MedCrave Step into the World of Research

Forestry Research and Engineering: International Journal

Research Article

Open Access

Terrain analysis for environmental sustainability in Taraba Central Senatorial Districts, North-East, Nigeria

Abstract

Terrain analysis is the process of analyzing and interpreting man-made and natural features on the earth surface, for the assessment of the topography, environmental hazards, livelihood/human activities and infrastructural developments which include; suitability studies for agricultural, industrial, residential and transportation development, assessment of landuse/landcover (LULC), forestry management, military operations, soil erosion estimation and vegetation/ecology. Remotely sensed data (Digital Elevation Models and Landsat 8 image of 2021) were analyzed using Geographical Information System (GIS) techniques to assess the topography, drainage, vegetation, geology and soils of the study area for sustainable development. The result clearly revealed the location, extent and nature of the topography, the mountain ranges, Mambilla Plateau, valleys and the plains were conspicuously shown in different dimensions. The topography of the area is heterogeneous consisting of plains, mountains/highlands and the Mambilla Plateau. The plains could be utilized for agricultural (rain fed and irrigation), industrial, grazing and other activities, but are prone to flood hazard, while the mountains/highlands/plateau could be explored for transhumance, mineral resources, hydro-electricity, communication facilities and military operations. The mountain ranges and plateau were however vulnerable to soil erosion and landslides. The generated slope, depressions, aspect and LULC all revealed the nature of the area which can also be assessed for various environmental monitoring and management. It was recommended that, for sustainable planning and development on land, terrain analysis is necessary especially for suitability studies, natural resources exploration and environmental hazards assessments.

Keywords: environmental sustainability, geospatial techniques, terrain analysis, topography, Taraba State

Volume 5 Issue 1 - 2022

Tukura Ejati Danladi, Oruonye ED, Zemba A Ambrose, Ahmed YM

Department of Geography, Taraba State University, Nigeria

Correspondence: Oruonye ED, Department of Geography, Taraba State University, Jalingo, Nigeria, Email eoruony@gmail.com

Received: September 06, 2022 | **Published:** November 03, 2022

Introduction

Terrain analysis as defined by Kehinde et al.,[1] is the process of analyzing and interpreting man-made and natural features on the earth surface, it is the technical and scientific examination of the basic topographic parameters such as slope, aspect, and surface curvature as well as specific applications. Terrain analysis are useful tool for the assessment of the topography, environmental hazards, livelihood, human activities, infrastructural and environmental developments which include; suitability studies for agricultural, industrial, residential and transportation development, assessment of landuse/landcover, drainage basin morphology, forestry management, military operations, soil erosion estimation and vegetation/ecology.[2,3]

Guset[4] postulated that terrain analysis is use for scientific pursuit, that is, to properly understand the terrain characteristics. Among the numerous existing studies on terrain analysis are; Ikusemoran et al.,[5] in the analysis of the terrain of Biu Plateau for transport development. The study used terrain analysis to select route locations and sites for highway survey and design and the assessment of alternative transportation corridors and potential trouble spots for road construction. Ikusemoran et al.,[6] applied geospatial techniques to terrain analysis of Gombe State and opined that geospatial analysis of the terrain gives quick, accurate and reliable data bank and information about the terrain of an area which are easier to update, store and transfer or communicated and which cannot be achieved through manual data. Kehinde et al.,[1] used terrain analysis for military operations in Kachia LGA, Nigeria and concluded that the interpretation and application of terrain analysis leads to effective military training for warfare operations in the battlefields to save lives. Most of the analysis before the advent of geospatial techniques was based on manual methods such as map reading and interpretations of topographical maps/aerial photographs through photogrammetry and land surveying. These conventional methods have been considered outdated, inaccurate, time consuming, lack of storage facilities and the problems of updating the data. Remotely sensed data and GIS technique help to overcome these numerous problems associated with the conventional methods by capturing data of large area in both day and night and the capability of obtaining data of any area without political boundary problems and any physical contact with the area.

In recent years, sustainable utilization of resources (land, vegetation, water, and the atmosphere) has been emphasized to enable the future generation to benefit from the current available resources.[7] Land is one of the most important resources because it determines the quantity and quality of soils, water availability and the nature of the vegetation.[8] Proper land analysis, otherwise called terrain analysis for developmental projects, is a vital way of sustainable development as 'what is to be where are properly analyzed before the commencement of the projects. Furthermore, North-East Nigeria (including the study area) has faced security challenges in recent years. One of the best ways, especially by the military, to identify the possible hideouts of the bandits/terrorists and the nature of the environment of such hideouts and the best route for military operations is using terrain analysis. Environmental hazards such as floods,[9] soil erosion[10] and landslides[11] have been rampaging within the study area which also require the assessment of the affected areas. Therefore, in this study, geospatial techniques for the analysis of the terrain of Taraba

Central Senatorial District for sustainable development, taking into consideration the prone areas to environmental hazards like floods, landslides, and soil erosion and suitability assessment of the areas to developmental projects like residential, agricultural, industrial, transport and communication are carried out.

The study area

Taraba Central Senatorial District comprises of the entire geographical areas of five LGAs which include: Bali, Gashaka, Gassol, Kurmi and Sardauna as shown in Figure 1.

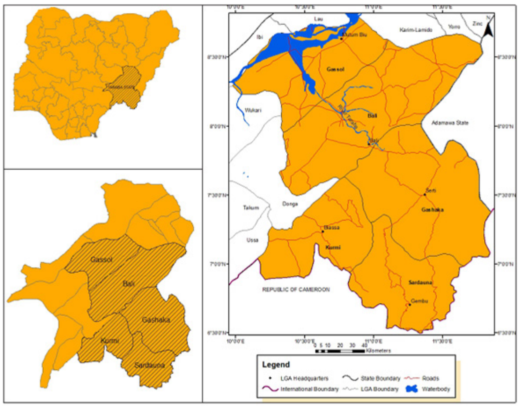


Figure 1 The Study area.

