed field survey. This is because of the absence of any National Elevation Dataset (NED) as specified in the National Spatial Data Infrastructure (NSDI) in Nigeria. The field work method is also adopted by [17] and [18] to ascertain and/or correct global elevation dataset (such as the SRTM) for various local topographic mapping activities.

Based on the contributions of [2,15,16,19,20,21], this study adopts the Cartographic Information Transferal Model (CITM), suggested by [2,22,23,24], to produce a topographic map of Anyigba at a new scale of 1:25,000. This study is based on the philosophy that the particular approach adopted represents a balance or consideration between available time, acceptable cost (labour, equipment, materials, etc.) and accuracy.

2. MATERIALS AND METHODS

2.1 Study Area

Anyigba is a town in Dekina Local Government Area of Kogi State, Nigeria. It occupies areas (almost centrally located) within Blocks Dekina 248 and Ejule 268 of the Index map of Nigeria (Appendix 1). The town is absolutely located between Latitude 7°27' – 7°31' North of the equator and between Longitude 7°09' – 7°12' East of the Greenwich meridian (Fig. 1).

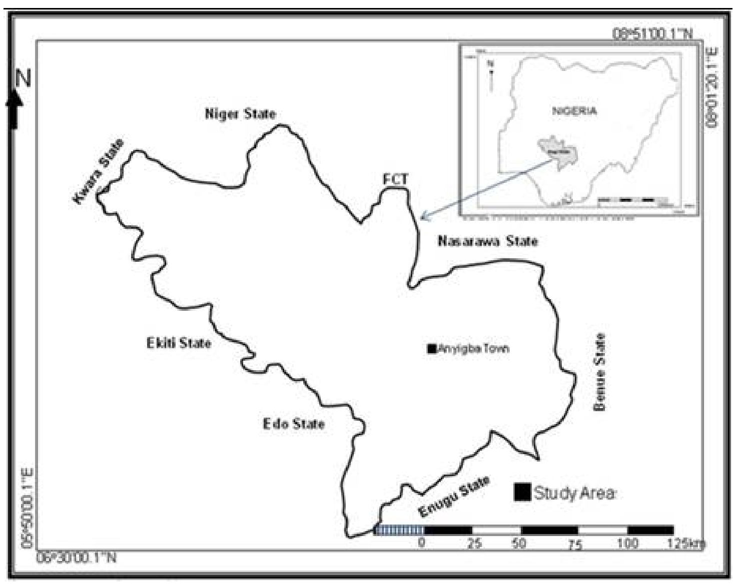

Fig. 1. Location of the study area

2.2 Software and Secondary Data

ESRI's ArcGIS 9.3 was used to perform mapping, visualization, and analysis of spatial data, while ortho-rectification, geo-referencing, creation of sub-maps, classification and vectorization of satellite imageries and existing maps were done using ILWIS 3.3 Academia. Also, data collected using GPS during field survey was converted to other formats using Lat/Long Converter 1.0.1. Lastly, conventional signs and symbols collected from the Office of the Surveyor General of the Federation, Nigeria in AUTOCAD 2002 were accessed using AUTOCAD 2010. Table 1 contains all secondary data (and sources) used for the study.

Table 1. Secondary data and sources

Data	Resolution	Bands
*Spot 10	10m	1, 2, 3
*Nigeriasat-1	32m	2, 3, 4
Google Earth Pro	5m	-
Planimetric Maps	1:50,000	-

** Images are for the year 2006*

2.3 Methodology

A reconnaissance survey of the study area was conducted, preceded by a pilot survey to verify the effectiveness of the data-gathering instruments and processes. Subsequently, field surveys were conducted using a Garmin GPSMap 76CSX handheld GPS to obtain three dimensional dataset (Altitude, Latitude and Longitude) of various points in the study area. The dimension of the study area is measured to be about 7.48km x 5.94km. The readings from the GPS device were established with a standard error of ±4m across the study area. A summary of the methodology application is shown in Fig. 2 below

