Application of Geospatial Techniques in Modeling and Analysis of Topographical Settings in Kogi State, Nigeria

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Keywords: Topography, Geospatial Techniques, DEM, SRTM,

ABSTRACT

Mapping and visualization of topographic setting is paramount for the understanding and management of the physical environment. Based on this, state-of-the-arts techniques that produces accurate result must be adopted to ensure that the right decision is made during planning. The application of geospatial technologies (Remote sensing and GIS) in analysis and management of spatial information is gaining popularity in recent times due to its accurate and timely delivery of information needed for decision making. Base on this the aim of this study is to adopt geospatial techniques in modeling and analysis of topographical settings of Kogi State. Data used includes 3arc seconds (90m) resolution DEM created by SRTM, Landsat image with resolution 30m, 2012 flood remote sensing satellite imagery captured by moderate resolution imaging spectroradiometer (MODIS) and administrative map of the study area from which the administrative boundary of the study area was extracted. These datasets of the study region was entered into various GIS software for manipulation and extraction of terrain features. Progressively, vital topographic features were digitally extracted and these were used to build a GIS-assisted topographical database consisting of such Physical features as the stream network of the region, contour ,3-D models, DTM, slope, land use/land cover map, and Aspect etc. Result revealed that the study area is highly undulating and lies in a relief region of between 20m to 580m above mean sea level. The analysis further revealed that there are four land use/land cover types covering the following extents; Built up areas covers 1858.347km^2 (6%), forest areas covers 8088.108km^2 (28%), agricultural lands and water bodies covers 17892.850 km^2 (62%) and 1096.870km^2 (4%) respectively. Further analysis revealed that the study area has drainage density of 0.1533km^{-1}with a total length of **4437km** of rivers covering it. These digital derivatives are essential for the understanding of the region's landscape for the purpose of further investigation, planning and decision making.

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1.0 INTRODUCTION

The advent of geospatial technologies has revolutionized the method of acquisition, analysis, and displaying of geographic referenced data. Terrain variable influences our everyday life and mapping and visualization of topographic settings is essential and paramount for the understanding and management of the environment (Nkeki 2014). Based on this, sophisticated method that produces accurate result must be adopted to ensure that the right decision is made during planning. Topographical analysis facilitates understanding of drainage pattern, river morphology, watershed pattern, surface roughness assessment, land use etc. Therefore the aim of topographic modeling and analysis is to provide detail or in-depth understanding of the arrangement of the earthly features and landscape patterns (Calogero Schillaci2015). As technology advances, so does the ability to predict and model real world phenomenon. Typical modeling attempts to accurately demonstrate and quantify the interaction of multiple environmental variables in order to not only understand the role of such parameters in nature, but also to predict their behavior under varying conditions (Steven Hall 2018). Before the introduction of GIS and remote sensing technologies cartographers relied heavily on data derived from conventional survey for modeling and analysis of topography (Alpha & Winter, 1971). The manual method of topographic mapping and visualization can no longer satisfy the contemporary planning needs (Nkeki 2014). Recognition of the tremendous role that topographic map play in national development by advanced countries of the world resulted to huge investment in technology both in data collection, manipulation and geo-visualization by these countries. In developing countries, the lack of reliable topographical data for greater part of such countries generally hinders topographic mapping (Valeriano et al, 2006). This deficiency is common with Africa countries like Nigeria, where poverty and inadequacy in technological advancement in the aspect of geospatial information has resulted to inability of such countries to regularly produce new topographical map especially on a wider scale (Ozah & Kufoniyi, 2008). Because topographical information is fundamental to a large variety of environmental planning and resource management, most of these countries resort to utilizing existing topographic map which are very old and out of date and most of these maps are stored and visualized using map sheets which often limit further manipulation and integration.

The use of earth observation system (EOS) technology and GIS platform is currently gaining popularity over conventional ground techniques (Gallant, 2011). Digital Elevation Model (DEM) and satellite imageries are fundamental pieces of information needed to understand and manage the environment. Its manipulation in GIS environment enables qualitative and quantitative information's that facilitates understanding of our environments to be derived. DEMs have become important sources of topographical data for many scientific and engineering applications such as hydrological and geological studies, infrastructure planning and environmental management (Yu and Ge, 2010).Where local topographical data is unavailable, incomplete or out-dated, DEMs from remotely sensed data can be the main source of information. The Shuttle Radar Topography Mission (SRTM) used in this study is a digital topographic database on nearly global scale. It was co-sponsored by the National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA) (Dowding 2004). The Shuttle Radar Topography Mission is an international research effort that obtained digital elevation models on a near-global scale from 56° S to 60° N to generate the most complete high-resolution digital topographic database of Earth prior to the release of the ASTER GDEM in 2009. The extent of the coverage means that Nigeria, lying between latitudes 4° and 14°N is covered by this mission (Nwilo2017). SRTM consisted of a specially modified radar system that flew on board the Space Shuttle Endeavour during the 11-day STS-99 mission in February 2000, based on the older Space borne Imaging Radar-C/X-band Synthetic Aperture Radar (SIR-C/X-SAR), previously used on the Shuttle in 1994 (Nkeki 2014). The elevation models are arranged in tiles, each covering one degree of latitude and one degree of longitude, named according to their south western corners. It follows that "n45e006" stretches from 45°N 6°E to 46°N 7°E and "s45w006" from 45°S 6°W to 44°S 5°W. The resolution of the raw data is one arc-second (30 m), but this has only been released over United States territory. A derived one arc-second dataset (with trees and other non-terrain features removed) covering Australia was made available in November 2011; the raw data are restricted for government use. For the rest of the world, only three arc-second (90 m) data are available. Each one arc-second tile has 3,601 rows. The dimensions of the three arc-second tiles are 1201 x 1201. The original SRTM elevations were calculated relative to the WGS84 ellipsoid and then the EGM96 geoid separation values were added to convert to heights relative to the geoid for all the released products. The elevation models derived from the SRTM data are used in Geographic Information Systems. They can be downloaded freely over the Internet, and their file format is supported by several software developments.