The study area extends from latitude 6º 30' 00" N to 8º 48' 46" N of the Equator, and longitude 10º 01' 00" E to 11º 50' 18" E of the Meridian (Figure 1). The District shares common boundaries with the Republic of Cameroon in the South, Adamawa State in the North East, Karim-Lamido, Ardo-Kola, and Yorro LGAs to the North, Wukari and Donga LGAs, to the West and Ibi LGA to Northwest. The district covers a total land area of 32,110.82 km² (Figure 1). The relief of the study area comprises two main parts: the Benue floodplains consisting of the mountains/highlands and hills in the north, and the Mambilla Plateau in Sardauna LGA. The floodplains, popularly called Muri plains,[12] is very vast land area with elevation from 240 m above sea level and consisting isolated hills, and undulating relatively highlands, high mountains, and riparian plains.[13]

The most important river within the study area is River Benue which forms a natural boundary to Gassol LGA in the north. All other Rivers that drain the study area are tributaries to River Benue. Taraba Central Senatorial District has a wet and dry climate. The wet season lasts, on the average, from April to October.[12] Abubakar and Ibrahim[14] stated that the temperature in Bali region in the north is warm to hot throughout the year with a slight cool period between November and February, and that temperature ranges between 23 and 40º C. According to Tagowa and Buba,[15] there is a wide range in humidity from 26-78% in the GGNP section of the study area. The vegetation of the area consists of the Northern Guinea, the Southern Guinea and the Mountane Vegetation. The vegetation of Gassol LGA is made up of the wooded savanna which consists of different trees scattered all over the region and dense growth of grasses.[16] The soils of major parts of Gassol and Bali in the floodplains of Benue River are Luvisols soils, while along the main rivers such as Rivers Taraba and Donga are Fluvisols. At the foot of the highland regions are Leptosols.

Materials and methods

The five major physical aspects that was considered for the terrain analysis of the study area are; relief, drainage, geology, soils and vegetation. The relief or topography of the study area was assessed by generating the shape file of the study area after which SRTM DEM data of the area was acquired and processed. Using the generated shape file, the study area was extracted from the DEM data. The Extracted DEM data was classified into four: Mountains/ Hills, Highlands, Uplands and floodplains. Using the area calculation module of ArcGIS 10.5, the land area of each of the relief classes in the entire area was determined as well as in each of the five LGAs within the study area. Other surface parameters like 3-Dimentional view, Triangulated Irregular Network (TIN), slope, contour lines among others were generated from the DEM data to analyze the topography of the study area.

The drainage of the area was classified into two: open water areas (large valleys and lakes) and the rivers/streams. Normalized Difference Water Index (NDWI) was used to extract areas covered by open water body in the study area. NDWI is determined by using the Green and NIR bands. For Landsat 8 OLI/TIRS data, Band 3 and Band 5 were used as the Green and NIR bands, respectively.[17] The raster calculator module of ArcGIS 5 software was used to process Bands 3 and 5 of Landsat 8 to extract water body areas. The formula for NDWI for Landsat 5 is:

$$NDWI\ LANDSAT\,8 = \frac{Band\ 3 - Band\ 5}{Band\ 3 + Band\ 5}$$

The output of the results was extracted from the study area, which forms the open water body areas.

Rivers and streams were generated from the same extracted SRTM data that was used for topography assessment with the following steps. The extracted DEM data was filled by using the fill module of ArcGIS 10.5. The essence is to fill all the places that are ordinary depressions and not rivers or streams. Using the output fill image, direction of flow of rivers/rivers were generated. Flow accumulation module of the ArcGIS 10.5 was used to generate the flow accumulation from the flow direction image. Stream Order (Strahller's method) were generated from the flow accumulation image using the stream order module of ArcGIS 10.5. The Stream Order lines were converted from raster to polyline. All the bold lines with higher stream order formed the rivers, while tiny lines with lower order such as 1-3 formed the streams. Spatial patterns of soil types based on texture were used in this study to examine the soil units. Therefore, since the emphasis of soil is only the spatial pattern, the spatial pattern of soils within the study area was extracted from the spatial pattern of soil types in Nigeria which was generated by FAO/UNESCO.[18] The spatial patterns of the soil types were used to analyze the terrain of the area.

To analyze the current vegetation cover of the study area, the 2020 Landsat 8 image of the area was obtained and processed using NDVI to extract the vegetation of the area in ArcGIS 10.5 software by using the formula:

$$NDVI = \frac{(R\ \ - R)}{(R\ \ + R)}$$

Where: IR = Infrared Band (Band 5), R = Red Band (Band 4)

The formula and the bands were therefore expressed as:

$$NDVI\ = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4}$$

NDVI values ranges from -1 to 1.

Citation: Tukura ED, Oruonye ED, Zemba AA, et al . Terrain analysis for environmental sustainability in Taraba Central Senatorial Districts, North-East, Nigeria. *Forest Res Eng Int J.* 2022;5(1):34‒42. DOI: 10.15406/freij.2022.05.00105

NDVI values are interpreted as follows (Kshetri, 2018): -1 to 0 = Water bodies, -0.1 to 0.1 = Barren rocks or sand, 0.2 to 0.5 = Shrubs or grasslands 0.6 to 1.0 = Dense vegetation. The output image was finally classified into five classes based on the values of the NDVI. The NDVI values depend on how dense or how sparse the vegetation is. The spatial pattern and the land areas covered by each of the classes of vegetation were generated and determined respectively.

The geologic units of the study area was extracted and digitized from the Nigeria Geological Survey Agency,[19] while the spatial pattern of soils within the study area was extracted from the soil types in Nigeria by FAO/UNESCO.

Results and discussion

Terrain analysis

Terrain analysis entails the assessment and analysis of the physical aspect of the earth especially topography, drainage, geology, soils and vegetation.