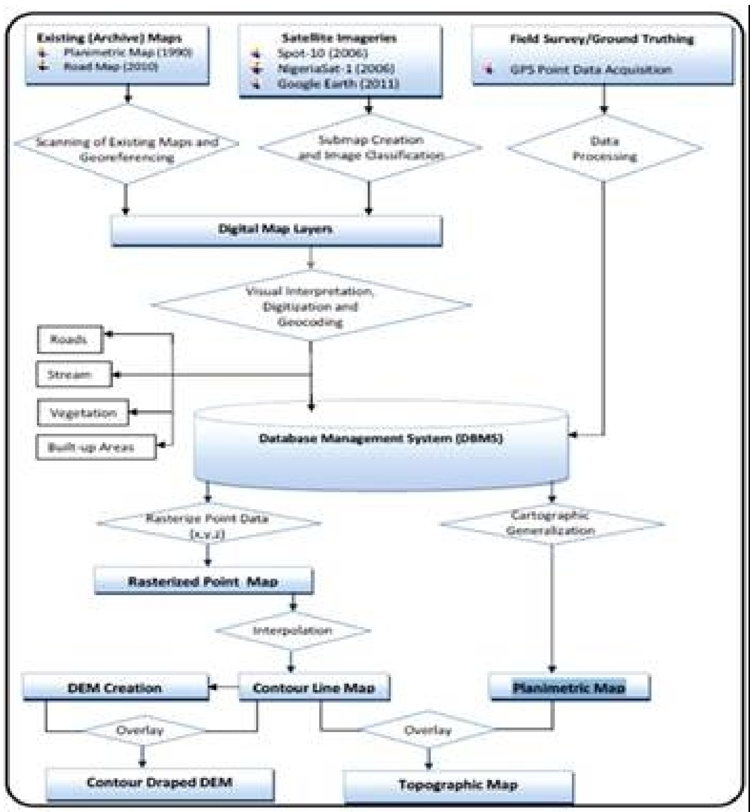

Fig. 2. Cartographic model designed for the study

All spatial dataset acquired in-situ and ex-situ were first pre-processed to enhance further analysis in the GIS environment. These include scanning and geo-referencing (of existing base maps and the Google Earth Pro image used for the study) to UTM Zone 32ºNorth; edge-matching of the old planimetric map sheets of the study area (since the study area is located between sheets 248 S.W and 268 N.W); re-sampling of SPOT-10 imagery to 32m; creation of sub-maps from satellite imageries; re-sampled satellite imageries and planimetric map sheets of the study area. The pre-processed composite images (SPOT-10, NigeriaSat-1 and re-sampled SPOT-10) were subjected to visual image interpretation while supervised image classification using the maximum likelihood classifier algorithm was used to identify homogeneous groups of pixels, which represent various land use classes on each colour composite (fused image). The Google Earth Pro data adopted for this study played a key role at this stage of the mapping process, as features not clearly visible on the satellite imagery (due to limited image resolution) were relatively more visible on the Google Earth Pro data. Hence, ground truthing was done using the Google Earth Pro imagery. The application of Kappa Index for accuracy assessment was not considered for two main reasons: first, concerns and contests have been expressed by [25,26] regarding the overall accuracy of the method; secondly, the application of Kappa Index for accuracy assessment is expected to be adopted in the next phase of this study to enable comparison of the two methods. The classified images were further vectorized to enable selection, digitization and representation of features to be displayed on the topographic map. Fig. 3 shows the process for the image classification applied in this work.

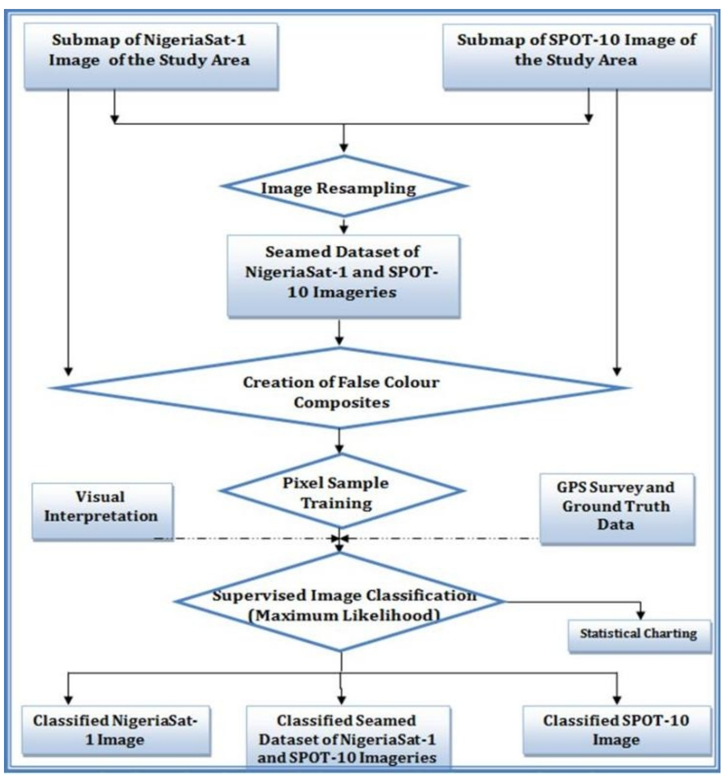

Fig. 3. Image classification procedure for the study

The base maps, satellite imageries as well as other classified and vectorized datasets were imported into the ArcGIS 9.2 environment (as separate layers) to enhance further generalization, selection, simplification, classification, exaggeration, symbolization and induction. The topographic objects were first classified into object classes according to their characteristics and then further organized into object groups, then into object entities. Thus, the vector data comprised of a digital topographic model, saved as points, lines or polygons, systematically organized into spatial layers (Table 2), i.e. object entities. Layers digitized in this study are shown on Table 2 below.

Table 2. Landuse / landcover classes

Geo-features	Input feature
Built-up areas	Polygon feature
Roads	Line feature
Streams	Line features
Vegetation Area	Polygon feature
Bare surface area	Polygon feature
Schools, Churches, Markets, etc.	Point features

The features digitized were then geo-coded using conventional signs, symbols and abbreviations exported from AUTOCAD 2010 environment into the ArcGIS 9.2 environment. Using contour lines to display altitude, the locational dataset (x, y, z) acquired during field survey was imported into the ArcMap environment. This was used to produce a point map of the elevation of the study area. From the elevation data (z) on the map, contour lines were generated via the processes of rasterization and contour interpolation (using the Nearest Neighbour algorithm). A Contour Interval (CI) of 10m was used in generating the contour (line) map for the study. All datasets generated from all stages of the topographic mapping process (i.e. point maps, contour line map, planimetric map, classified and vectorized land use maps, etc.) were then integrated. A Digital Elevation Model (DEM) and a Triangular Irregular Network (TIN) surface were built from the linearly interpolated contour lines of the study area and an overlay operation/analysis in the Spatial Analyst Extension of ArcGIS 9.2.

3. RESULTS AND DISCUSSION

3.1 Production of Isarithmic and Contour Lines Maps

The first map layer considered is the Isarithmic map layer that displays surface configuration of the study area through the use of contour lines. The elevation scatter point data acquired during field survey was used to produce a point map (Fig. 4A). From the point map produced, interpolation (using the Nearest Neighbour algorithm) was carried out to join areas of equal elevation thereby creating a contour line map as well (Fig. 4B). The minimum, maximum and mean altitudes (z) in the study area are 264m, 415m and 356.6m above sea level, respectively. This indicates a relatively highland area.

