GEOGRAPHICAL SYNTHESIS OF BIU PLATEAU, NORTH EASTERN NIGERIA

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ABATRACT

Geospatial techniques were used to analyze the position and size, topography and relief, drainage and hydrology, soils, landuse and landcover as well as the settlements of Biu Plateau in this paper. The land area of Biu plateau was extracted from Digital Elevation Dataset of Shuttle Radar Topographical Mission (SRTM) DEM data which was acquired online. The DEM data was processed to generate the elevation, slope and 3-Dimentional view of the plateau which were all used to analyze the plateau. The soil type of the plateau was extracted from the Food and Agriculture Organization (FAO) soil types, while the landuse and landcover was generated from a classified Landsat Satellite image of 2015 obtained online from earthexplorer.usgs.gov. ArcGIS 10.1 software was used to classify and calculate the land areas of the plateau and to determine the heights and area coverage of some features of interest. The study revealed that the plateau was found to occupy mainly Biu and Hawul LGAs with little extensions into Kwaya Kusar in Borno State as well as into Gulani and Gujba LGA in Yobe State. The total land area of the plateau that has been hitherto quoted as more than 5,000 km^2 was discovered in this study to occupy only a land area of 2635.12 km^2. The Craters and Crater lakes on the plateau were identified, while the heights and area coverage of each of them were also generated. The main soils type of the plateau was found to be Phaeozem and Leptosols, the plateau was also found to be mainly covered by grasses and shrubs. It was recommended that the plateau can be harnessed for tourism because of the presence of attractive natural features like plateau, craters and crater lakes, and since the plateau consists of abundant grasses and shrubs, the Federal and Borno State government can make the plateau a good site for animal grazing like the Obudu cattle ranch in southern Nigeria.

Keywords: Biu Plateau, Craters, Crater Lakes, Geospatial

INTRODUCTION

Nigeria is blessed with numerous natural resources, among which are the beautiful hills, plateaus, plains, rivers and vegetation. The Mandara highlands in the north east, the Obudu hills in Cross River State, the Jos Plateau from which Plateau State derived its name, the Rivers Niger and Benue, the Niger-Benue trough and other natural endowed features all add to the beauty, and as well serve as tourist sites in Nigeria. The Biu Plateau is the second most popular plateau after Jos Plateau in Nigeria. It serves as watershed to so many rivers, a site of animal grazing and transhumance and tourist centers among others. Until recently most of the natural endowments in the country are rarely studied or when they do, they are often generalized which creates loss of information and dearth of data on some of the features.

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Moreover, most of the studies that have been carried out on these natural features on the plateau were achieved through manual techniques [1, 2, 3]. Though, in the work of [3], some digital maps were used in their analysis of the morphology of volcanic craters but all other measurements were manually determined. The use of manual techniques have been proved to consume so much time, energy and resources and at the end may not be reliable because of its prone to human errors, excessive generalization and difficulty in updating and storage of such information [4,5].

The use of remotely sensed data and Geographical Information System have however been adopted on few studies on Biu plateaus. For instance, [6] used Geospatial techniques in the analysis of the terrain of the plateau for road transport development. This means that a lot is yet to be done on the plateau in order to have extensive knowledge and documentation on the plateau which may serve as data bank for current researchers or for the future generations.

Due to the current security challenges especially in north-eastern Nigeria, effective studies are needed on the natural endowments in the region for proper terrain assessments which can only be effectively achieved through geospatial techniques. For instance, in the previous studies, different values were recorded for the size, shape, height and location of Biu Plateau. In terms of size, [7] reported that the plateau is a rugged terrain overlain by volcanic rocks, whose extent covers over 500 sq. km. In the study of [8] the plateau was said to have covered about 2000sq miles, while, [9] reported that the elevation of the plateau is less than 900m, [3] put the elevation to fall between 600 and 800 m above sea level.

Since all the aforementioned values on the size and heights of Biu plateau are not the same, it means they are not accurate probably because most of them were based on mere estimation or at best by the use of manual methods of measurements. It is therefore necessary to apply modern techniques of spatial analysis which is less in human error and more accurate [4,5] and can be considered to be more reliable to assess the plateau in order to have accurate and reliable documentation of the plateau. Therefore, the main objectives of this study are to: analyze the topography of Biu Plateau using remotely sensed data and GIS techniques, generate some digital maps of the area which portray its true shape, size and heights for reliable data generation and documentation for present and future use.

