3D Reconstruction of University of Ilorin Campus using High Resolution Satellite Imagery and Conventional Survey

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Key words: ArcGIS, 3D Mapping, Database, Spatial Analysis

SUMMARY

There is an increasing demand for 3D geospatial data and modelling for urban planning, design and management. This paper presents the production of a 3D map of the University of Ilorin Main Campus to provide accurate spatial information database to enhance adequate planning and maintenance of infrastructural development. Geometric data (spot heights and building elevations) were acquired using Trimble M1 Total Station and Global Positioning System (Hi - Target). From high resolution (0.6m) Google Earth image of the study area, building footprints and road network were vectorized to produce 2D map while the attribute data were obtained through social survey by means of oral interview and visual inspection. The data collected were processed in ArcMap 10.6 and Surfer 15 environments to generate data products. Using the building footprint and the building height measured with Total Station, the 3D map was generated. Spatial analyses, such as queries and network analysis, were executed to demonstrate some key infrastructural management issues this work will be useful for. The areas of application of these products cut across various disciplines such as urban planning, architectural visualization and environmental protection such as flood risk management.

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1.0 INTRODUCTION

The demand for 3D geospatial data and modelling for urban development has been continuously increasing since many GIS problems can only be solved in 3D rather than the traditional 2/2.5D spatial representations. So, at the higher level of space representation, 3D map addresses more effectively important urban applications such as asset management, infrastructural development planning, public safety, environment, tourism, telecommunications, transportation, car navigation and 3D web mapping services (Armenakis et al, 2009).

Efficient 3D urban mapping requires accurate digital surface model (DSM). DSM provides the geometry and structure of an urban environment with buildings being the most prominent objects (Bittner et al, 2018). It also allows depicting the elevation of surfaces such as building, tree, bare ground etc. in addition to representing a description of the terrain configuration based on measured or derived X,Y,Z coordinates of points on the surface of the earth or from remotely sensed platforms like Shuttle Radar Topography Mission (SRTM) and ASTER DEM. These datasets have continuously provided means of generating the most complete high-resolution digital topographic database of any location for various topographical analysis (Nkeki et al, 2014).

For 3D urban modelling, High-resolution elevation information for DSM can be achieved using various techniques: conventional surveying, aerial photogrammetry, remote sensing; Light Detection and Ranging (LIDAR) and Interferometric Synthetic Aperture Radar (IFSAR). The selection of a particular technique will rely on the accuracy required, the extent of the area of interest, the budget, time and the purpose of the project (Smith et al, 2006). While DSM generation using ground surveying technique is reliable and accurate, the requirement that observations for elevation be made directly in the field through conventional total station or spirit levelling is a limitation in urban 3D reconstruction since building roof tops cannot be accessed. In addition, it is costly and time consuming for large areas compared with other techniques.

As University of Ilorin Campus keeps expanding in population and infrastructural development, there is the need for an accurate spatial information database that will facilitate effective planning, management and productive decision-making process. Reliable 3D characterisation of the environment will enrich clearer view of environment. The objective of this study is to produce 3D map of the campus using freely available satellite imagery and conventional survey technique. The result will facilitate integrating spatial dimension to managing both the available space and facilities within the campus.

2.0 DATA AND METHOD

2.1 Study area and data

University of Ilorin (Unilorin) is a Federal Government-owned university established by a Decree of the then Federal Military Government in August 1975 and located in Ilorin in Kwara State, Nigeria. The university has a landmass of about 5,000 hectares; the part covered by this work is approximately located between longitude 4° 39' 36" E to 4° 41' 19" E and latitude 8° 27' 54" N to 8° 28' 09" N (Figure 1), which constitutes the core developed area, typical of an urban set up with a mix of low and high building and vegetation. In this study, high resolution Google Earth imagery, spot height of the study area, building height values and social survey (oral interview and visual inventory) of building information were acquired.