Topography

The topography and the drainage of the study area is shown in Figure 2. Figure 2 and Table 1 show that more than 90% of the total land areas in Gassol and Bali LGAs are floodplains (high and low floodplains). In contrast, Sardauna LGA had about 5% of the land area within the floodplains and more than 85% within the Mountains/highland areas which has also been reported by Mubi[13] that the Gashaka Gumti National Park section of the Mambilla Plateau is characterized by undulating relatively high lands, high mountains, and riparian plains. Gashaka and Kurmi LGAs also have more than half of their land areas in floodplains regions, but both LGAs had less than 15% and 3% within the mountains/highland terrain respectively. The implications of the nature of terrain in the low terrain areas are that the land areas within the floodplains (Bali, Gassol and parts of Kurmi and Gashaka) are wetland areas and suitable for irrigation agriculture[20] and availability of pastures for animal rearing especially during the dry season. These areas are however prone to environmental hazards especially flooding and soil erosion;[12] the swampy nature of the soils poses difficulty for construction of roads, residential and industrial.

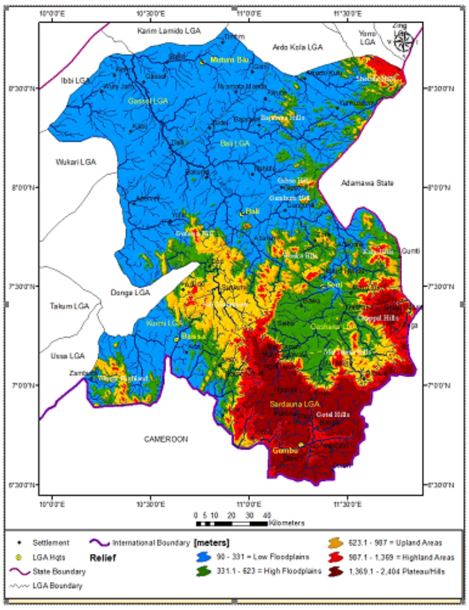


Figure 2 Relief and drainage of the study area.

Tables 1 & 2 show the terrain classes and the highest peak of the main hills/mountains within the study area. While Figures 2a-2d show the spatial patterns of slope, aspect, stream density and TIN maps of the study area. Table 2 shows some of the study area's high mountains/highlands/hills and their respective highest peaks. Figure 2a shows the slope of the area. Slope is one of the principal ways of analyzing the terrain of an area. It is the degree of steepness of an area. Very steep slopes are conspicuous around the Gashaka depression, Chappal Mountain ranges, Wanka highlands areas in Kurmi LGA and the Shebshi Mountains in Bali LGA (Figure 2a). Almost the entire Benue plains (except the intermittent hills) are flat terrain. Since slope determines the thickness of soils, the amount of sun's rays, the amount of run off and vegetation density,[21] very steep slope areas are bound to be subjected to high run off resulting into soil erosion where the soil cover is thick, the aspects of the slopes also determines the amount of LST as sun facing slopes are hotter than the leeward sides.

Table 1 Terrain classes and area covered in the LGAs of the stud area

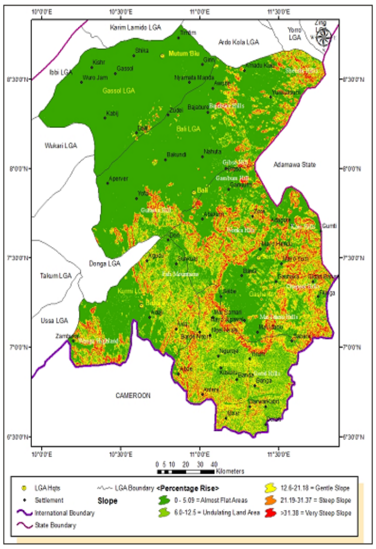
LGAs	Mountains	Highlands	Uplands	High floodplains	Low floodplains	Total
Bali	3.89 0.04%	156.56 1.71%	469.71 5.13%	1420.09 15.51%	7104.08 77.60%	9,154.33
Gashaka	351.49 4.18%	786.97 9.35%	2103.84 25.01%	3529.98 41.96%	1640.81 19.50%	8,413.09
Gassol	-	-	-	3.25 5.84%	5563.77 94.16%	5,567.02
Kurmi	0.84 0.02%	125.92 2.89%	1442.31 33.05%	764.74 17.52%	2030.64 46.53%	4,364.45
Sardauna	2991.69 64.87%	1009.38 21.89%	343.85 7.46%	177.50 3.85%	89.52 1.94%	4,611.94
Total	3347.91 10.43%	2078.83 9.28%	4359.71 13.58%	5895.56 18.36%	16,428.82 51.16%	32,110.83

Source: Computed from the SRTM DEM data analysis by the researcher.

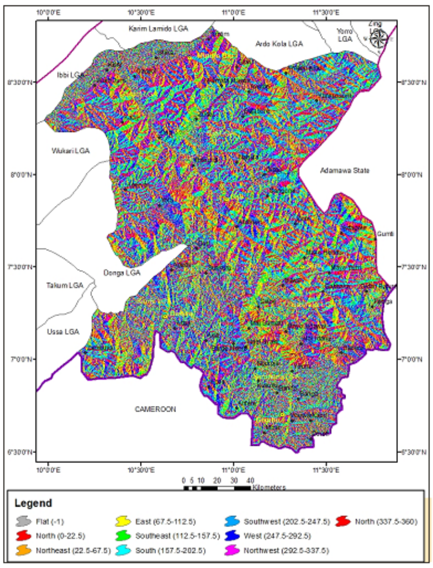
Table 2 Highest peaks of the main hills/mountains within the study area

Mountains/Hills/ Plateaus	LGAs	Heights (m)
Gotel Mountains/Mambilla Plateau	Sardauna	2404
Chappal Mountains	Gashaka	2031
Mai Idanu Hill	Gashaka	1596
Shebshi Mountains	Bali	1533
Kam Hills	Gashaka	1361
Gufama Hill	Bali	1342
Bali Hill	Bali	1248
Wanga	Kurmi	1246
Fali Mountains	Gashaka/Kurmi	1229
Wonka	Gashaka	1189
Agudu Hills	Kurmi	1143
Gibso Hill	Bali	1193
Gambum Hill	Gashaka	1169
Bajabure Hill	Bali	1139