THE STUDY AREA

According to [7] Biu Plateau is a structural and topographic divide between the Upper Benue Basin to the south and the Chad Basin to the north. A number of well-preserved volcanic hills, made up of basaltic agglomerates, ash, lavas and tuff create miniature escarpments and also form permanent relief features in the northern parts of the plateau. In the work of [6], there is evidence of early volcanic activity in the Biu plateau during the Cretaceous, however, the plateau was built around the end of the Miocene, and the bulk of the rocks are Pliocene basalts that have erupted from small vents or fissures, and then spread in a thin layer over wide areas. Activity resumed in the Quaternary with thin flows of lava issuing from small cinder cones and filling the valleys. Most of the basalts date between 7 and 2 million years ago, but some are less than a million years old. The plateau includes many small pyroclastic cones caused by explosions when water penetrated downward and came into contact with fresh lava. There are a number of well-preserved volcanic cones rising above the Plateau along a NNW-SSE axis in the Miringa volcanic zone.

According to [10], Biu plateau which is largely owing to its varied geological composition provides a great variety of topographical forms featuring rugged hills of granite and sandstone, volcanic plugs and plateau developed on sedimentary and volcanic rocks. Maiduguri Metrological Services (1992) in [6] described Biu Plateau as an area that is

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characterized by three seasons the cold dry season (harmattan) from October to March, hot dry season from April to June and rainy season from July to September. Temperatures are high all the year round with hot season temperature ranging from 39 and 47 °C. The mean annual rainfall on the plateau is about 800mm and rain season lasts for about 150 days. The plateau is covered with the Sudan savannah type of vegetation which consists mainly of scrub vegetation interspersed with tall trees and woodland. The vegetation has been modified in most parts of the area as a result of over cultivation and overgrazing.

Biu plateau also has its problems, [9] reported that the problem in the Biu plateau is lack of extensive good farmland owing to great dissection of the high relief of the area. Moreover, water supplies are also poor on the Biu plateau which is heavily dissected by numerous streams, most of which contain no water during the dry season. He concluded that the water supply problem is a major handicap not only to cropping but also to attempts at sedentarization of the cattle Fulani.

MATERIALS AND METHODS

SRTM DEM of Biu plateau was acquired online from Landsat Earth Data Interface. The DEM was classified into three based on altitude. Other relief features like contours, 3D view and flow accumulation was generated from the DEM map. The area land cover and heights of features of interest were derived by extracting such areas from the entire DEM map and using the area calculation modules of ArcGIS to calculate the areas. The classified DEM also shows the minimum and maximum elevation which gives the heights and depth of such areas. The coordinates of sixty eight (68) numbers of settlements were obtained, processed and added to the DEM image. The results show the actual position of such settlements on the plateau.

The positions of the rivers and streams on the plateau were also obtained from the DEM map by generating the flow accumulation data from the DEM. In fact, no river or stream was digitized in this paper as they were all processed from the DEM, which means positional accuracy and shape of all the rivers and streams were maintained. The Strauller's method of stream ordering was adopted which was also generated from the DEM map by the use of the stream ordering module of the ArcGIS.

The acquired Landsat image was classified into seven identifiable landuse and landcover features of interest using a supervised type of classification. The area coverage of each landuse and landcover types from the classified image was obtained by the use of the area calculation module of the ArcGIS software. The soil map of the area was extracted from an existing soil map of Nigeria prepared by [11]. The identified soil types on the plateau were digitized while the area of each soil type was also calculated in ArcGIS environment. The coordinates of Sixty eight villages were obtained and added to the digital map so as to assess the villages that fall in each of the soil type.

RESULTS

The results of the various generated features in terms of the position and size, relief, drainage and vegetation among others are discussed in this section.

Position and Size of Biu Plateau

Biu plateau is located in Biu, Hawul and Kwaya Kusar LGAs in the southern part of Borno state with extension into Gulani and Gujba LGA in southern Yobe State. The plateau lies between latitudes 10˚.18N and 11˚.06'N and longitudes 11˚.49' and 12˚.25'E as shown in Fig.1.