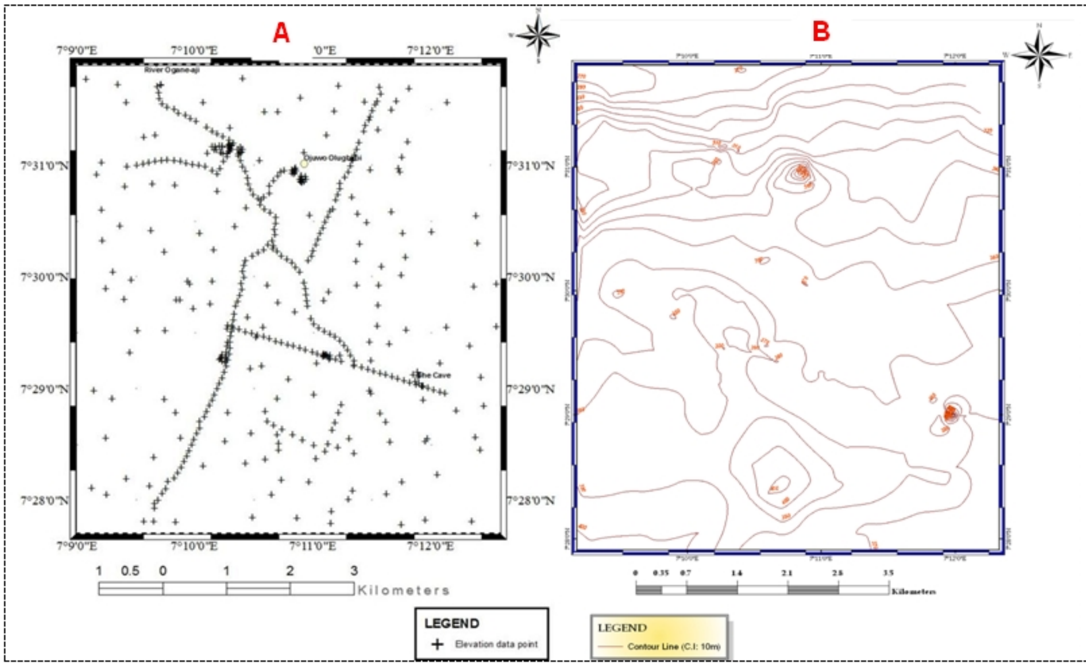

Fig. 4A. Isarithmic and (B) contour line maps produced by the study

3.2 Digital Elevation Model (DEM) and Triangular Irregular Network (TIN)

Digital Elevation Model (DEM) was used for the continuous representation of the contoured surface/map by the use of an array of z-values referenced to a common datum. Thus, the DEM Visualization function in the ILWIS 3.3 and the spatial analyst function in the ArcMap environment were used to display the DEM and the TIN surface of the study area, respectively.

The DEM (Fig. 5A) and TIN (Fig. 5B) reveal the surface configuration of Anyigba's terrain in an appealing manner. The 'Cave', located at the South East area of the study area is shown to be characterized with a (very hollow) depression. This is also observed at the Excavation site at the northern portion of the study area. The DEM also shows that the hill, Ojuwo Onugbabi, gently rose from a relatively lower surface to a height of about 415m asl. A height of 410m asl was also obtained in Anokwu area, at the lower southern part of the study area.

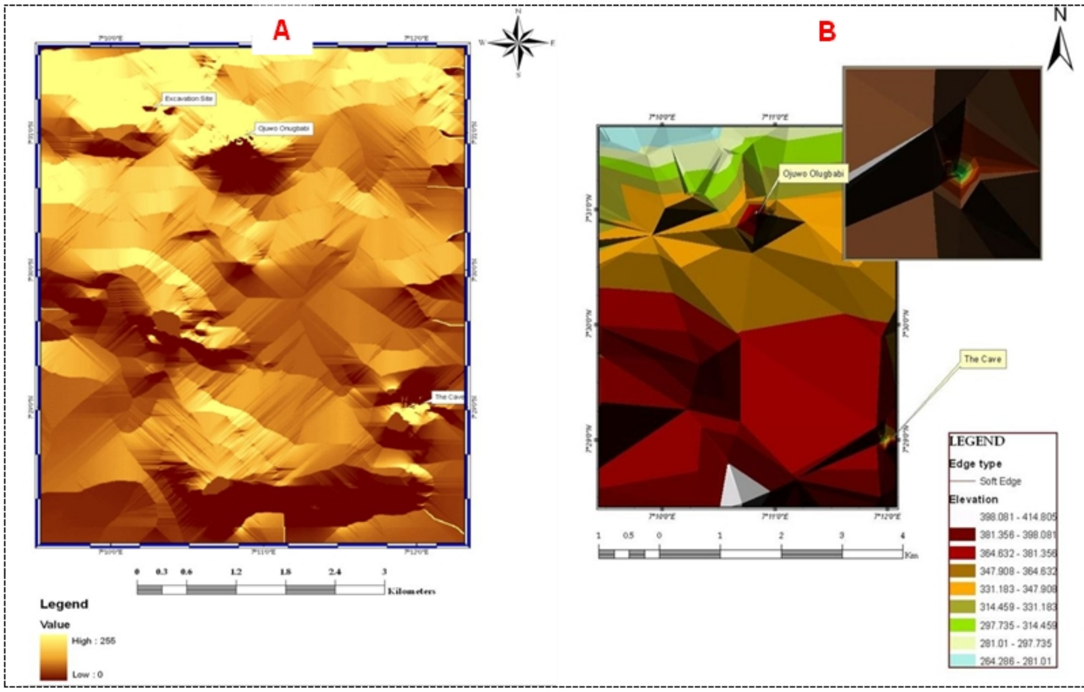

Fig. 5A. DEM and (B) TIN produced by the study

3.3 Landuse/Landcover Classification

Results from the classified NigeriaSat-1 (Fig. 7), SPOT-10 and re-sampled SPOT-10 image (Fig. 8) shows variations when compared with the Google Earth Pro image (Fig. 9) used for the study.