1.1 Aim and Objectives

The aim of this paper is to demonstrate the application of geospatial technique in extraction and analysis of terrain features in kogi state. The main objectives includes :

i. To produce 2.5-D and 3-D topographical models of the study area.
ii. To investigate the relationship between the landscape and river inundation.
iii. To investigate the drainage network pattern of the study area.
iv. To understand the land use/land cover pattern of the study area

1.3 Study Area:

Kogi State is located in North central part of Nigeria and covers an area of 28936.175Km2. Geographically it is located at latitude 7° 30´N and longitude 6° 42´E. The word Kogi is Hausa name which means a river. Kogi state shares common boundary with Niger, Kwara, Nasarawa and the federal capital territory in the North. In the east the state is bounded by Benue and Enugu states, in the south by Enugu and Anambra state and in the west by Ondo, Ekiti and Edo State. The 1991 population census recorded the state to have a population of populations 2147756 while the 2006 census recorded the population as 3278487. Politically, the state is divided into three senatorial districts i.e. Kogi central, kogi east and Kogi west.

The state is further divided into 21 local government areas (LGA) the capital of Kogi State is Lokoja the confluence town of river Niger and Benue.

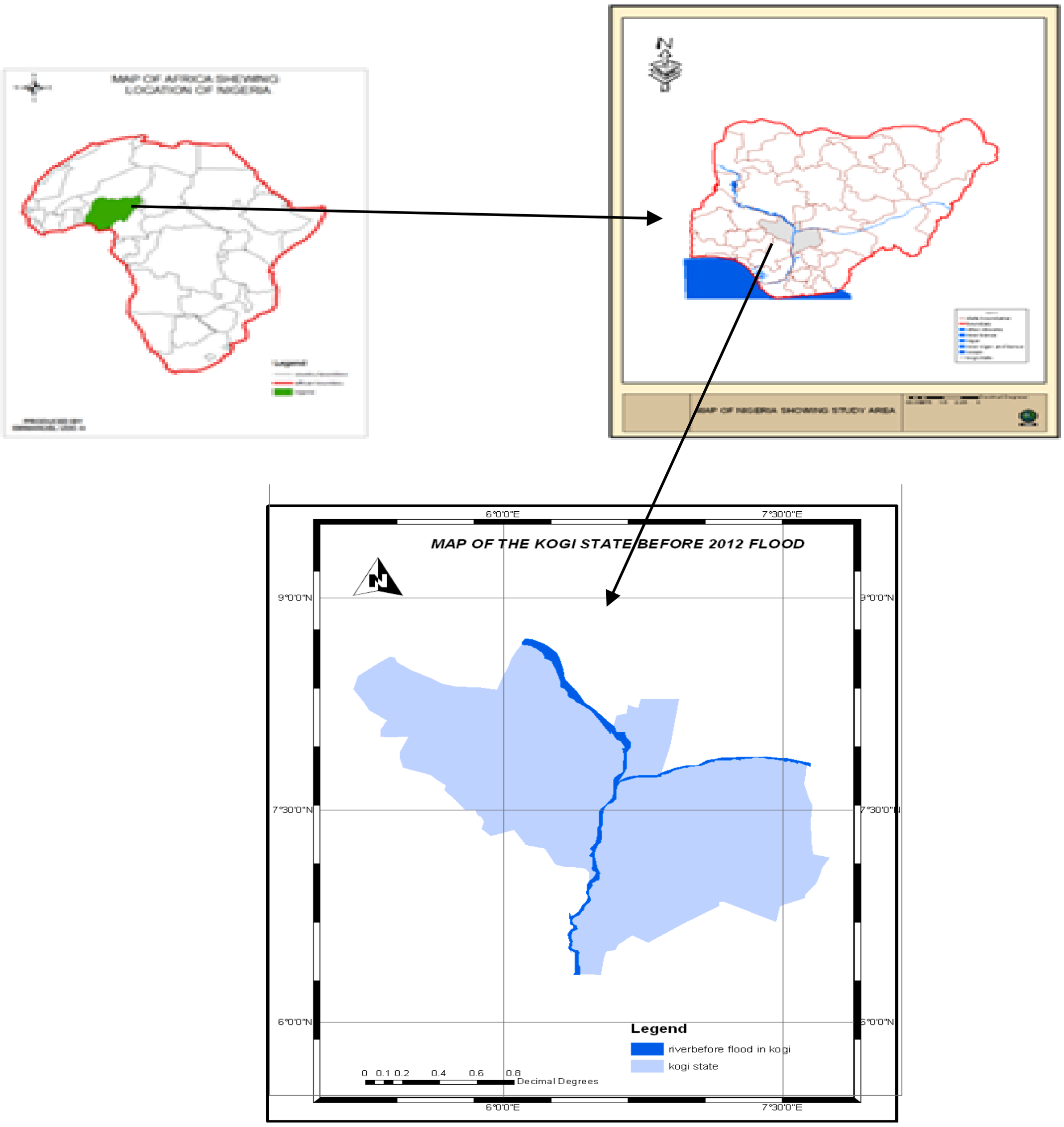


Fig 1 Location Map of The Study Area

2.0 MATERIALS AND METHODS

The use of earth observation system technology and GIS platform has become an integrated well developed and reliable approach in geospatial analysis. As a result, this paper utilized 3arc seconds (90m) resolution DEM created by SRTM. This was downloaded from USGS explorer. Other datasets includes Landsat image with resolution 30m which was downloaded from Global land cover facility, 2012 flood remote sensing satellite imageries captured by moderate resolution imaging spectroradiometer (MODIS) on NASAS terra satellite and administrative map of the study area from which the administrative boundary of the study area was extracted. Software used includes ArcGIS10.1, ERDAS Imagine, and Sufer11.