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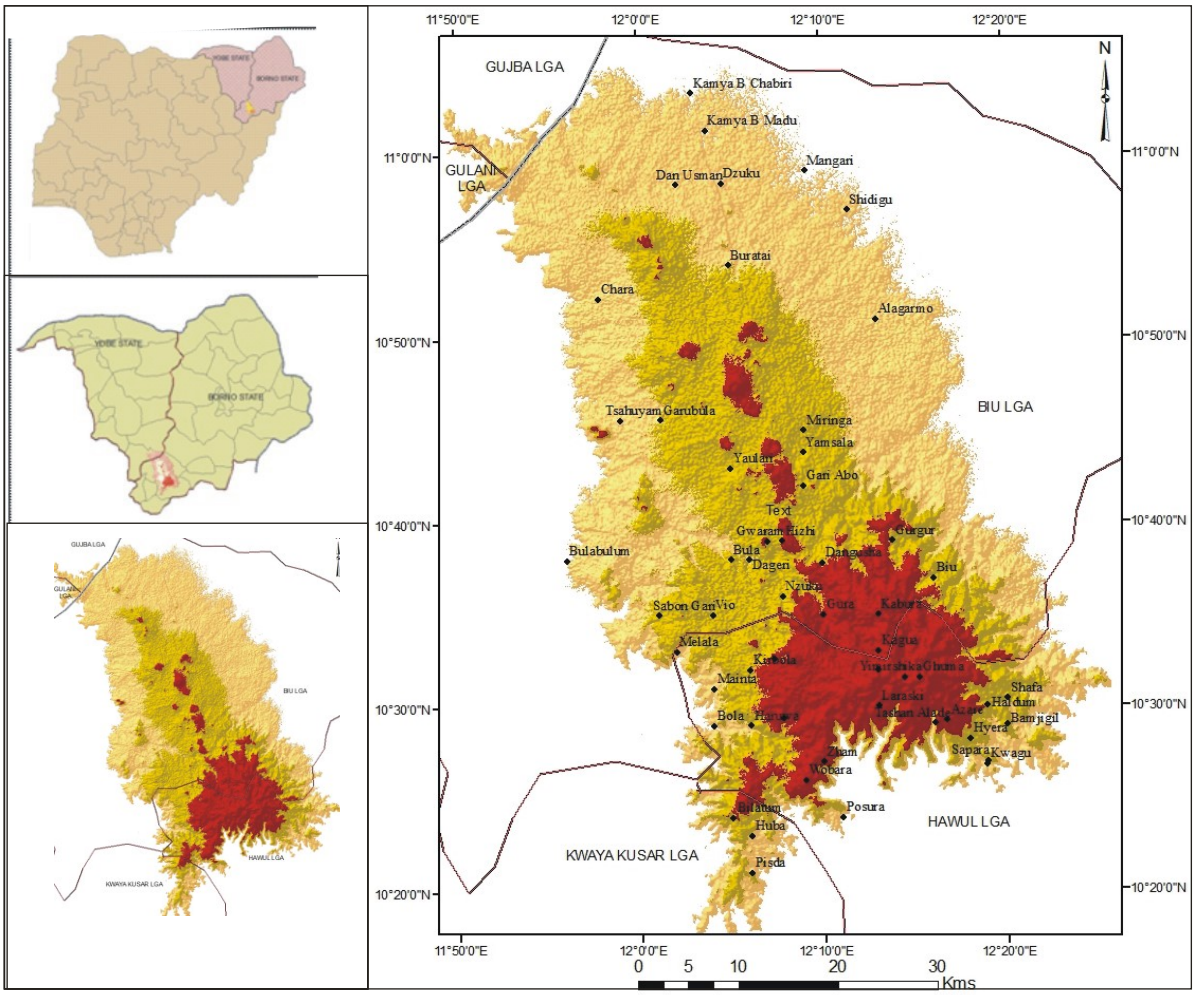

Figure 1. The Study Area

In terms of size, Biu plateau covers a land area of 2635.12km^2 from the total land area of 74832.71km^2 of Borno State, which means that the plateau covers 3.52% of the land area of Borno State. The small isolated hills at the foot of the plateau are however excluded from the plateau. The area coverage of the plateau in each of the five LGAs is presented in Table 1.