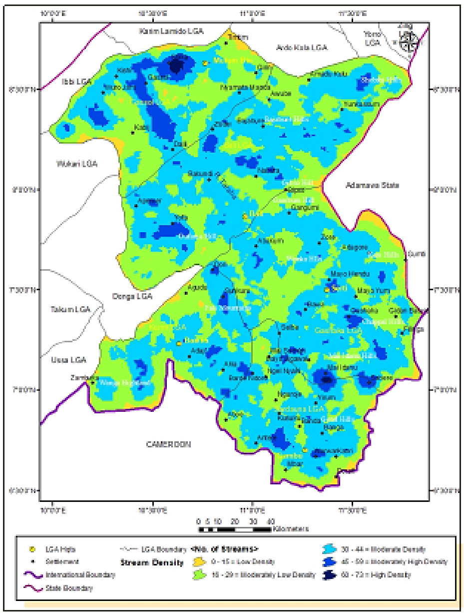
Source: Calculated from the SRTM DEM data by the researcher.



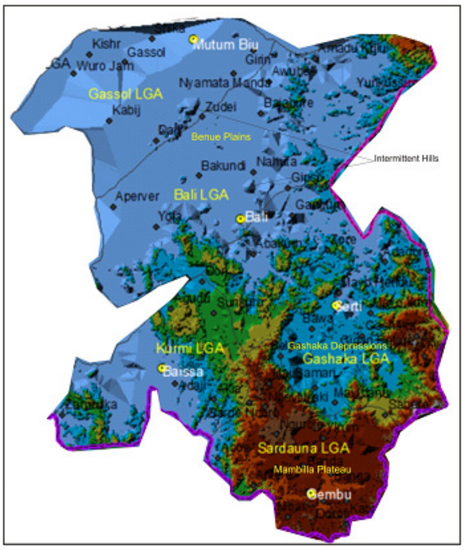
a) Slope of the study area



b) Aspect of the Study Area



c) Stream density of the study area



d) TIN of the study area

Aspect is the direction of the steepness of a slope, the directions are shown with numerous colours and a legend showing each of the directions. Aspect map of the study area is shown in Figure 2b. The almost flat nature of River Benue and the top of Mambilla Plateau makes the areas to have directionless aspect as seen in Figure 2b. The direction of steepness of slopes in terrain analysis has been considered as very important. For instance, Marque and Mora[22] and YinZhi et al.,[23] stated that aspect controls temperature, moisture, and water supply and then vegetation and soil development. These capabilities of aspect makes it one of the factors determining the level of LST, water availability and retention, rate of vegetation depletion and the nature and thickness of soils in the areas.

Stream density which is described as the number of streams in a unit area[24] was generated as shown in Figure 2c to analyze the spatial pattern of drainage system in the study area. Areas with high stream densities of more than 60 streams per square kilometers are found mainly along Rivers Benue and Taraba. Because of the numerous streams, the soils in the areas may be properly drained, resulting in high water availability. This positively enhances plant growth and hence reduces LST and minimizes LULC changes. Guhal and Guhil [25] itemized the following; humidity, vegetation, wetland, bare land, air pollution, rock surface, dry or wet soil and heterogeneous man-made materials as factors controlling water and LST relationships. Agricultural suitability areas and vulnerable areas to environmental hazards such as flood and soil erosion are also determined using Stream density.[26]

Figure 2d shows the TIN map of the study area. TIN map is a 2-Dimensional map which portrays the depressions but not the height of an area. The advantage of TIN map over DEM is its ability to show the depressions and the slopes of an area.[3] Figure 2d conspicuously reveals the Benue plains depression with its numerous intermittent hills such as Dali-Zudei axis in Gassol LGA, and the Awube through Bajabure to Gibso in Bali LGA. The Gashaka Depression is also clearly revealed flanked by the Chappal hills by the east, Mambilla Plateau to the south and the Fali Highlands by the west. The steepness of the sides of the mountain ranges and the intermittent hills are also shown on the TIN map. Depressions are places where runoff from upland areas usually accumulates, therefore, the vast Benue and Gashaka Depression areas are bound to consist vegetation and high capability of water retention with wetter soils than the surrounding environs. However, such areas are highly vulnerable to flood hazards,[3] but suitable for agricultural activities.[27]

3-Dimentional view as the name implies portrays a land area in three different perspectives (length, breath, and height) on the same map. 3-D view are normally utilized to quickly assess the nature of the terrain of an area such as the locations, shapes, sizes, extents and heights of the features in an area. 3-D view is mainly used in the following areas of terrain analysis: to show the actual land area in a 3-d way; length, breath and height for quick assessment of inaccessible areas especially high or rugged topography like the Mambilla areas; for assessing the nature of the terrain such as the plains, slopes, highlands, valleys and drainage[6] to quickly assess areas that are vulnerable to natural hazards such as floods like the Benue plains, landslides[11] and soil erosion.[10] It serves as sources of data or information in the determination of suitability study such as transportation and communication facilities on highland areas,[5] like Mambilla, Wanga, Gangirwal, Shebshi and the intermittent hills within Benue plains; places at risk to environmental hazards; Benue plains for flood,[9] steep sided slopes for erosion,[10] very high plateau and hills like Gangirwal and Chappal for landslides[11] and safe zones for hazard risk management.[9] Figure 3 shows the 3-D view of the study area.

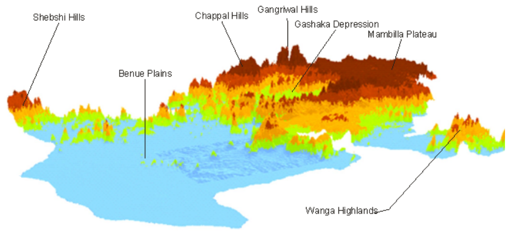


Figure 3 View of the study area.