2.1 Terrain Analysis

Creating the DEM for the analysis requires merging the SRTM DEM tiles into one raster grid entity (mosaicing). Progressively, the tiles were entered into the ArcGIS10.1 environment for processing. With the help of data management module within this environment, the DEM tiles were misaiced. The GIS approach to topographical mapping requires a DEM that is spatially corrected. Such corrected terrain model is one in which all depressions have been filled. The fill sinks module was used to modify the elevation raster to ensure that all depressions are filled. The generated data was transformed from geographic coordinate system to projected coordinate system (i.e. from GCS-WGS1984 to WGS1984 World Mercator. Using the boundary shape file, the study area was clipped out from the merged elevation raster. The clipped DEM was used for generation of flow accumulation map (fig2b) Aspect map (fig9), and slope map (fig10) of the study area. For the purpose of further analysis the clipped raster was converted to XYZ point data and exported to surfer10 worksheet where a .dat file was created. The output (.dat file) was blanked and used for generation of contour (fig2a), Wireframe (fig3), 3-D model (fig4) and digital elevation model (fig5) of the study area. In addition elevation profile lines drawn along distinct relief areas were also produced (fig8). The multiple terrain analysis was made for better understanding of the terrain. These models revealed terrain elevation range of 20m to 580m above mean sea level with elevation decreasing towards the river Niger.

2.2 Drainage Network Extraction

The elevation raster was used to delineate the drainage network of the study area while the largest river (River Niger Benue) was extracted from the Landsat imagery. The drainage map is the flow accumulation processed from void filled DEM (SRTM). This was processed using the hydrological module of ArcGIS 10.1. The fill sink extension was used to fill the void areas of the elevation raster (SRTM) and the output from this manipulation was used to generate the flow direction raster which was further processed to drainage network. The drainage network was digitized and overlaid with river Niger-Benue layer which was extracted from the landsat imagery (fig11)

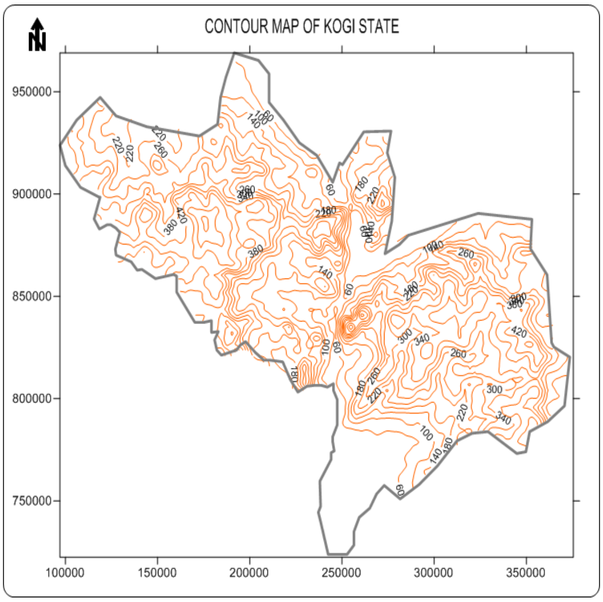
2.3 Land use/Land cover (LULC) Analysis

Remote sensing is the dynamic detection and recording of the earth’s surface using reflected or emitted electromagnetic energy. Landsat satellites use the Worldwide Reference System (WRS) of scenes divided up into paths and rows. According to NASA (2004), The Worldwide Reference System (WRS) is a global notation system for Landsat data. It enables a user to inquire about satellite imagery over any portion of the earth by specifying the PATH and ROW numbers. The WRS has proven valuable for the cataloguing, referencing, and day-to-day use of imagery transmitted from the Landsat sensors. The image tiles covering the study area was imported to ERDAS Imagine window and mosaiced using the *Mosaic Tool*. The merged data was pre-processed for radiometric and geometric correction and later classified using un-supervise classification algorithm. Field verification was carried out in other to assign the proper LULC categories to the various classes. The classified image was exported to ArcGIS10.1 environment where it was registered to UTM (Universal Transverse Mercator) coordinate system WGS 84 Zone 32. To maintain the boundary limit, the classified image was masked with the boundary shape file using extraction by mask tool in ArcGIS. Finally, the various identified land use land cover categories were digitized as layers and overlaid with the drainage map previously extracted (fig12).

3.0. RESULTS AND DISCUSSIONS

3.1 Results

Figure 2a is the contour map of the study area. Fig 2b is the flow accumulation map of the study area. fig3 is the wire frame of the study area. Fig4 is the overlay analysis of flood layer (red) and 3-D model of the study area. Fig5 is overlay analysis of contour map on DTM of the study area. Fig 6 is overlay analysis of contour map on wireframe of the study area. Fig 7 is overlay analysis of flood layer, contour map and DTM of the study area. Fig8 is three elevation profile lines drawn along distinct relief areas. Fig 9 is Aspect map of the study area. Fig 10 is Slope map of the study area. Fig 11 is drainage map of the study area. Fig12 is Land use/land cover map of the study area. Fig13 is reclassified elevation map of the study area. Fig14 is chart revealing Percentage of land occupied by elevation categories in the study area. Fig 15 is chart revealing area of land occupied by elevation categories in the study area. Fig16 is chart revealing area of land occupied by land use categories in the study area. Fig 17 is chart revealing percentage of Land occupied by land use categories in the study area and Table 1 contains the result of land use/ land cover analysis and drainage density of the study area.