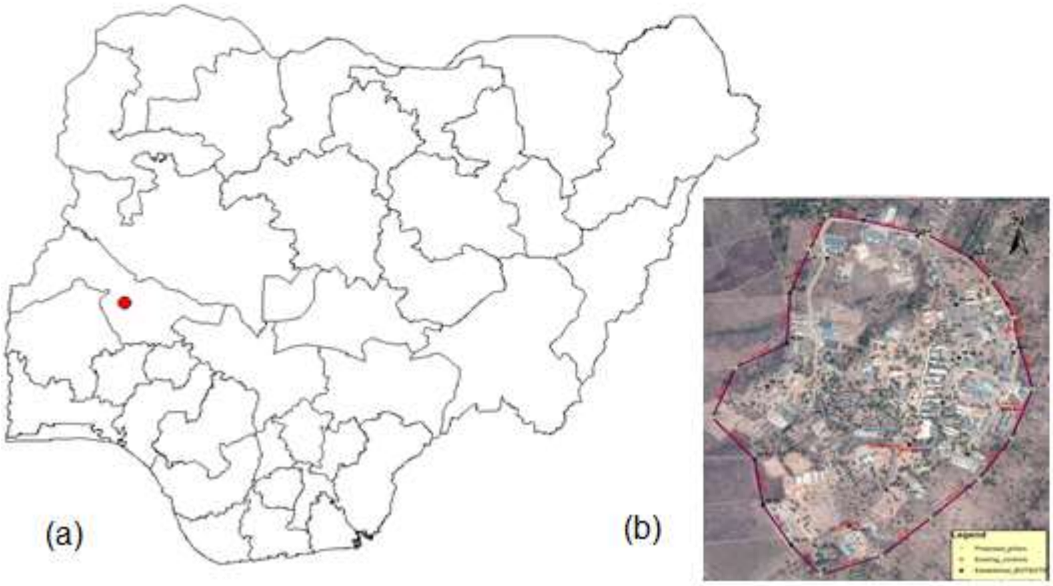


Figure 1: Location of the study area (a) in Kwara state, Nigeria and (b) Google Earth image of Unilorin campus

2.2 Data collection

The data collection, processing and analysis tasks involve a number of steps (Figure 2). To obtain geometric data, high resolution Google Earth imagery of the study area was downloaded from SAS Planet (SAS.Planet.Release.181221) and vectorized in ArcGIS 10.6 environment to generate 2D building footprints and road network. Subsequently, building heights were obtained by direct measurement using Trimble M1 Total Station in reflectorless mode. For terrain elevation data, 1 arc second SRTM data was downloaded from USGS (www.earthexplorer.usgs.gov) and ortho-rectified using GCPs (XYZ ground control points) collected with a Hi-Target GPS equipment. Also, point objects like trees and telecommunication masts were collected with the GPS equipment.

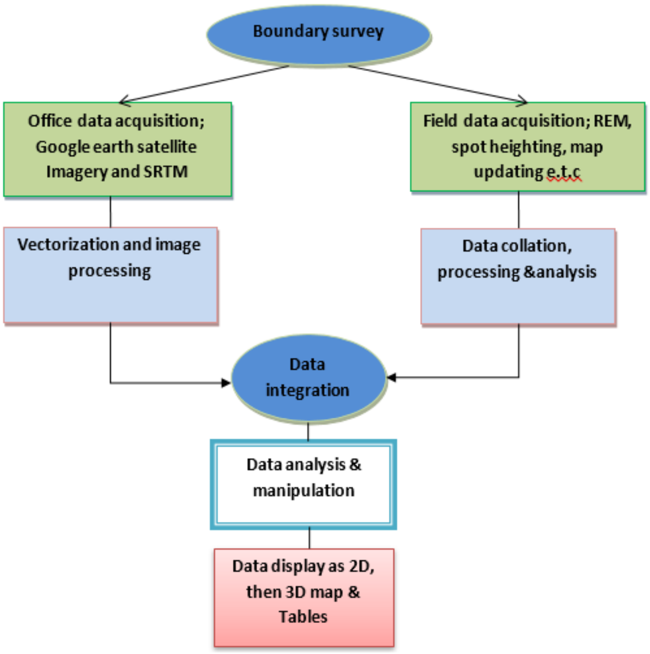


Figure 2: Data acquisition, processing and analysis workflow

Attribute data of the features of interest were obtained through oral interview (Social Survey) and visual inspection. It was during the social survey that information such as building name, building use, road name and other relevant information were collected from the students and staff within the school premises.