Vegetation

Figure 4a revealed that the current spatial pattern of the vegetation in the study is not only inclined to latitudes[12] and Akinsoji et al.,[28] but also inclined to relief. The Chappal hills and Fali Mountains at the eastern part of Gashaka and Kurmi LGAs consists of Forest vegetation. Chapman et al.,[29] has also identified Chappal hills as a forest region with *Syzigium guineense var. guineense – Albizia gummifera,* and *Symphonia globulifera – Garcinia smeathmannii* as the two main types of riparian forest. Akinsoji *et al*.,[28] listed the following as some of the canopy trees in Chappal Forest: *Albizia gummifera, Symphonia globulifera, Croton monostachyus, Syzygium guineense subsp. bamendae, Prunus africana, Ficus spp., Entandrophragma angolense, Strombosia scheffleri, Garcinia smeathmanni.* At the lowland northern part of the study area are mainly shrubs and grassland covering most parts of Gassol and Bali LGAs. The Mambilla Mountain tops also consists mainly grassland commonly referred to as Montane Grassland which was also reported by Mubi[13] that the northern section of GGNP are mainly of grasslands with Gallery Forest in some places.

Table 3 shows the vegetation classes and their area coverage and the percentages in each of the five LGAs.

Table 3 Terrain classes and area covered in the LGAs of the stud area

LGAs	Forest	Woodland	Shrubs	Grasslands	Non-Vegetation	Total
Bali	149.84	906.70	3653.65	3525.62	918.52	9,154.33
%	1..64	9.90%	39.92	38.51	10.03	
Gashaka	1063.41	2554.38	2771.35	1295.65	728.30	8,413.09
%	12.64	30.36	32.94	15.40	8.66	
Gassol	9.73	58.33	1104.44	3792.13	602.39	5,567.02
%	0.17	1.05	19.84	68.12	10.82	
Kurmi	1257.63	1491.10	1182.69	270.56	162.47	4,364.45
%	28.82	34.16	27.10	6.20	3.72	
Sardauna	596.84	1169.58	1649.47	719.05	477.00	4,611.94
%	12.94	25.36	35.77	15.59	10.34	
Total	3077.45	6180.09	10361.60	9603.01	2888.68	32,110.83
%	*9.58*	*19.25*	*32.27*	*29.91*	*9.00*	

Source: Computed from the NDVI data analysis by the researcher.

The four vegetation classes and the areas without vegetation cover (built-up areas, roads, bare surfaces and rock outcrops) collectively called non-vegetation areas are presented in Table 3. Table 3 shows that at the northern part of Bali and Gassol LGAs, the vegetation cover is mainly made of shrubs and grasses. The Montane vegetation type of Sardauna and the protected (Gashaka Gumpti National Park) Gashaka LGAs have woodland and shrubs as their major vegetation cover. Kurmi LGA at the southern part is the only LGA with forest and woodland as their major vegetation cover. Except the protected Gashaka LGA and the densely vegetated Kurmi LGA, all the other LGAs within the study area (Bali, Gassol and Sardauna LGAs have more than 10% of the land area uncovered by vegetation. The degradation of the lands within the study area has been attributed to both natural (including climate change) and anthropogenic activities by several scholars. Chapman et al.,[29] listed cattle grazing and fire damage as the main cause of vegetation depletion within the GGNP, Bako et al.,[12] identified bush burning and fuel wood exploitation.

The northern lowland areas with mainly grasslands are utilized for grazing especially during the rainy season. During the dry season when the grasses are dried off, the herdsmen usually move upland in search of fresh pastures or along the main valley of River Benue. Farming (rain fed and irrigation) activities are also carried out in this area because of water availability from Rivers Benue and Taraba. The woodland and forest vegetation areas are known for lumbering regions where lumberable trees especially Rosewood (*P. erinaceus*) tree are available. Artificial forest plantation are also carried out in this zone especially the Ngel Nyake forest reserve on Mambilla plateau Sardauna LGA.

Geology

The spatial pattern of the geologic unit of the study area is shown in Figure 4b. Eleven geologic units comprising Alluvium, Amphibolite, Granite Gneiss, Younger Basalt, Shale and Limestone, Porphroblastic Gneiss, Blended Biotitie Gneiss, Biotite Hemblended Gneiss, Undifferentiated Schistics and Philities, Shale, Sandy Clay and Calcareous Sandstone, Undifferentiated Granite, Migmatite and Gneiss. Biotite Hemblended Gneiss covered most parts of the study area especially most parts of Bali, Gashaka and Sardauna LGAs. Alluvium, Amphibolite, Shale and Limestone and Undifferentiates Granite, Migmatite and Gneiss rock types are restricted to the valley of the Benue especially in Gassol LGA. Table 4 shows the geologic units, the description and locations of each unit, impacts on LULC and LST, land area coverage and the percentages of the land area of each of the units.