Table 3. Results of LULC classification

LULC Class	Nigeriasat-1 %	SPOT-10 %	Re-sampled SPOT-10 %
Built-up area	18.9	25.65	30.4
Grasses & scattered cultivation	77.97	28.32	29.21
Thick vegetation	2.38	30.2	34.63
Barren land	0.73	15.83	5.75
Total	99.98	100	99.99

The discrepancies in the result obtained from the classified satellite imageries are obvious (Table 3 and Figs. 6 and 7). The seaming together of SPOT-10 and NigeriaSat-1 imageries was carried out to collectively harness the individual characteristics of the two images. Generally, none of the satellite images were able to register the only known stream in the study area. However, the riparian vegetation type displayed on the northern margins of the images is good evidence that indicated the presence of a linear water body. This was adequately taken care of during the digitization stage.

However, when the results were compared with the Google Earth Pro Image (Fig. 9) acquired to aid image classification and the ground truth data, the vectorized SPOT-10 and the re-sampled SPOT-10 images were found to be more useful in enhancing the digitization of features to be registered on the planimetric map and the entire topographic mapping process.

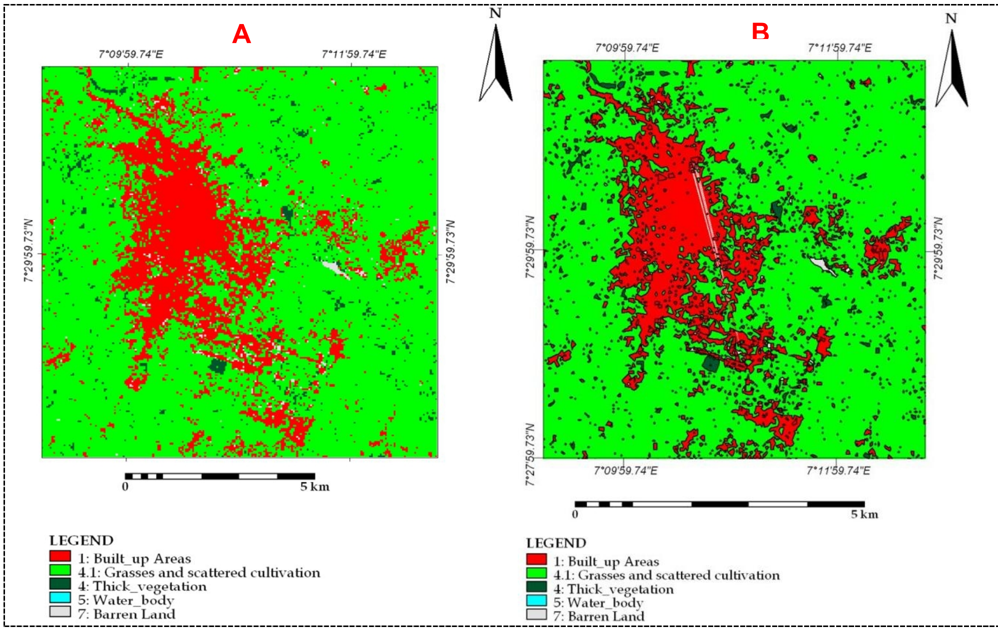

Fig. 6. Classified (A) and Vectorised (B) Nigeriasat-1 image of the study area

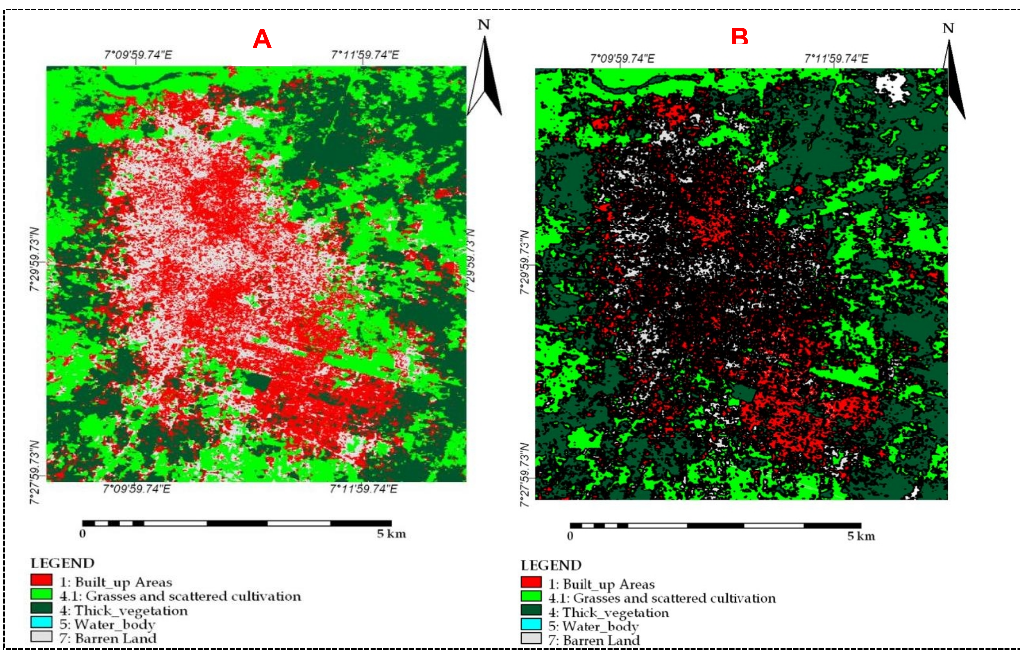

Fig. 7. Classified (A) and Vectorised (B) SPOT-10 Image of the study area

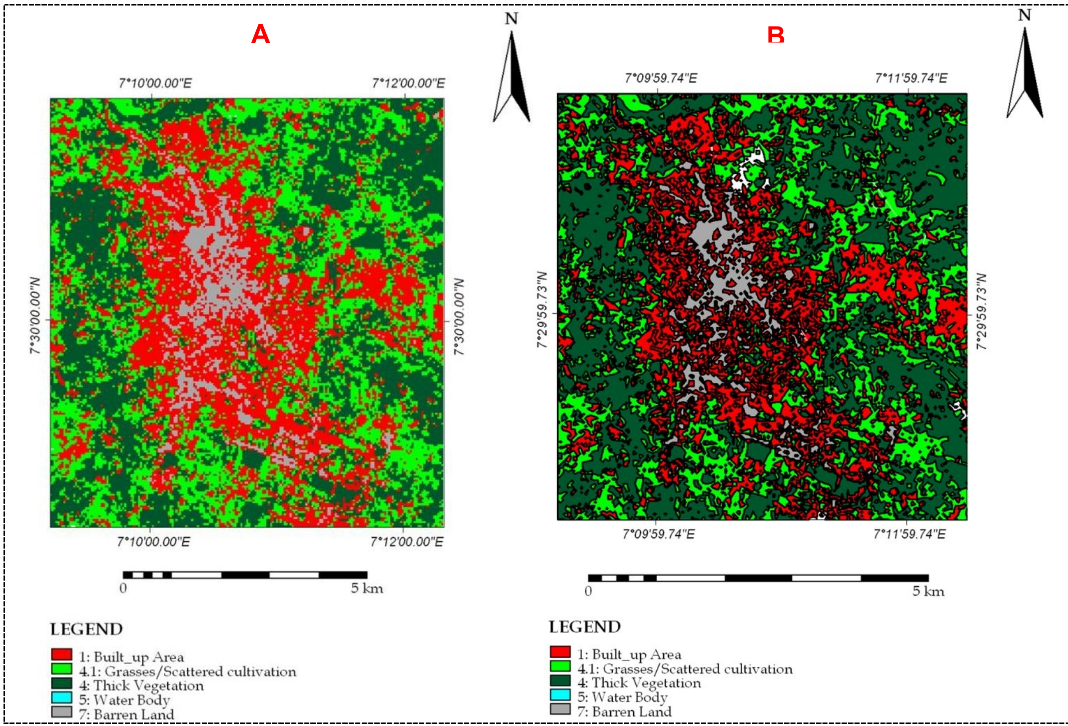

Fig. 8. Classified (A) and Vectorised (B) Re-sampled SPOT-10 Image of the study area

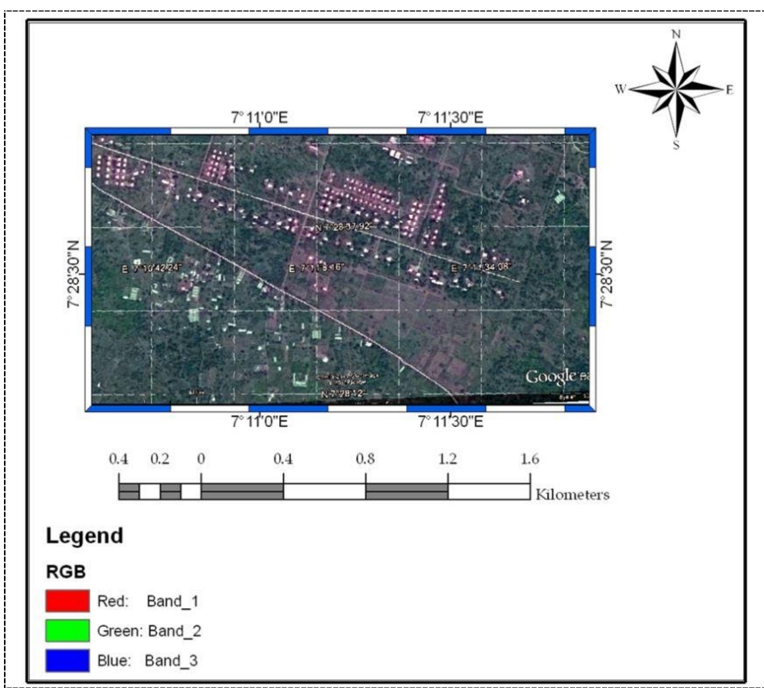

Fig. 9. Google earth pro image of the study area

3.4 Creation of a Planimetric Map of Study Area

Essentially, the Isarithmic map layer and the new Planimetric map (Fig. 10) layer were integrated via the layer algorithm using ArcView to generate a new layer - a Topographic map. This technique of overlay operation (likened to Sieve mapping) is similar to tracing of maps on a light table to bring out a landscape architecture from different maps of a particular area. Fig. 11 for the new 1:25,000 topographic map of Anyigba produced from this study. Fig. 12 presents the detailed legend of the new topographic map created by this study.