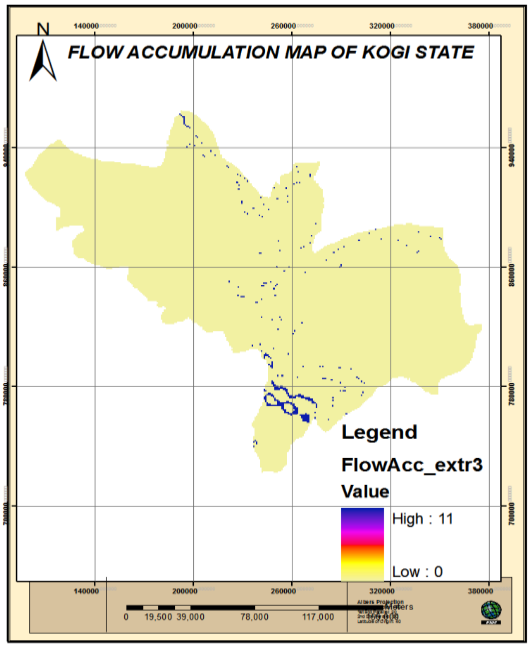
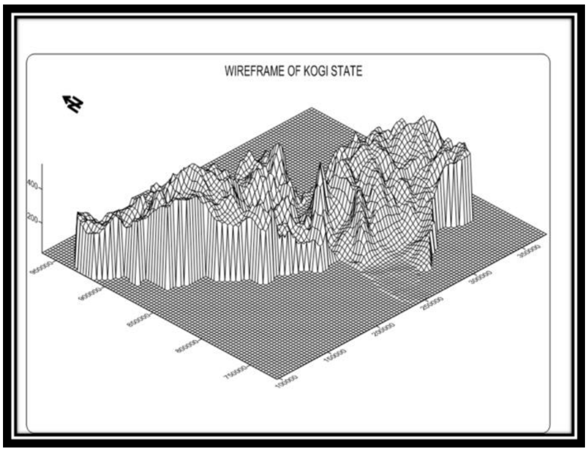


Fig2a contour map of the study area

Fig 2b Flow accumulation map of the study area



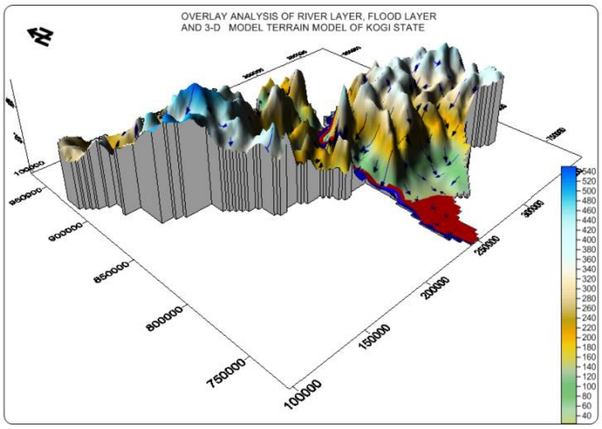
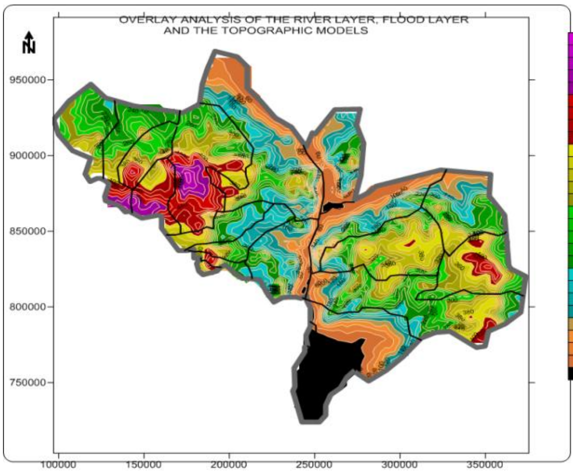
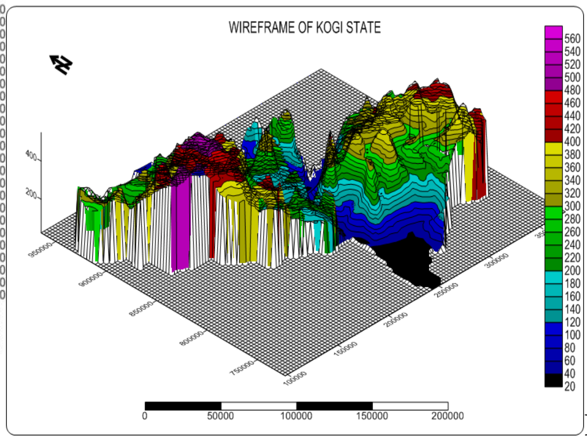


Fig3 wire frame map of the study area   Fig 4 overlay analysisof flood layer
on 3-D Model of the study area





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i Fig5 overlay analysis of contour map on DTM the study area   Fig 6 overlay analysis of
contour map on wireframe of the study area