Table. 1. Area landmass of Biu Plateau in each of the LGAs

LGA	Plateau Area (km^2)	Percentage
Borno State		
Biu	1979.54	75.12
Hawul	533.76	20.26
Kwaya Kusar	82.36	3.13
Yobe State		
Gujba	25.85	0.98
Gulani	13.61	0.52
Total	2635.12	100

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The actual size of Biu plateau (2635.12km^2) as revealed from Table 1, is far less than what have been quoted in some previous studies. For instance, [12] reported the size of the plateau to have covered over 5000 km^2.

Relief of Biu Plateau

The relief of Biu plateau comprises of the remnant of the dissected plateau itself and the numerous craters on the plateau. The elevation of the plateau ranges from 498 to 923m above the sea level. This finding is similar to the report of [8] that the plateau surface consists of undulating plains lying between 500-800m above sea level; Biu plateau has been heavily dissected as revealed from Figs 2, 3 and 4. The current shape of the plateau shows a step-like structure from the foot up to the top of the plateau as shown in Fig 2a. All the craters are found on the middle step as revealed in Figs 2a and 4.

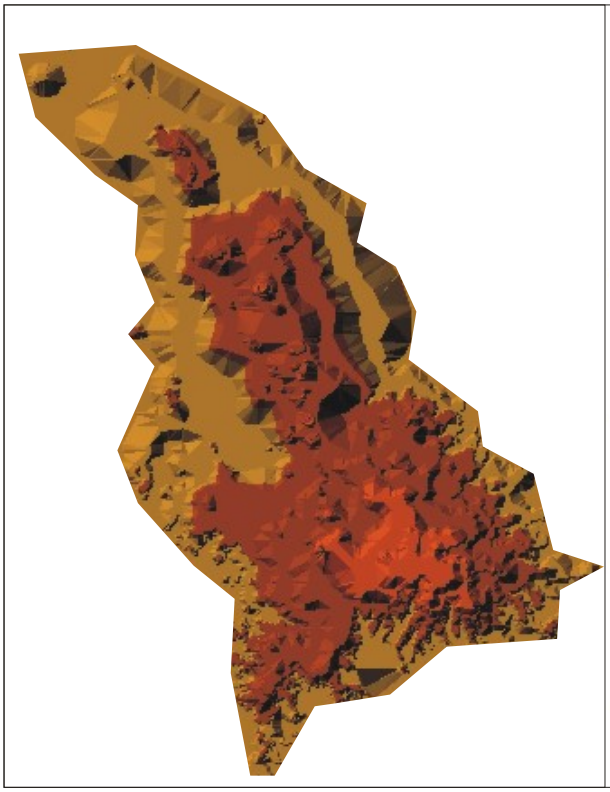

Figure 2a. Elevation of Biu Plateau

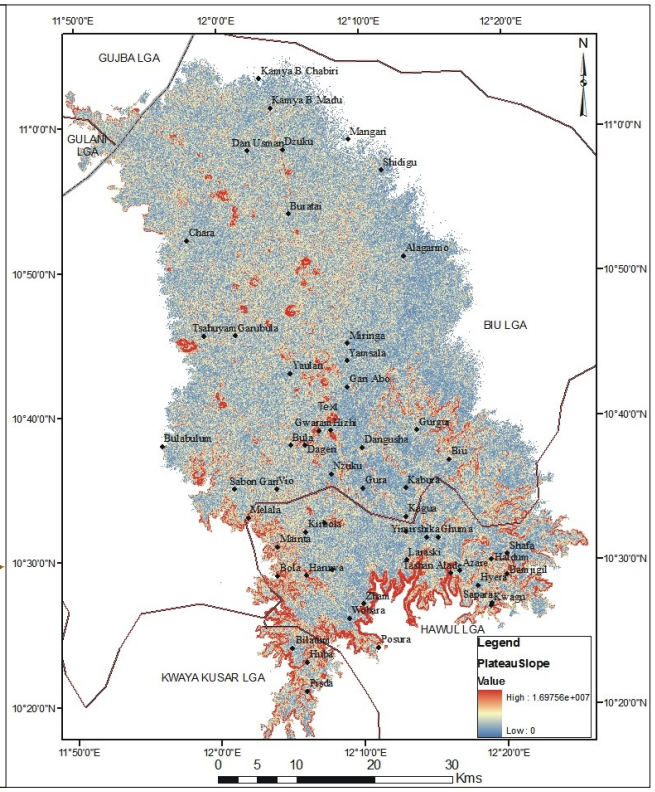

Figure 2b. Slope of Biu Plateau

According to [12], the elevation of the plateau descends gradually to the north and to the west, where the highlands of the plateau pass into the plains underlain by basaltic rock west of Buratai and north-west of Miringa as revealed in Fig.3. The Miringa volcanic zone has a number of well preserved volcanic cones, which stand above the plateau, along a north-northwest to south-southeast axis. These cones are characterized by well defined craters with breached rims and steep conical sides.