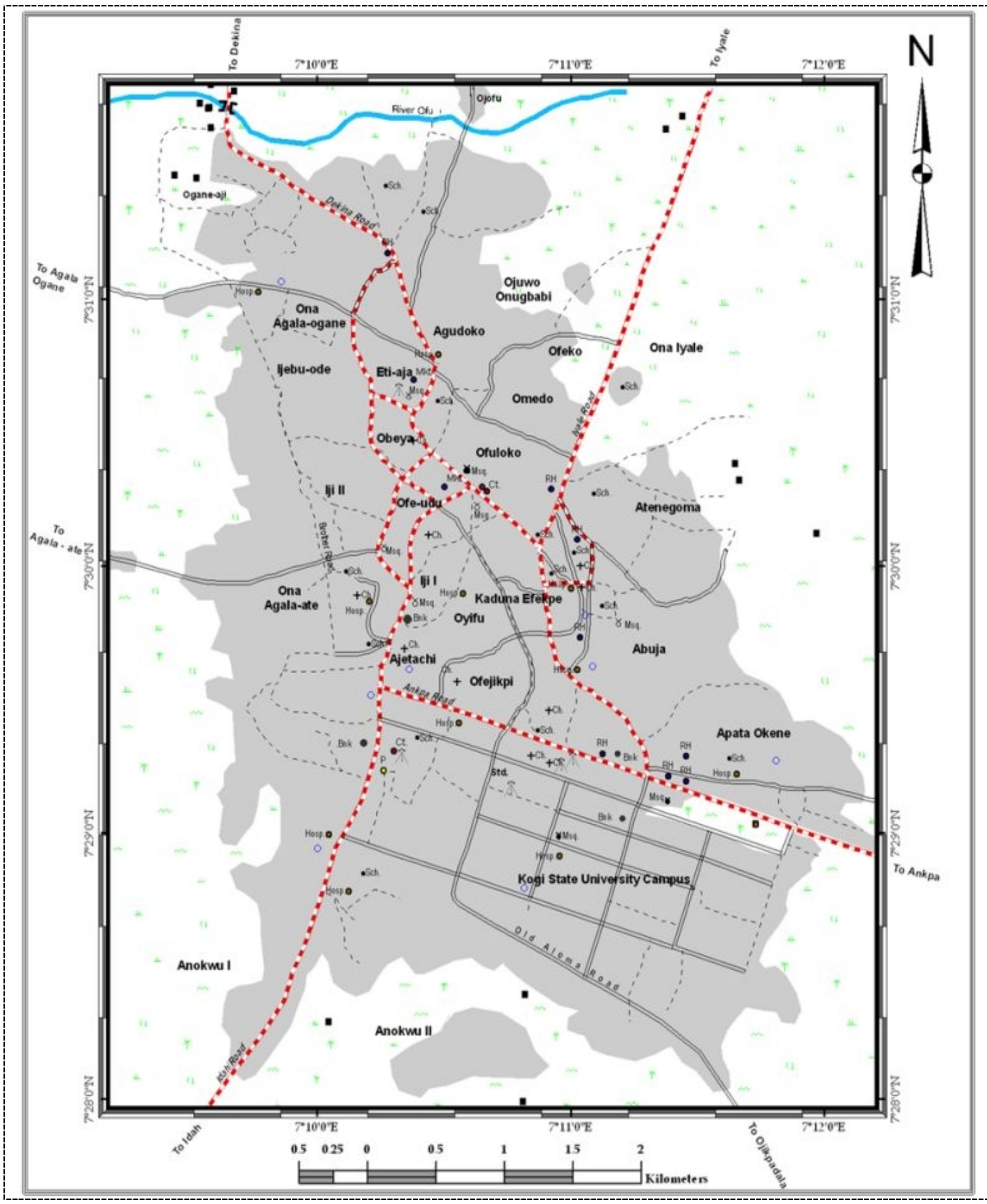

Fig. 10. Planimetric map produced by the study

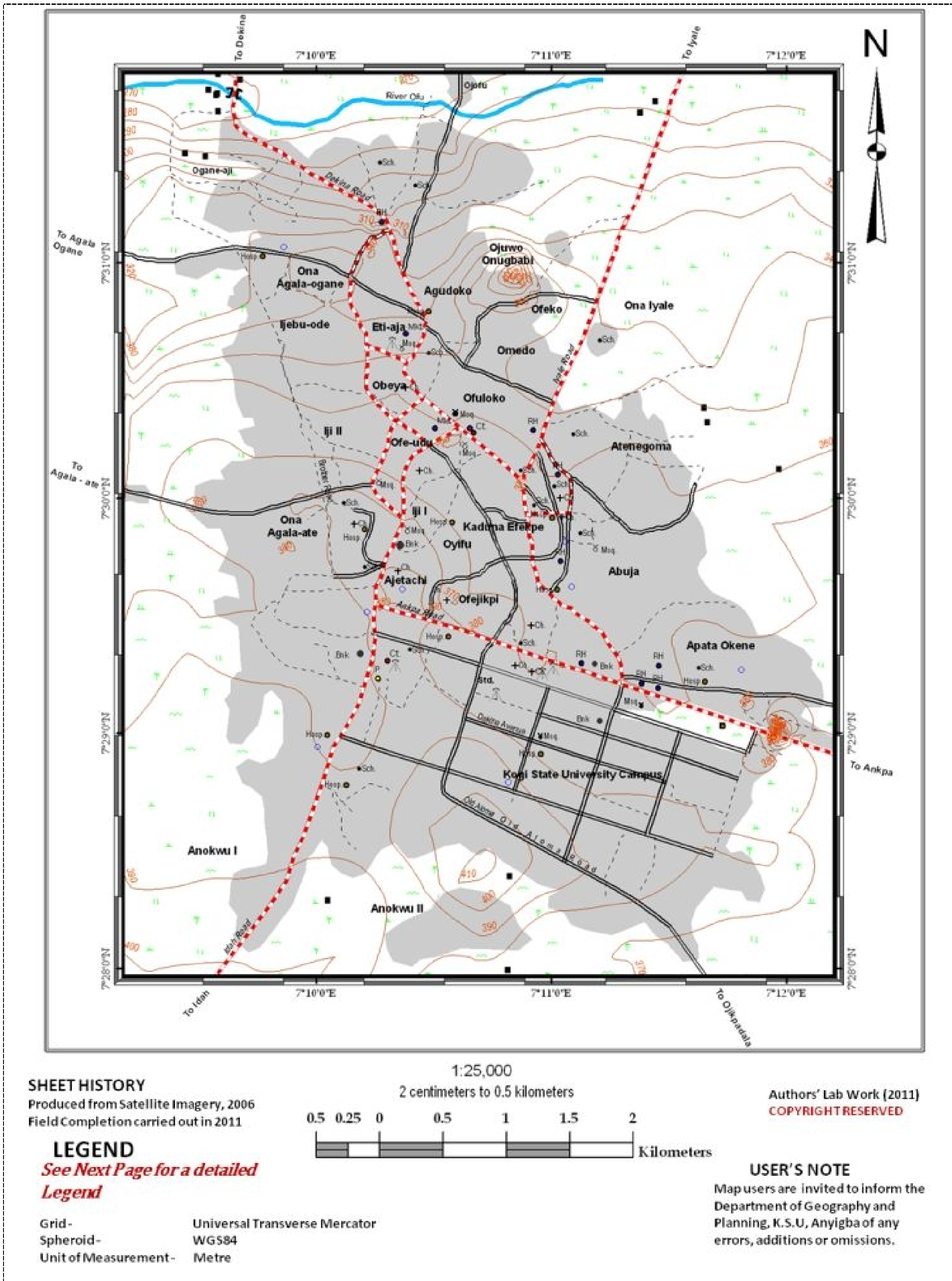

Fig. 11. New Topographic map with scale 1:25,000 produced for study area

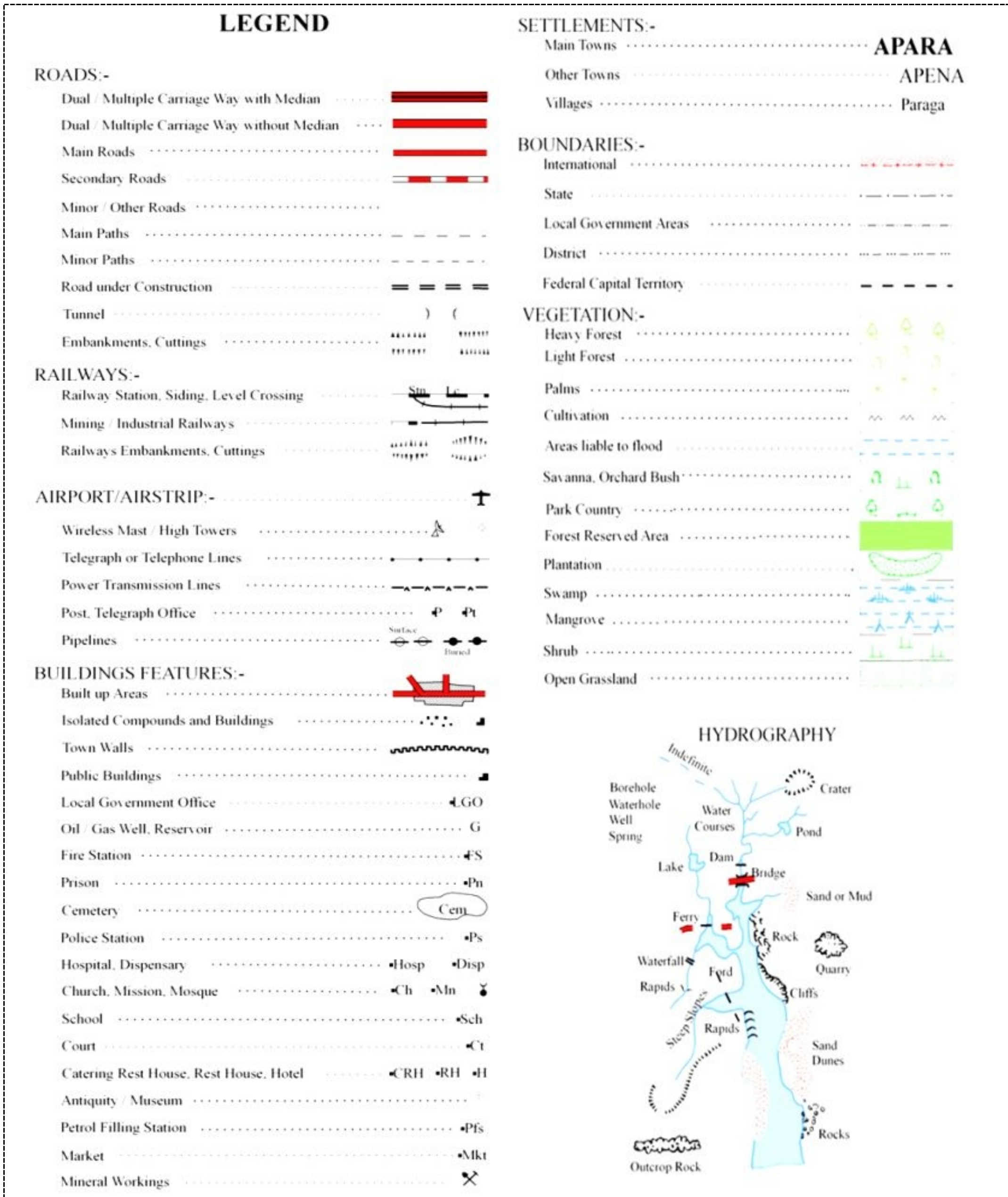

Fig. 12. Detailed legend of new Topographic Map of study area

4. CONCLUSION

This study has investigated and confirmed the possibility of applying available (even if insufficient) geospatial technologies in the topographic mapping of rapidly expanding towns in Nigeria. As earlier stated, mapping is a fundamental data required for appropriate planning. Since mapping in Nigeria is poorly done due to high costs, this methodology applied here can be adopted elsewhere to aid provisional, baseline map information upon which adequate planning authorities can build their planning strategies. In addition to a relatively low cost of production, the RS and GIS approach to Topographic mapping is very efficient and less tasking when compared to the traditional/manual map making process. Finally, it appears Nigeriasat-1 imagery is inadequate for independent adoption for topographic mapping (this conclusion is based on the wide discrepancies recorded from the classification of Nigeriasat-1 image when compared with the imageries from other platforms used). Therefore, a combination of imageries from several platforms is recommended.