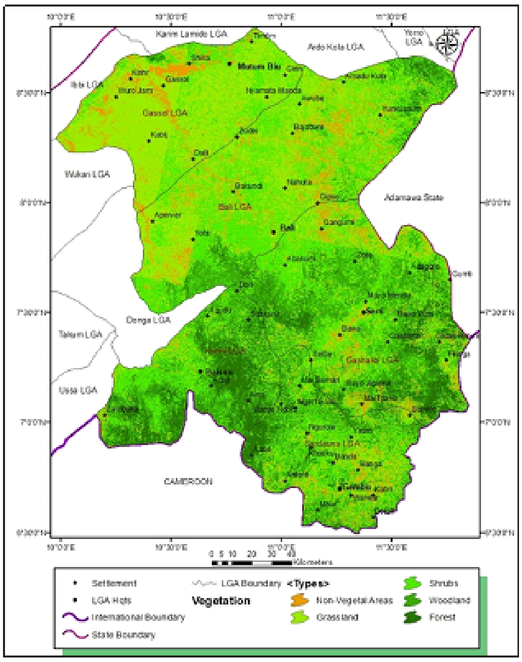
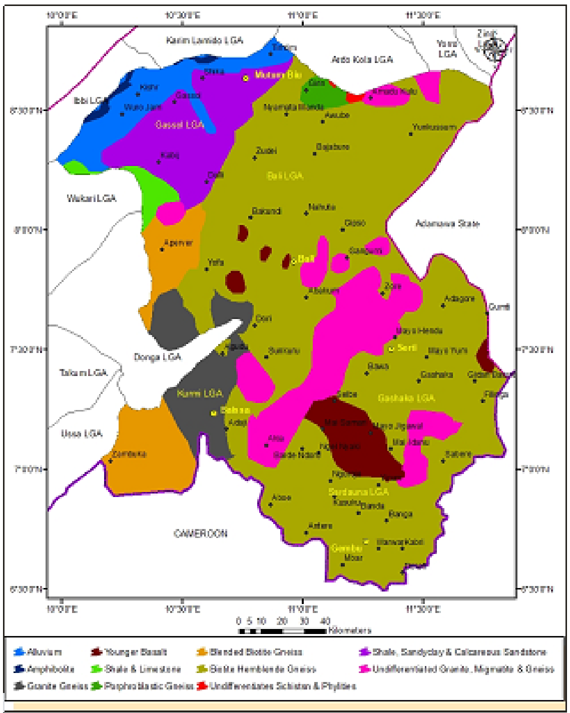


Figure 4 a) Vegetation cover of the Study Area



b) Geology of the Study Area

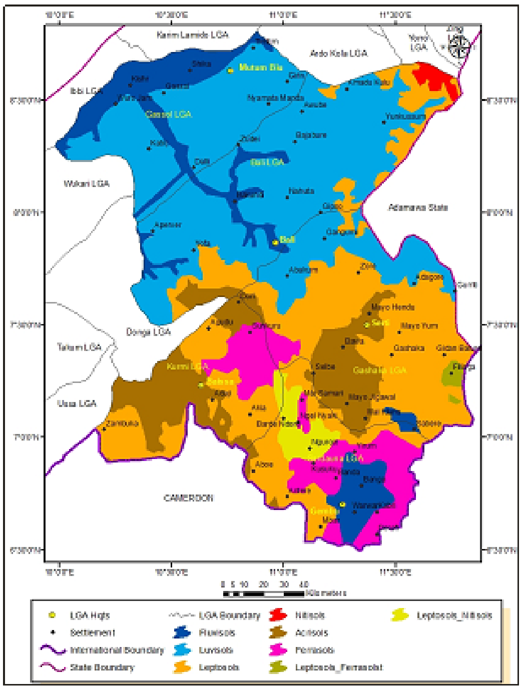


Figure 4c. Soil Units of the Study Area.

Soils

Figure 4c shows the eight soil units within the study area. Fluvisols are found along the main rivers especially River Benue and River Taraba. Donga valley at the top of Mambilla Plateau is also of Fluvisols soil unit. Luvisols is the largest soil unit within the study area covering the entire Benue Plains. Ferrasols covers main parts of the Mambilla Plateau, while Leptosols is the major soil type at the foot of the Mambilla Plateau covering major parts of Gashaka LGA which agrees with the finding of Mubi[13] that Leptosols cover mainly the undulating high plains of the southwestern and central parts of the Gashaka Gumpti National Park which is the major part of Gashaka LGA. Table 5 shows the characteristics of each of the soil units within the study area.[30–35]

Table 4 Geologic units in Taraba Central District

Geologic Units	Description	Locations	Impacts on LULC & LST	Area (km²)	%
Granite Gneiss	Intense heat and pressure can metamorphose granite into a banded rock known as *granite gneiss*. **Gneiss is** Metamorphic **while Granite is igneous rock.**	Located on the northern part of Fali Mts in Kurmi LGA and Gufawa hills in Bali LGA	Areas covered by the hard granite are not easily subjected to LULC changes like the Gneiss that are in layers.	1789.68	5.57
Younger Basalt	Basalt is dark in colour but fine grained igneous rock mostly forms as extrusive rock.	Found on Mambilla Plateau specifically around Ngel Nyaki-Mayo Jigawal axis in Sardauna LGA and some small areas in Bali LGA	Since mainly bare surface or rock outcrop, it is more exposed to higher LST,	1193.28	3.72
Porphroblastic Gneiss	This type of rock has been described as a large mineral crystal in a metamorphic rock.	The geologic unit is found in the plains between Bali and Gassol LGAs around the border with Ardo Kola LGA.	Metamorphic rocks areas being an ongoing processes are liable to frequent changes in LULC and also changes in LST	239.83	0.75
Undifferentiates Schistsn & Phylities	Undifferentiated Schist is associated with many igneous intrusion of older granite	A small land area at the western side of Porphroblastic Gneiss between Bali and Gassol LGAs.	Intrusive rocks are prone to volcanism and landslides (Mubi & Tukur 2005). Dangerous to human habitation	34.32	0.11
Shale, Sandyclay & Calcareous Sandstone	Any group of fine-grained sedimentary rocks. Sandstone are derived from the erosion of basement complex rocks.	Solely found in the Benue plains at the central portion of Gassol LGA	Potential area for limestone deposit for man's use but subject the area to few streams, deep water table and low vegetation growth (Usman *et al.* 2018)	2440.70	7.60
Blended Biotite Gneiss	A large group of black mica minerals found in many rocks including granites, igneous schists and gneisses.	Located around the Wanga hills and the Benue plains at the western part of Bali LGA	Possible areas for granite extraction for construction,	2194.17	6.83
Undifferentiated Granite, Migmatite & Gneiss	Granites are coarse or medium grained intrusive rock that is rich in quartz and feldspar. (FAO/UNESCO, 1996)	It is located in the five LGAs within the study area but largest portion around the mountain ranges separating Fali highlands/Depression/Mambilla Mountains	It is mainly mountainous type of rocks and hence, increases LST. The less vegetation cover, steep slope and thin soil cover leads to soil erosion.	4003.60	12.47