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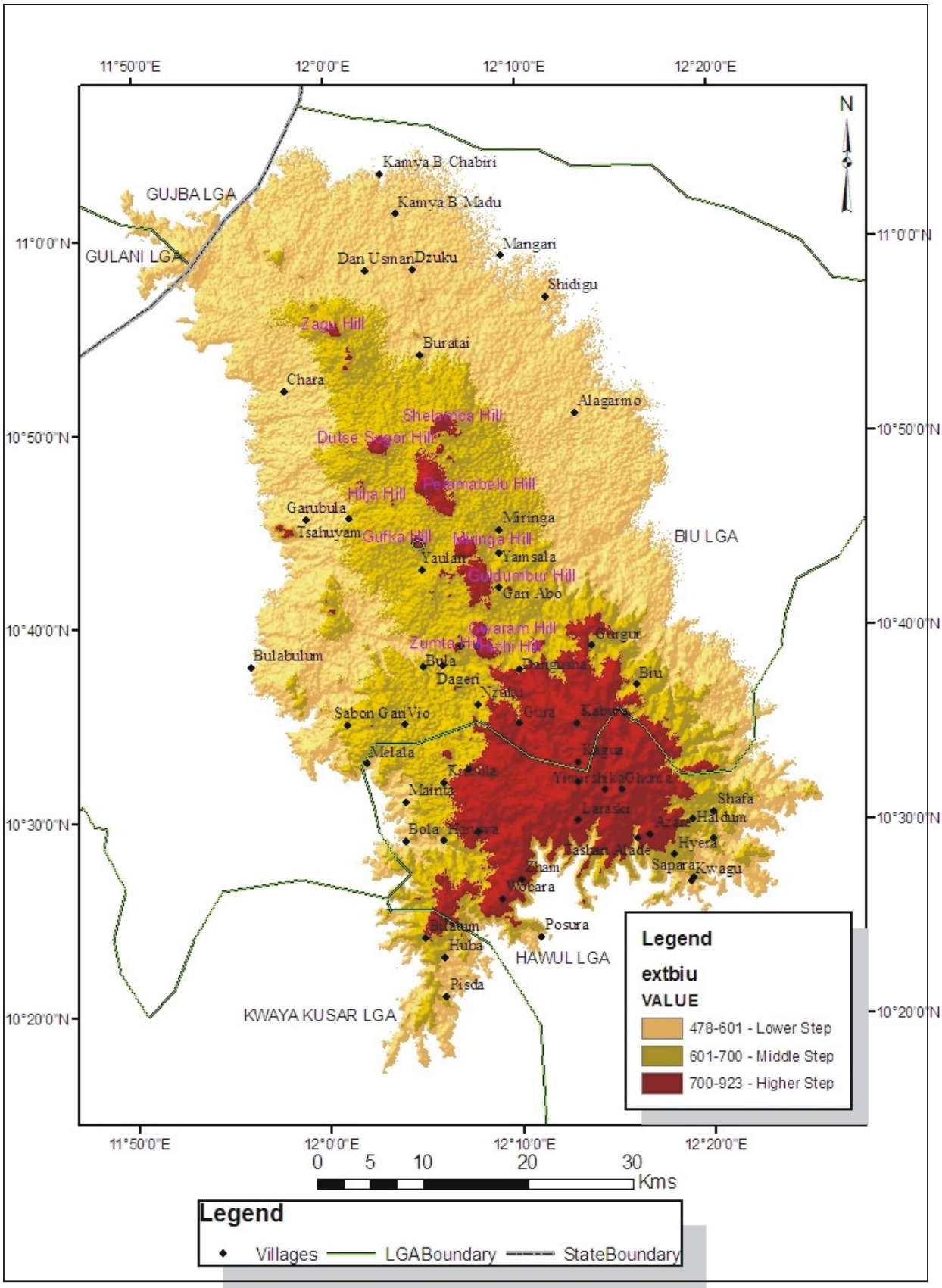