2.3 Data processing

The data processing was done in ArcGIS 10.6 and Surfer 15 environments. Putting the user requirements into consideration, which in this case is to create an inventory of some available facilities within the main campus, conceptual, logical and physical database designs (Kufoniyi, 1998) were carried out. Table 1 and Table 2 present building attributes and their description and data types respectively. The purpose of building a physical design is to optimize performance while ensuring data integrity by avoiding unnecessary data redundancies. Here, entities were transformed into tables, instances into rows and attributes into columns. In summary, this is a stage where the entity and its attribute generated in the logical design stage were actualized in an acceptable format of the implementing software and hardware. Attribute data set obtained about the building were linked with the geometric data and stored in the computer system. The fundamental interest of the study is 3D reconstruction; therefore, height values of buildings and other objects of interest such as trees and telecommunication towers are particularly important. In ArcScene, the height values of the features were used to project the third dimension for perspective visualization. In addition to the building database, other elevation derived topographical elements (contour, TIN, slope, aspect, and water flow pattern) were generated from the orthorectified SRTM and integrated with the building layer to support a holistic view of the campus environment. Spatial analysis and query were done and presented to demonstrate some routine management applications that require observations in 3D space.

Table 1: Area Entity and its Attributes

S/No	Attribute Name	Description of Attributes
1	B_ID	Polygon object identifier
2	B_Use	Building Use
3	Perimeter	Perimeter of area object
4	B_Name	Building Name
5	B_No of Floors	Number of floors in a building

Table 2: Building Table

Attribute	Data Type	Width	Decimal
B_NAME	String	50	-
B_CONDITION	String	50	-
B_USE	String	50	-
B_HEIGHT	Number	15	3
B_PERIMETER	Number	15	3
NO_FLOORS	Number	15	-
B_AREA	Number	15	3

3.0 RESULTS AND DISCUSSION

The results of this study are presented in figures 3, 4, 5 and 6. Figure 3 provides the general view of the University of Ilorin main campus in 2D with detail physical infrastructures. It can be observed that the study area depicts typically an organized urban environment that need to be well captured in 3D geometry.