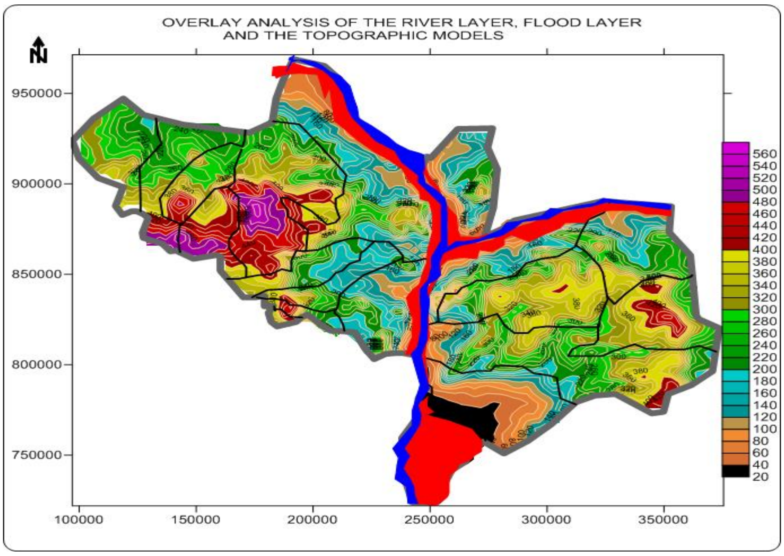


Fig 7overlay analysis of flood layer, contour map and DTM of the study area

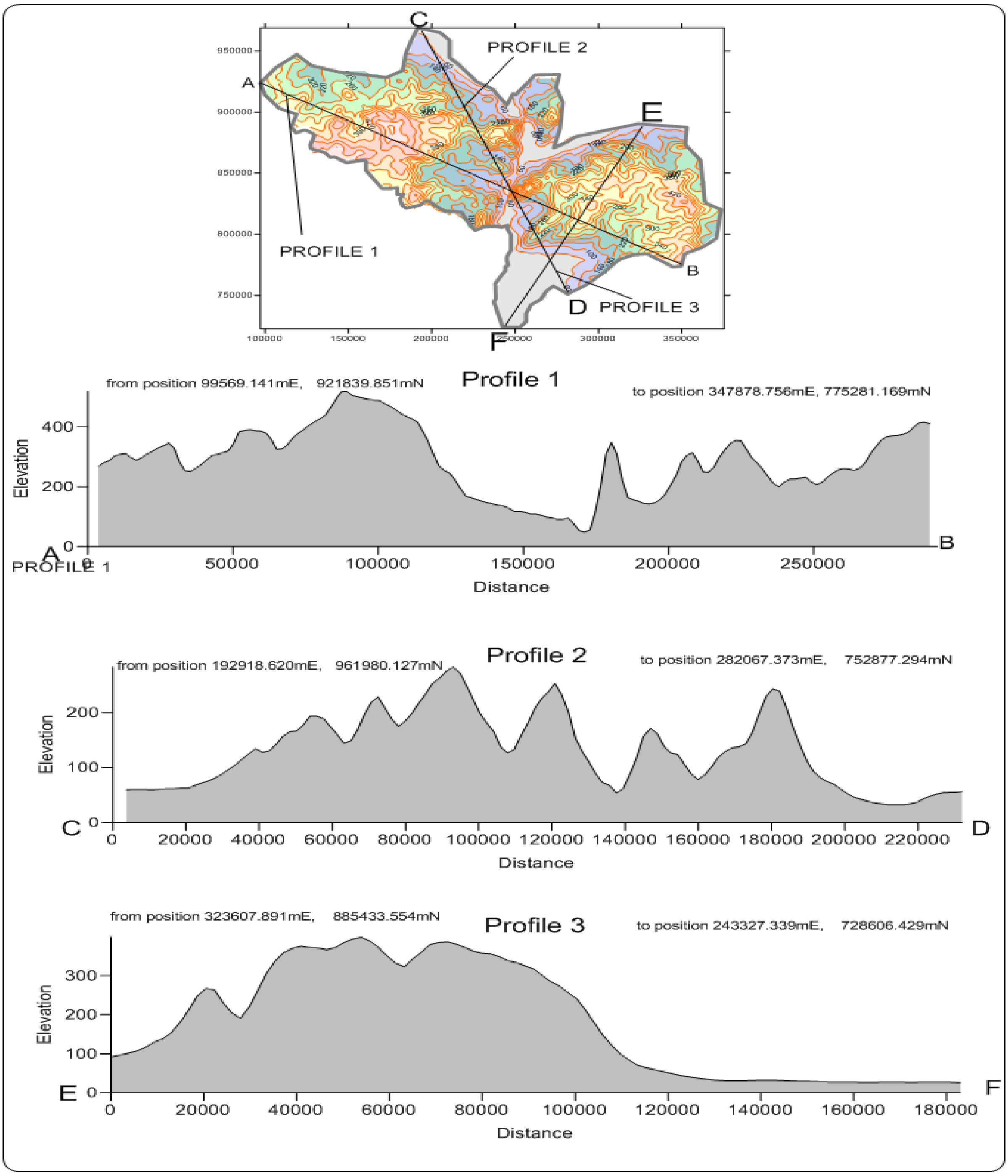
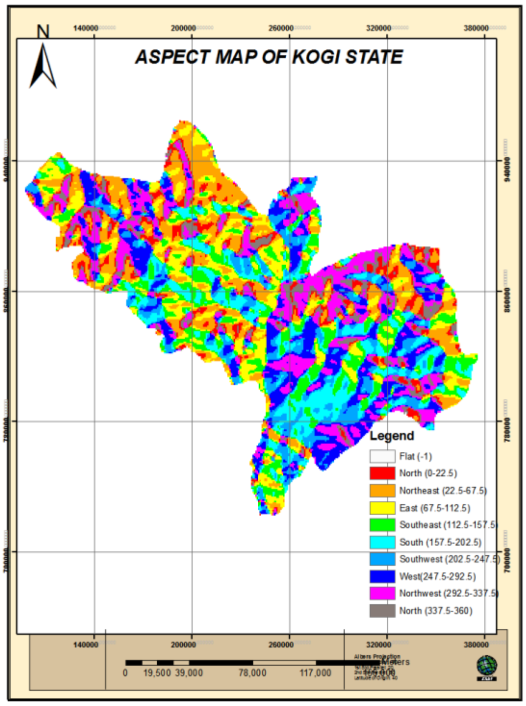