Figure 3. The Relief of Biu Plateau

The relief of Biu Plateau cannot be effectively analyzed without discussing the Craters. [13] described volcanic crater as a circular depression in the ground caused by volcanic activity. It

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is typically a basin, circular in form within which occurs a vent (or vents) from which magma erupts as gases, lava, and ejecta. A crater can be of large dimensions, and sometimes of great depth. A crater can be of large dimensions, and sometimes of great depth. [10] also reported that a number of well preserved volcanic hills, made up of basaltic agglomerates, ash, lavas and tuff create miniature escarpments also form permanent relief features in the northern parts of the plateau. [4] took the coordinates of some craters on the plateau to assess the morphology of the craters. These coordinates were used in this paper to identify the craters as well as to determine the area coverage and the heights of each of the craters as presented in Table 2. The craters were arranged in descending order based on their heights.

Table. 2. The coordinates, area coverage and heights of some important Craters on Biu Plateau

S/N	Craters	Latitudes	Longitudes	Area Coverage (km^2)	Maximum Heights (m)
1	Kumba	10˚47′33.023″N	12˚5′ 25.441″E	10.21	923
2	Padam	10˚50′39.037″N	12˚6′ 9.862″E	3.72	874
3	Tilla	10˚39′54.929″N	12˚7′ 55.363″E	1.78	868
4	Kwari Tilla	10˚38′48.297″N	12˚8′ 3.692″E	3.11	850
5	Jali Tagurmi	10˚42′38.732″N	12˚7′ 35.528″E	0.62	836
6	Kufakana	10˚44′7.575″N	12˚7′ 19.27″E	3.34	824
7	Hujiga	10˚49′24.076″N	12˚2′ 38.861″E	2.84	814
8	Pidarta	10˚55′19.446″N	12˚0′25.597″E	1.20	805
9	Sugwi	10˚54′1.709″N	12˚1′12.795″E	0.22	771
10	Sugur	10˚44′18.68″N	12˚4′ 49.349″E	1.48	768
11	Higzi	10˚40′17.139″N	12˚14′ 7.391″E	1.28	767
12	Zamta	10˚40′49.7″N	12˚0′ 17.329″E	0.23	765
13	Kidi	10˚46′29.167″N	12˚6′ 1.533″E	3.18	759

Table 2 shows that in terms of area coverage, Kumba (10.21 km^2), Padam (3.74 km^2) and Kufakana (3.34 km^2) were the three largest craters on the plateau, while Kumba (923m), Padam (874m) and Tilla (868m) were the three highest craters on the plateau. Figure 5 shows the locations of the thirteen craters, while the 3-Dimentinoal view in Figure 4 shows the shape and height of each of the craters.