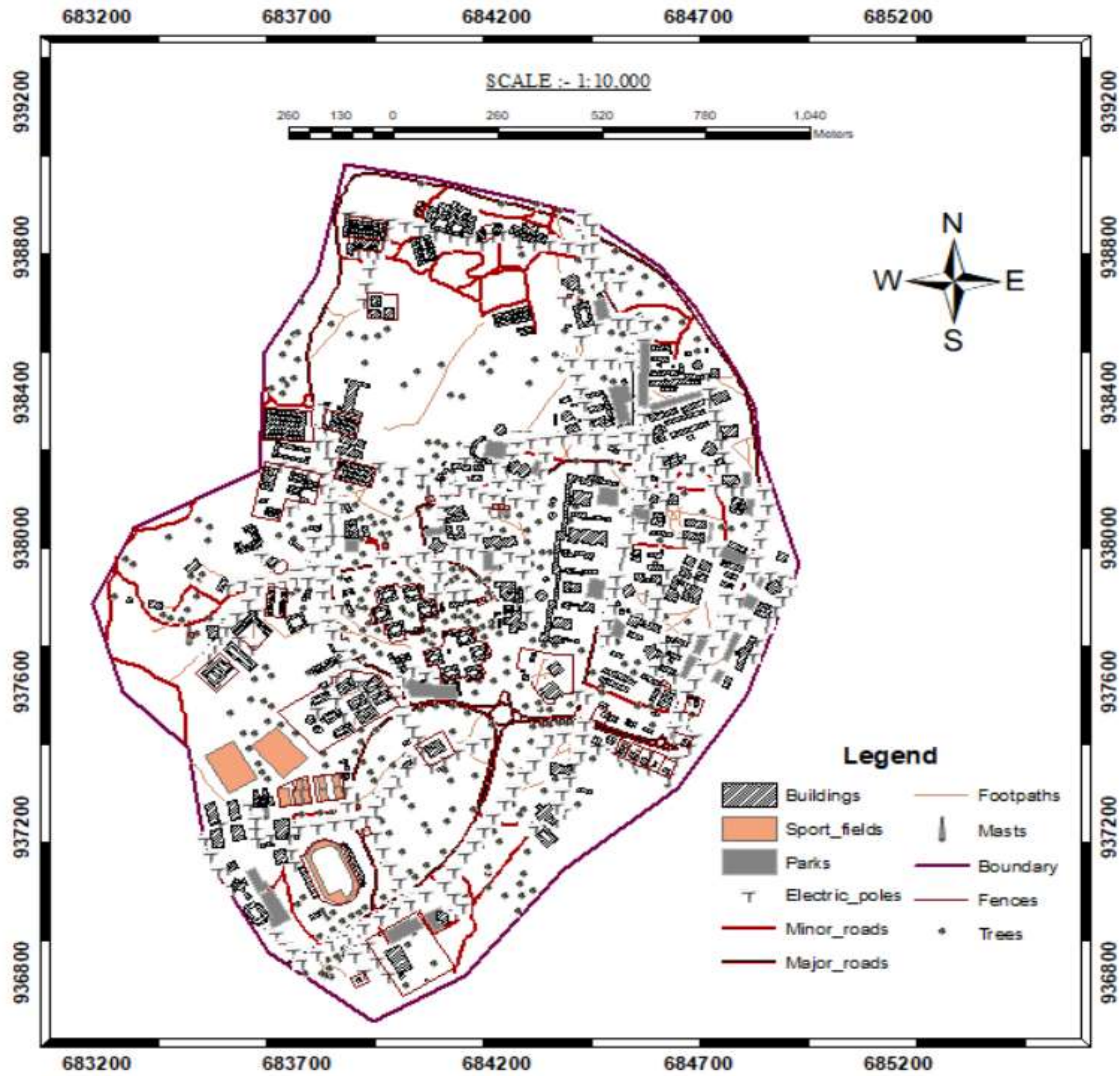
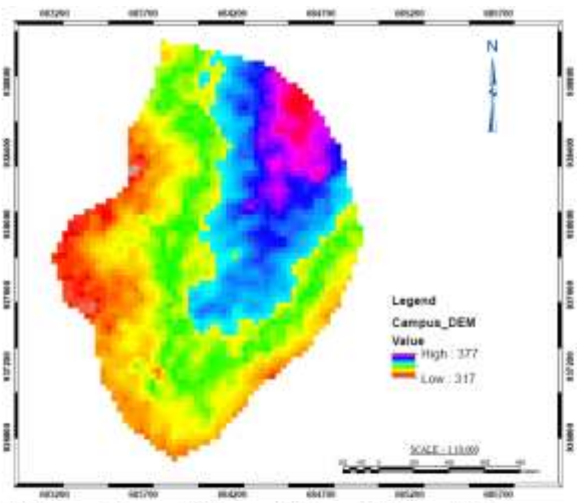
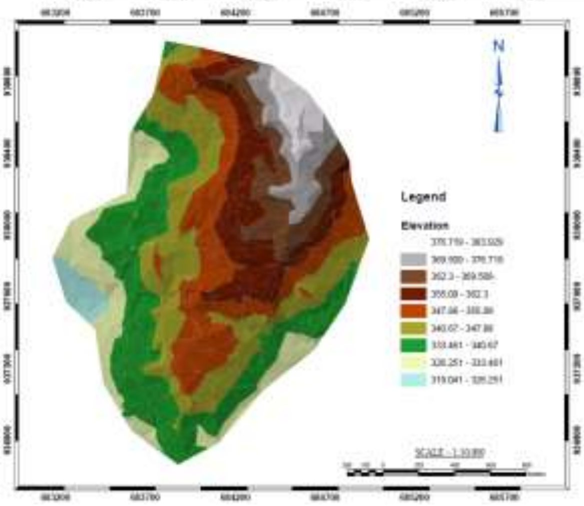