Fig 8 Three elevation profile lines drawn along distinct relief areas. At top is the DEM of the study region showing path profile lines on the surface (A--B, C-D, and E-F)



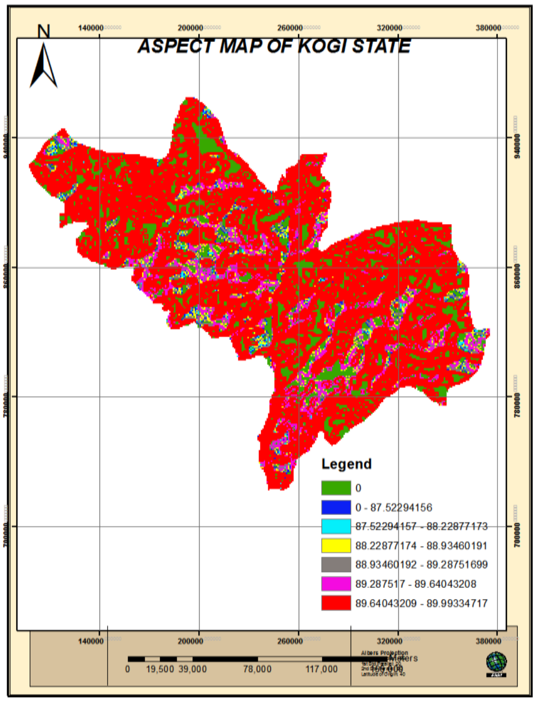


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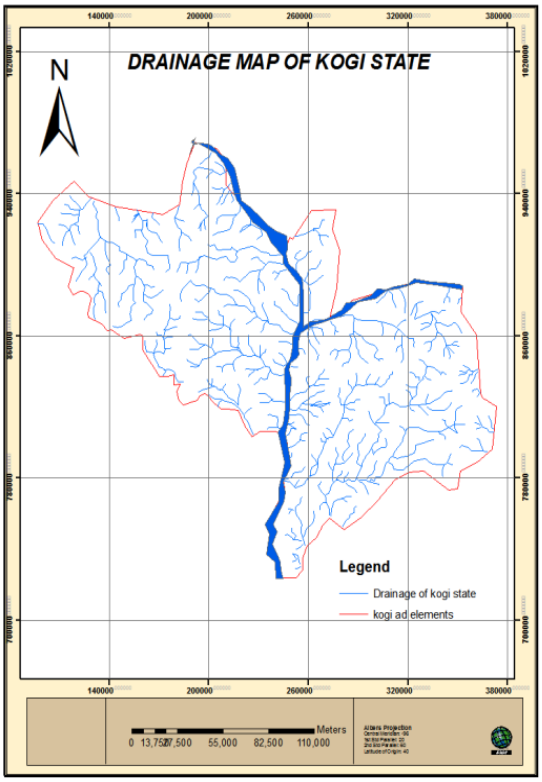
Fig 9 Aspect map of the study area Fig 10 Slope map of the study area