Nevertheless, and in spite of any shortcomings of this study, it is also important to note that the map produced from this work is the first topographic map of Anyigba using geospatial techniques. Indeed, these maps are the first three-dimensional (3D) rendition of the terrain on a two-dimensional surface (2D rendering) for the study area. Hopefully, considerable improvement in subsequent studies is anticipated in future efforts at mapping the study area.

ACKNOWLEDGEMENTS

The authors are grateful to the residents of Anyigba Town who assisted with information during the field work and ground truth exercise. We are also thankful to two anonymous reviewers whose comments improved the quality of this work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Balogun TF. Spatial data infrastructure: prospects and challenges in Nigeria. Confluence J Env Std. 2006;6(1):101–106.
2. Ufuah ME. Basic principles of Cartography. Benin-City: Ever-Blessed Publishers; 2006.
3. Office of the Surveyor General of the Federation. Status of mapping in Nigeria. Abuja, Department of Mapping and Geo-Information, OSGOF; 2009.
4. Haastrup AA. Interview Session. Department of Mapping and Geo-Information, OSGOF; 2011, 22nd August.
5. Balogun OY. A century of colonial mapping in Nigeria (1861-1960). Nig Cart J. 1992;2(1);30-43.
6. Ufuah ME. Non-revision of the 1:50,000 topographic maps and its implications for sustainable development in Nigeria, in Zietsman L, editor, Cartographic Renaissance. The International Cartographic Association, Durban South Africa. 2003;2579–2590.
7. Ikhuoria IA, Eseka EN. Cartographic issues in census of population in Nigeria, in Ikhuoria IA, editor, Cartography and Geographic Information Systems for Sustainable Development. Benin-City: Nigeria Cartography Association; 1997.
8. Federal Surveys Department: "Ankpa and Dekina Topographic Map Sheet 248 N.W. and 268 S.W". 1964, 1st Ed. Lagos Nigeria.
9. Soneye AO. The application of satellite remote sensing and geographical information systems in the evaluation and revision of the Nigerian topographical maps. Unpublished PhD Thesis, Department of Geography, University of Lagos, Akoka, Lagos State; 2000.

10. Ufuah ME. Revision of the Nigerian 1:50,000 topographic maps with SPOT remotely sensed data. PhD Thesis, Ambrose Alli University, Ekpoma, Nigeria; 2000.
11. Ufuah ME. The use of SPOT remotely sensed data for the revision of Nigeria 1:50,000 topographic maps in resource management. Proc. Nig Cart Association. Ibadan, 2002;98–108.
12. Obot MM. Topographic map revision: a case study of University of Uyo Campus, in Ufuah ME, Olomo RO. editors. Cartography and GIS for Sustainable Solid Minerals Development in Nigeria. A special publication of the Nigerian Cartographic Association (NCA). 2005;122-129.
13. Adesina JG. Revision of Nigerian 1:2500 Township map using cadastral techniques in Owo GRA, Ondo State. Ph.D Thesis Proposal, Department of Geography and Regional Planning, Ambrose Ali University, Ekpoma, Edo State; 2005.
14. Okpala-Okaka C, Igbokwe JI. Revision of Nsukka N.E. Topographic Map Sheet 287 1:50,000 (1964) using Nigeriasat-1 imagery, Nig J Space Res. 2010:7;13–22.
15. Isioye OA, Jobin PD. An Assessment of Digital Elevation Models (DEMs) from different Spatial Data Sources; 2011
Available: www.fig.net/pub/fig2011/papers/tso5i_Isioye-jobin-4911.pdf.
16. Jobin PD. An Assessment of Digital Elevation Models (DEMs) From Different Spatial Data Sources. Research Project, Department of Geomatics Engineering, Ahmadu Bello University, Zaria; 2010.
17. Ufuah ME. Contemporary methods in cartography. 2006, Benin-City: Ever-Blessed Publishers.
18. Menaker O. LiDAR Mapping: Data Accuracy in Digital Era. Geospatial World Magazine of GIS Development, 2010;5(2):42–43.
19. Ivana J, Miljenko L, Ivana L. Research on Topographic Map Updating. J Cart Geoinfo, 2002;1(1):32–39.
20. Ayanlade A, Babatimehin O. Geospatial Data Infrastructure Problems and Development in sub-Saharan Africa. Proc. Contemporary Issues in Infrastructural Development and Management in Nigeria. Ogidiolu A, Musa SD, Ifatimehin OO editors. 2010;323–330.
21. Ojo AG, Adesina FA. An assessment of the efficiency of Landsat, Nigeriasat-1 and SPOT Images for landuse/landcover analysis in Ekiti West area of Nigeria, in Wagner W, Székely B. editors, ISPRS TC VII Symposium – 100 Years ISPRS, IAPRS. 2010, Vol. XXXVIII, Part 7B, Vienna, Austria.
22. Balogun OY. Cartographic Information Transferal: A New Look at Communication Cartography. Proc 3rd Australian Cartographic Conference, Brisbane. 1978;64–84.
23. Heywood C, Carver I, Cornelius S, Carver S. An introduction to Geographic Information Systems". Delhi: Pearson Education Publishers, 2001.
24. Olomo RO. Modern comprehensive practical Geography. Warri: El-Jowoma Enterprises; 2004.
25. Strijbos J, Martens R, Prins F, Jochems W. Content analysis: What are they talking about? Comp & Educ, 2006:46:29–48. doi:10.1016/j.compedu. 2005.04.002
26. Uebersax JS. Diversity of decision-making models and the measurement of interrater agreement. Psych Bulletin, 1987:101;140–146. doi:10.1037/0033-2909.101.1.140.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=290&id=22&aid=2237