Table 5 Soil Units in Taraba Central District

Soil Units	Description	Locations	Impacts on LULC & LST	Area (km²)	%
Fluvisols	Fluvisols are typically found on level topography that is flooded periodically by surface water or rising groundwater, as in river floodplains, deltas, and coastal lowlands.	Fluvisols are found around the valleys of the main rivers: Benue, Taraba and Suntai extension into the study area. It is also found in the Donga valley on the Mambilla Plateau	High water holding capacity results in wetlands and vegetation, hence, suitable for dry season agriculture but prone to flooding, reducing suitability for residential purposes.	3285.23	10.23
Luvisols	Luvisols are formed on flat or gently sloping landscapes covering an extensively leached layer that is nearly devoid of clay and iron-bearing minerals.	Luvisols cover almost the entire Benue plains within the study area	Similar to Fluvisols, but with lower capacity as water retention in the soil uits is not as high as that of Fluvisols. Same impact with that of Fluvisols but at lower magnitudes.	11,621.34	36.19
Leptosols	Leptosols are soils with a very shallow profile depth. Leptosols are free-draining soils, shallow and/or stony, and implicit low water holding capacity.	Covers large areas of Gashaka LGA and Fali Mountains/Wanga highlands in Kurmi LGA. The western side of Sardauna LGA is also made up of Leptosols	The stony nature of the area as well as the low water holding capacity can aggravates rapid LULC changes as well as increasing LST of the area. Such areas are also prone to soil erosion and can easily be degraded.	9897.85	30.82

Table Continued...

Soil Units	Description	Locations	Impacts on LULC & LST	Area (km²)	%
Nitisols	Nitisols are deep, red, well-drained soil with a clay content of more than 30% and a blocky structure	It covers a small land area and found on the top of Shebshi Mountains in Bali LGA	Because of its well-drained but high clay content, the soil is subjected to cracking and may not support vegetation nor retain water which can results into rapid changes in LULC	205.1	0.64
Acrisols	A clay-rich subsoil with woodland as natural vegetation but mostly have been degraded by constant bush burning. Extensive leaching have led to low levels of plant nutrients, and high erodibility.	It covers the plains of Kurmi LGA and the depression of the central Gashaka LGA	Clay soils are good for dry season farming but prone to floods.	3836.93	11.95
Ferrasols	Fine reddish/orange color soil with exposures of rock outcrop and bare surfaces	It covers most parts of Sarduna LGA and the Fali Mountain area in Kurmi LGA	Since they are mainly rock outcrop or bare surface, they are not prone to constant LULC changes but are subjected to high LST.	2469.4	7.69
Leptosols & Ferrasols	Combination of Leptosols & Ferrasols	Found on the highest part of the study area (Mt Gangirwal hills)	Similar effects as that of areas covered by Leptosols and Ferrasols	135.29	0.42
Leptosols & Nitisols	Combination of Leptosols & Nitisols	It is found in the curve mountain areas around Ngel Nyaki	Similar effects as that of areas covered by Leptosols and Nitisols	659.69	2.05
Total				32,110.83	100

Conclusion

The use of geospatial techniques for analysis of the terrain of Taraba Central Senatorial district for sustainable development has been carried out in this study. It was revealed in the study that what were initially seemingly manually considered impossible to assess and analyze the terrain of an area such as 3-D view, depression analysis, aspect, slope, stream density and spatial pattern of vegetation distribution has been demonstrated in this study. Terrain analysis has also been proven as an important technique or procedures for analyzing the terrain of any area for sustainable development. The topography of the area has been found to be heterogeneous consisting of plains, mountains/highlands and the Mambilla Plateau, which can be utilized for various developmental projects like agriculture (farming, poultry and animal rearing), residential, industrial, military operations. The principal limitations for terrain analysis are data unavailability and the expertise of the analysts. These two factors limit the ability and capability of geospatial technique for terrain analysis. Terrain analysis of the entire Taraba State is recommended for further studies.

Recommendations

(i) For sustainable planning and development on land, terrain analysis is necessary especially for suitability studies, natural resources exploration and environmental hazards assessments.

(ii) Government establishments on environmental management should be trained on the use of geospatial techniques for terrain analysis

(iii) The current security challenges within the study area can be monitored and minimized through terrain analysis for discovery of possible hideouts (forest and mountain areas), routes, and spatial locations of settlements.

Acknowledgements

None.

Conflicts of interest

Authors declare that there is no conflict of interest.

References

1. Kehinde OI, Ikusemoran M, Odihi JO. Geospatial analysis of the terrain of Kachia LGA, Kaduna State, Nigeria, for military operations. *Current journal of applied science & technology*. 2017;19(6):1–18.
2. Wilson JP, Gallant JC. Digital terrain analysis. In: Wilson, J.P. and Gallant, J.C, Eds, Terrain analysis: Principles and applications, John Wiley & Sons, New York; 2000. p. 1–27.
3. Ikusemoran M. Geospatial assessment of hydrological hazards and disaster risk in Kiri dam's catchment, Adamawa State, Nigeria. An Unpublished Ph.D thesis, Department of Geography, Modibbo Adama University, Yola, Nigeria; 2022.
4. Guset U. Introduction to terrain analysis. 2015.
5. Ikusemoran M, Abdullahi J, Dami A. Terrain analysis of Biu Plateau, for road transport development, Borno State, Nigeria. *Journal of geography and geology*. 2014;6(2):28–35.
6. Ikusemoran M, Bala BW, Lazarus AM. Geospatial techniques for terrain Analysis of Gombe State, Nigeria. *Journal of geography, environment and earth science international.* 2016;6(1):1–20.
7. Tomislav K. The concept of sustainable development: From its beginning to the contemporary issues. *Zagreb International Review of Economics and Business.* 2018;21(1):67–94.
8. Nebere H, Tolossa D, Bantider A. Analyzing factors affecting the sustainability of land management practices in Mecha Woreda, Northwestern Ethiopia. *Sustainability*. 2021;13:7007.
9. Adebayo AA, Orunoye ED. An assessment of climate change in Taraba state, Nigeria. *Nigerian Journal of tropical geography*. 2013;4(2).
10. Idakwo VI, Mark MJ, Idakwo FA. Geomorphology and GIS analysis for mapping gully erosion susceptibility in Taraba State, Nigeria. *International Journal of Trend in Scientific Research and Development*. 2020;4(5):1728–1736.