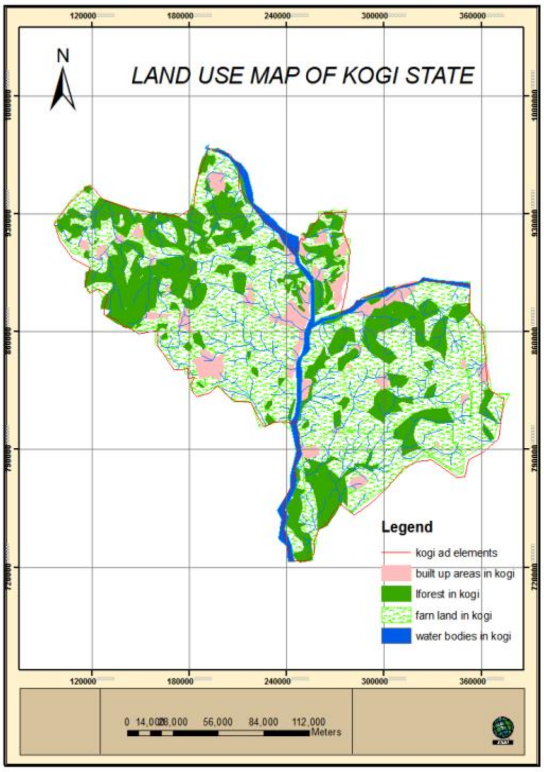


Fig 11 Drainage map of the study area

Fig 12 LU/LC map of the study area

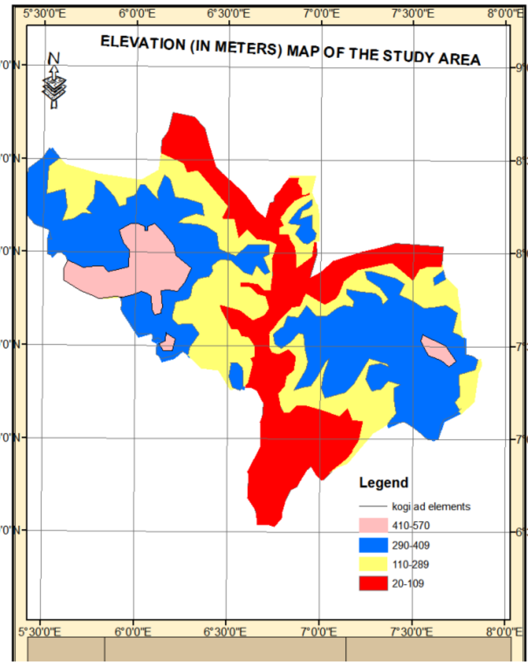


Fig 13 Elevation map of the study area

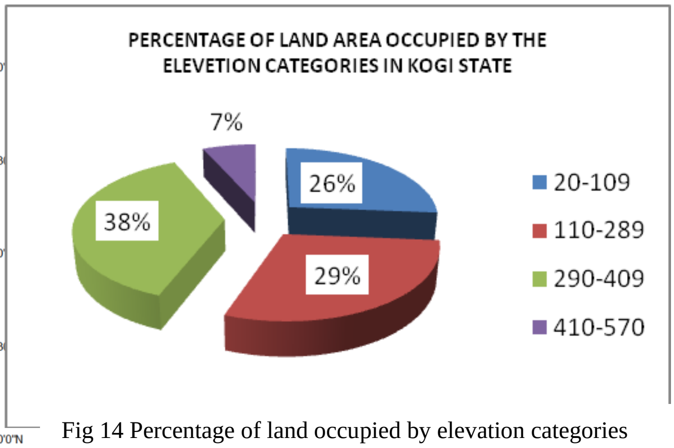


Fig 14 Percentage of land occupied by elevation categories in the study area

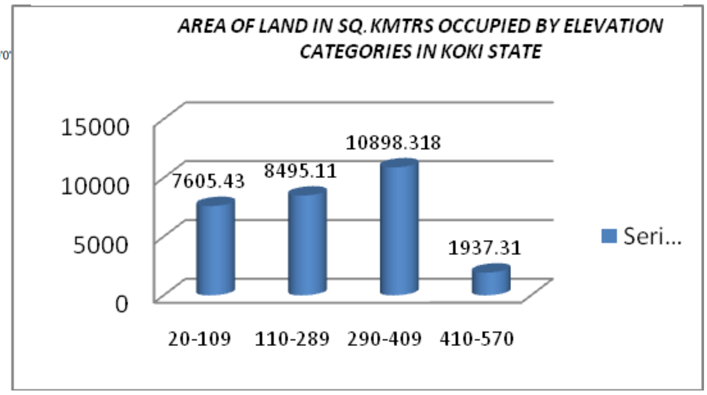
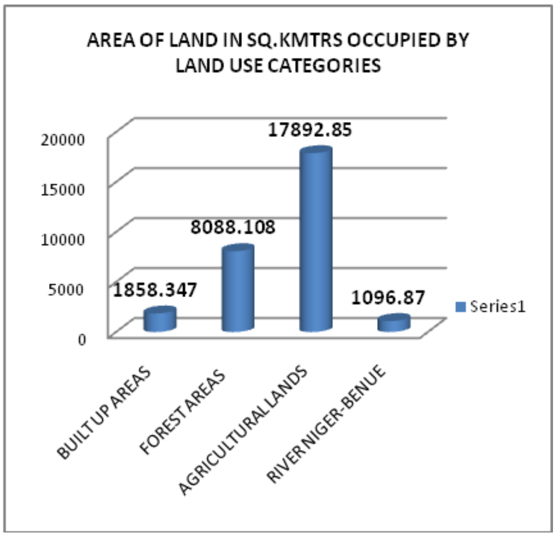


Fig 15 Area of land occupied by elevation categories in the studv area



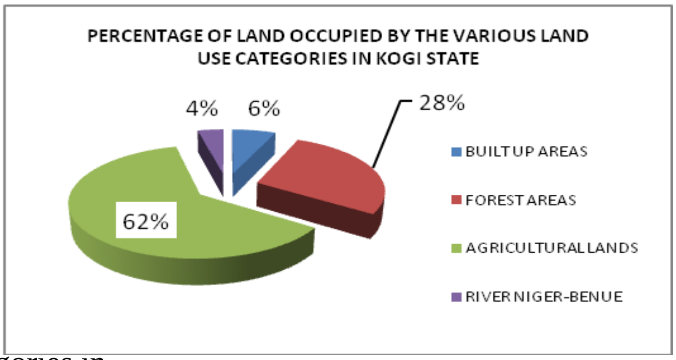


Fig 16 area of land occupied by land use categories in the study area

Fig 17 percentage of Land occupied by land use categories in the study area

Table 1 LULC/ Drainage density of study area

LAND USE LAND COVER	AREA OF LAND OCCUPIED IN km^2	PERCENTAGE OF LAND OCCUPIED BY LAND USE TYPES	DRAINAGE DENSITY OF KOGI STATE
BUILT UP AREAS	1858.347	6.42	**∑L of rivers = 4437km** **Drainage Area = 28936.175** **Drainage density = 0.1533Km^{-1}**
FOREST AREAS	8088.108	27.95	
AGRICULTURAL LANDS	17892.850	61.84	
RIVER NIGER-BENUE	1096.870	3.79	