Figure 3: Detailed map of University of Ilorin Main campus

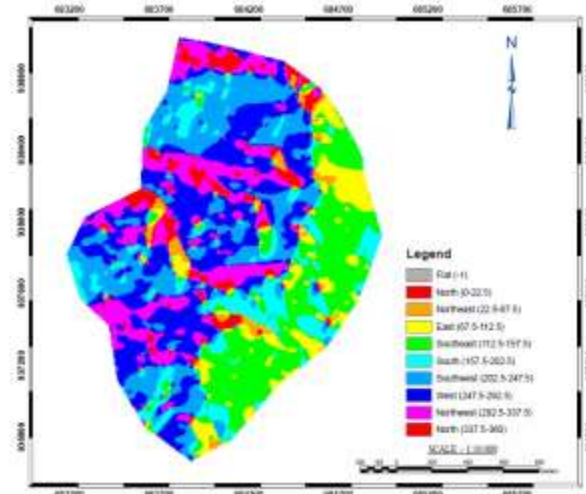
The topographic characteristics are shown in Figure 4. University of Ilorin lies between elevation of 317 m to 377 m above mean sea level (Figure 4a) and slopes downward in the north-south trend with slope value between 0.01% and 13% (Figure 4f) with predominant west, southwest and east slope facing sides. Based on standard slope classification, the study area sits within the very gentle, gentle and moderately gentle (Figure 4d) slope classes with corresponding water draining pattern.

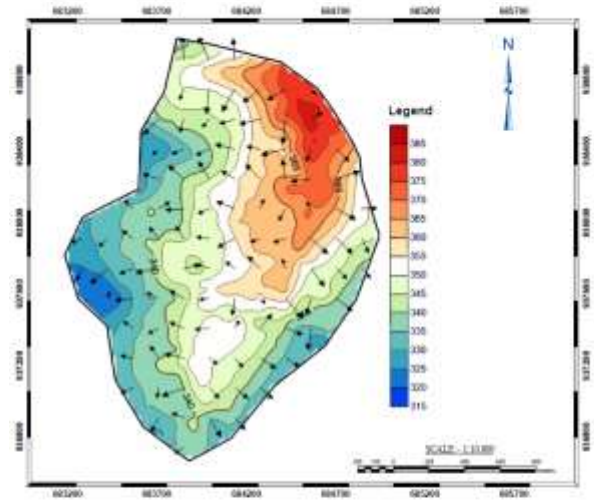




(a) DEM of the study area map

(b) Triangulated irregular network (TIN)