11. Mubi AM, Tukur AL. Geology and relief. In The land and people of the Mambilla Plateau. In: Tukur AL, Adebayo AA, Galtima M, editors. Educational books (Nigeria Ltd). 2005. p. 16–24.
12. Bako T, Oparaku LA, Flayin, JM. The environmental issues of Taraba State. *International journal of scientific & engineering research.* 2016;7(2):286–294.
13. Mubi AM. Remote Sensing–GIS supported land cover analysis of Gashaka–Gumti National Park, Nigeria. *FUTY Journal of the Environment*. 2010;5(1).
14. Abubakar B, Ibrahim M. Assessment of boreholes water quality in Bali Local Government, Taraba State, Nigeria. *FUTY journal of the environment.* 2016;10(1):1–10.
15. Tagowa WN, Buba UN. Emergent strategies for sustainable rural tourism development of Gashaka–Gumti National Park, Nigeria. *WIT Transactions on Ecology and The Env*. 2012.
16. Oruonye ED, Ahmed YM, Gambo MN, et al. Effect of rainfall variability on maize yield in Gassol LGA, Taraba State, Nigeria. *Journal of Agriculture Biotechnology.* 2016;01(01):1–8.
17. Kshetri TB. NDVI, NDBI & NDWI calculation using Landsat 7, 8. Research Associate at GeoInformatics Center (GIC), AIT, Thailand; 2018.
18. FAO/UNESCO/ISRC. Dominant soils of Nigeria. Center for world food studies, thirteen west and central African soil correlation sub–committee meeting, Kumasi. Ghana; 1996.
19. Nigeria Geological Survey Agency. Geology map of Nigeria. 2009.
20. Gani AT, Ali A, Agber PI, et al. Effects of seasonal flooding on the quality of irrigation water in the floodplains of Wukari, Taraba State of Nigeria. *Asian Journal of soil science and plant nutrition*. 2020;6(3):18–27.
21. Peng X, Wu W, Zheng Y, et al. Correlation analysis of land surface temperature and topographic elements in Hangzhou, China. *Sci Rep.* 2020;10(1):10451.
22. Marque's MA, Mora E. The influence of aspect on runoff and soil loss in a Mediterranean burnt forest (Spain). Catena (Elsvier). 1992;19(3–4):333–344.
23. Yin Zhi, Liang Shan, Lina K, et al. Analysis of land surface temperature driving factors and spatial heterogeneity research based on geographically weighted regression model. *Hindawi Complexity*. 2020.
24. Shrirao SD, MR Vaishampayan MR. Analysis of stream frequency and drainage density: A case study of Aner Basin. *Journal of Emerging Technologies and Innovative Research.* 2019;6(4).
25. Guha S, Govil, H. Relationship between land surface temperature and normalized difference water index on various land surfaces: A seasonal analysis. *International Journal of Engineering and Geosciences*. 2021;6(3):165–173.
26. Levavasseur F, Lagacherie P, jean–Stephanie B, et al. Spatial modeling of man–made drainage density of agricultural landscapes. *Journal of landuse science*. 2014.
27. Dindaroglu T, Babur E, Battaglia M, et al. Impact of depression areas and land–use change in the soil organic carbon and total nitrogen contents in a semi–arid karst ecosystem. *CERNE*. 2021;27:e–102980.
28. Akinsoji A, Adeonipekun PA, Adeniyi TA, et al. Evaluation and flora diversity of Gashaka Gumti National Park, Gashaka Sector, Taraba State, Nigeria. *Ethiopian journal of environmental studies & management*. 2016;9(6):713 –737.
29. Chapman HM, Olson S M, Trumm D. An assessment of changes in the montane forests of Taraba State, Nigeria, over the past 30 years. Oryx. 2004;38(3):282–290.
30. Abdus–Salam MO, Bolarinwa AT, Olatunji VO. Geochemical characteristics of Amphibolites in parts of Iseyin–Oyan schist belt, Southwestern Nigeria. *European journal of environment and earth sciences*. 2020;1(5).
31. Mayomi I, Dami A, Maryah UM. GIS based assessment of flood risk and vulnerability of communities in the Benue floodplains, Adamawa State, Nigeria. *Journal of geography and geology*. 2013;5(4):148.
32. Oruonye DO. An assessment of fadama dry season farming through small scale irrigation system in Jalingo LGA, Taraba state. *International Research Journal of Agricultural Science*. 2011;1(1):014–019.
33. Oruonye ED. An assessment of the trends of climatic variables in Taraba State, Nigeria. *Global journal of science frontier research: Environment & earth science*. 2014;14(4):1–14.
34. Levavasseura F, Lagacheriea P, Bailly JS, et al. Agricultural management strategy on food security in Taraba State. *Journal of biology, agriculture and healthcare*. 2014;4(8):29–31.
35. Usman UA, Abdukadir AB, El–Nafaty JM, et al. Lithostratigraphy and geochemical characterization of limestone deposits around Kushimaga Area in Yobe of North–Eastern Nigeria. *Nigerian journal of technology*. 2018;37(4):11–15.

Citation: Tukura ED, Oruonye ED, Zemba AA, et al . Terrain analysis for environmental sustainability in Taraba Central Senatorial Districts, North-East, Nigeria. *Forest Res Eng Int J.* 2022;5(1):34–42. DOI: 10.15406/freij.2022.05.00105