4.0 DISCUSSION OF RESULTS

X,Y,Z point data generated from the SRTM was resample and contour map and DTM (Figure 2 and 5) were generated. The density of contour lines in the north eastern part and north western region of the study area indicate the ruggedness of the landscape. The DEM or surface analysis of the study area reveals that the relief falls within the range of 20 and 580m above mean sea level. The lowest elevation is found around River Niger-Benue. The elevation of the state increases gradually up towards the Northern western and north eastern part of the state with the highest elevation at 580m above sea level. The blue region in fig2 (flow accumulation map) reflects areas of high flow accumulation. These areas is expected to have longer inundation time during flood disaster. The wire frame and 3-D model (fig 3 and 4) reveals a wide valley (river Niger valley) which created a distinct dichotomy between the western and eastern relief. They further revealed that the southern part of the study area is flat and lies within elevation range of between 20m to 40m above mean sea level. A close look at the overlay analysis of the 2012 flood layer (red) on the 3-D model (fig4) revealed that this region was extensively flooded due to relatively low relief. Figure7 is the overlay analysis of contour map, DTM, river Niger Benue layer (blue) and 2012 flood layer (red). The map revealed that generally, areas around the river Niger-Benue are at very low relief. This accounts why these areas were extensively inundation during the 2012 flood.
Profile drawing for visualizing topographic shape and structure is a prominent method often employ by Geomorphologists and Geologists. This method is particularly helpful when the desired result is to visualize the pattern of mountain ranges, comparing the depth of two or more valleys and showing landscape variation in terms of ruggedness, height, steepness plane and when chosen the most economic areas for route construction. Fig8 reveals profiles drawn along distinct and suspicious landforms. Profiles were drawn along (A-B), (C-D), and (E-F). These graphical models revealed high level of undulations between the locations. Slope

Aspect detects the down slope or downhill direction of the maximum rate of change in value from each cell to its neighbors. It is often referred to as the slope direction. The slope direction grid can be used effectively for advance topographical modeling such as identifying and characterizing areas of high water runoff and landslide, estimating the portion of land that will receive high and low solar illumination for agricultural research purposes. At a particular location a value is generated for the cell and this value indicates the compass direction of such slope. The aspect of a terrain is measured clockwise (in degrees) from 0° which is the north through northeast and move to the north again through the northwest which complete 360°. In Figure9, the slopes are given values which indicate their steepness and colors series which indicates the slope direction. The slope direction along the river Niger Basin characterize high water runoff towards the basin from all areas around the basin. Fig 10 reveals the categories of slopes levels at different locations within the study area. slope magnitude and slope direction are indispensable in erosion modeling.

4.1Drainage Network analysis

The overall stream network of the study area was mapped using the resample SRTM dataset. The drainage map is the flow accumulation map developed from void filled SRTM. This was processed using the hydrological module of ArcGIS 10.1. The sink areas are pixels which have heights that are lower than neighboring pixel values. when these sink are filled the runoff from the DEM will reach its edges. The void filled raster was use to generate the flow direction map which was subsequently used in mapping the drainage network (fig11).The resultant drainage network was vectorised for easy integration with other environmental datasets.

4.2 Elevation reclassification and Land use/land cover analysis;

Fig (13) revealed the reclassified elevation map of the study area, fig14 and fig15 also, reveals the percentages and area of land within the study area occupied by the elevation categories. Quantitatively, the analysis revealed that 7605.43 square kilometers (26%) red, 8495.11square kilometers (29%)yellow, 10898.318 square kilometers (38%)blue, and 1937.311 square kilometers (7%)violet of the study area are covered by elevation categories of 20m-109m, 110m-289m, 290m-409m and 410m -570m respectively. Fig 12 reveals the land use map of the study area while fig 16 and 17 revealed the landed area occupied by the LU/LC categories and the percentages of land also occupied by the various categories. Table (I) integrates the result of land use analysis and drainage density analysis. This study revealed that there are four land use/land cover types within the state. These are farmland lands, water bodies, built up areas and forest. The analysis further revealed that Built up areas covers 1858.347km^2 (6%), forest areas covers 8088.108km^2 (28%) of the land mass of kogi state, While agricultural lands and water bodies covers 17892.850 km^2 (62%) and 1096.870km^2 (4%) respectively. Further analysis revealed that the study area has drainage density of 0.1533km^{-1}with a total length of **4437km** of rivers covering it.

5.0 CONCLUSION

Accurate topographic information is essential and paramount for understanding and management of the environment. Geographic visual models of any topography is a complex task that requires complex state-of-the-art technology if the goal is to achieve accurate result. Based on this, sophisticated method that produces accurate result must be adopted to ensure that the right decision is made during planning. This paper has demonstrated that geospatial techniques can effectively be used to model and analyze topographical variables. The digital derivatives generated in this study clearly prove that geospatial technique is a better substitute to conventional mapping and visualization techniques. The integration of remote sensing and GIS facilitates the Production of detailed large-scale topographical maps of all regions of the world within a limited time frame and at a reduced cost. From the remote sensing datasets (SRTM and Landsat imagery) it was possible to extract multiple environmental features as evidence by the result above which is impossible by conventional approach especially considering the extent. Within the GIS platform it was possible to extract display and visualize the landscape in different visual formats for better understanding. Therefore this study clearly demonstrated that integration of remote sensing and GIS makes topographic information easier to understand and interpret. Moreover, such quality information is vital for spatial planning. It is therefore recommend that researchers should adopt the approach for environmental modeling and assessment.

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