(c) Aspect map (d) Vector map

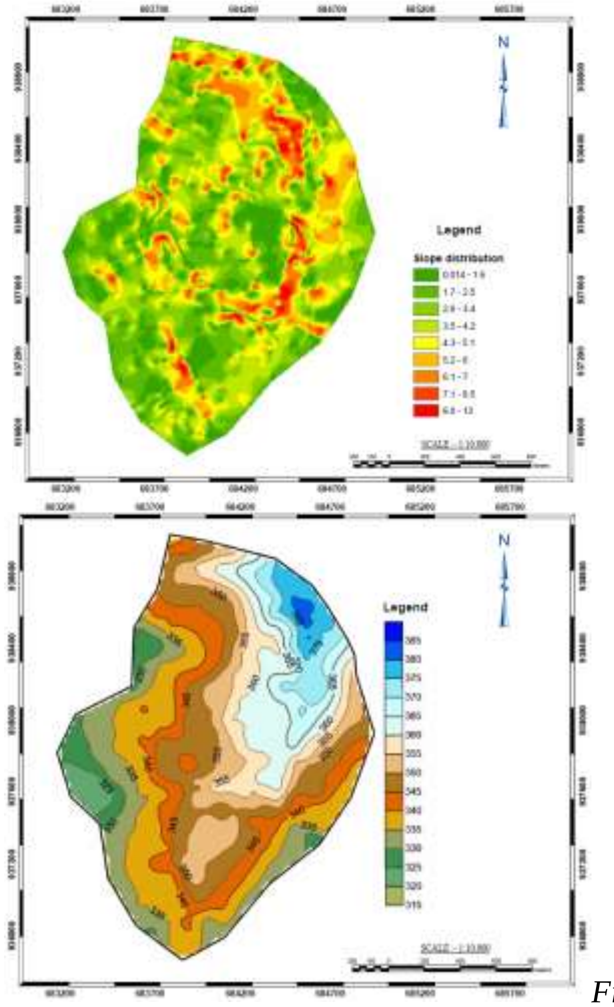
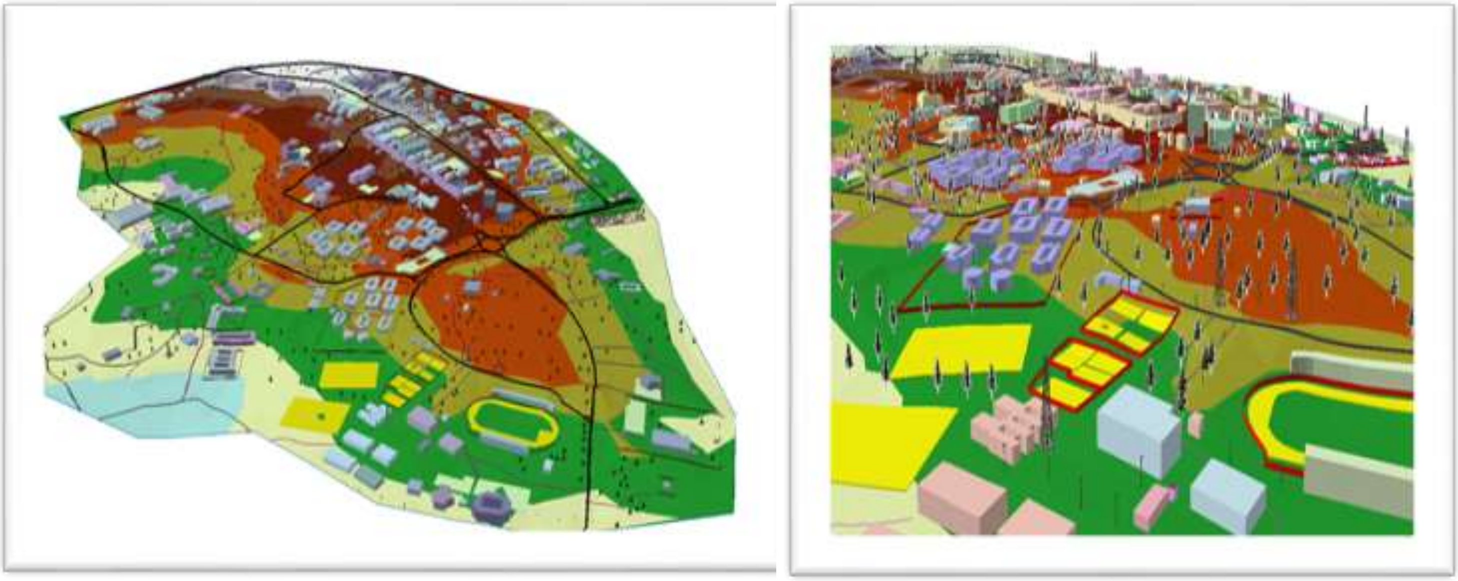


Figure 4: Terrain characteristics - (a) DEM, (b), contour, (c) TIN, (d) aspect, (e) drainage pattern, and (f) slope

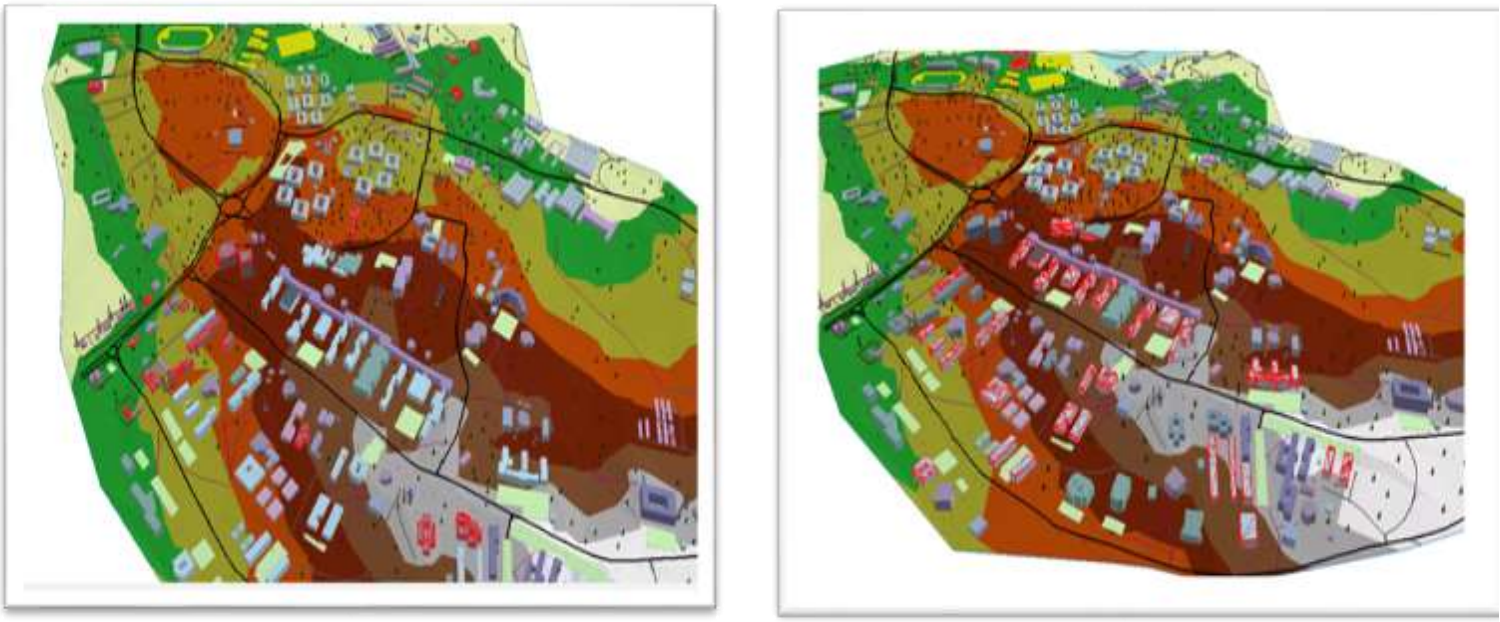
Apart from the terrain analysis, the height values of above ground features give a near real-world view of the campus in 3D space (Figure 5). This representation allows us to visualize the project area in 3D perspective (Figure 5a) beyond the 2.5D terrain perception. Overlaying the 3D model on the terrain (Figure 5b) accurately depicts the terrain configuration. This makes it possible to fully represent the real-world scenario for effective decision making.



(a) (b)

Figure 5: 3D building block model of University of Ilorin main campus (a) and draped on terrain model (b)

The power of any geographic analysis is the ability to solve problem particularly those of geographic content. One of those tasks is query which exploits geographic features, their attributes and the relationship between them. This was demonstrated using single criterion and multi-criteria queries (Figure 6). The single criteria (Figure 6a) indicates buildings used for administrative functions. The multiple criteria examine which of the building are used by faculties and story buildings (Figure 6b).



(a) (b)

Figure 6: (a) single criterion and (b) multi criteria query results

4.0 CONCLUSION

A method to reconstruct urban environment in three-dimensional space using freely available high-resolution satellite imagery, digital elevation data and traditional survey method has been presented in this study. The success of the work shows that accurate and reliable 3D model is still possible without sophisticated modern equipment such as LiDAR that requires high cost of implementation. This study lays the foundation for effective management of asset and space for developmental purposes and prompt decision making process in complex situation especially where the third dimension, on or above ground, is a factor. It also provides future researchers in investigation such as Building Information Modelling (BIM) and GIS integration with base data to advance.

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