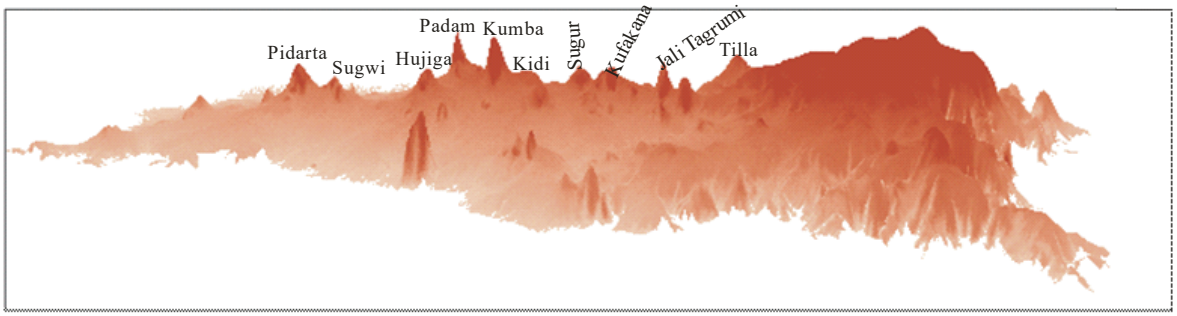

Figure 4. 3D-View of Biu Plateau

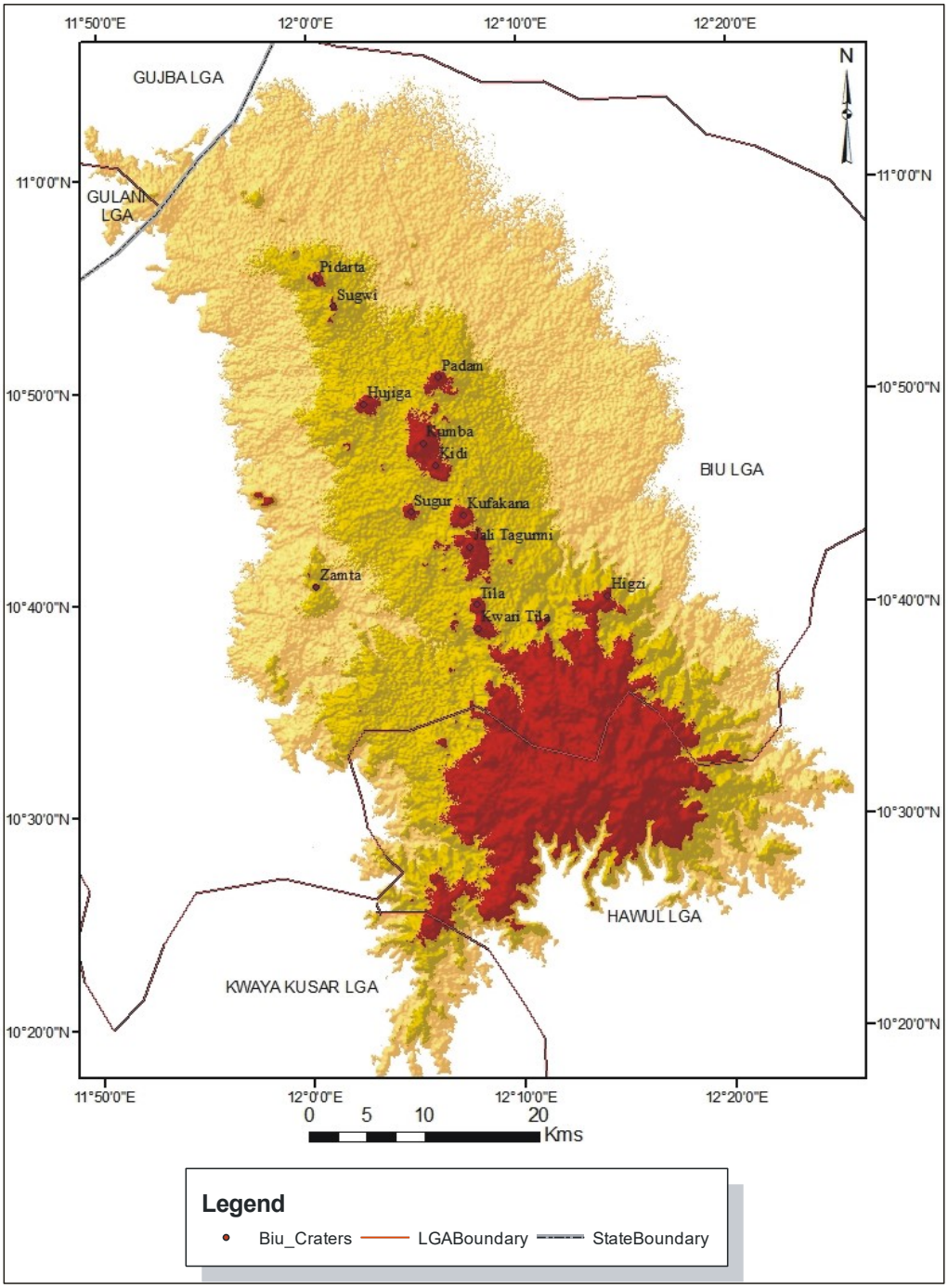

Figure 5. Craters on Biu Plateau

Drainage and Hydrology of Biu Plateau

Biu plateau is drained by three principal sources: rivers, streams and Crater Lakes. The main rivers as shown in Fig. 6 include Rivers Divana, Hauwale, Korode, Kajola among others. The longitudinal north-south alignment of the central part of the plateau forms the watershed for most of the rivers from the third-half northwards. All the rivers take their sources from this watershed area and flow either eastwards or westwards (Fig.6). At the extreme north, the rivers takes their sources from the central plateau and flow northwards, while the rivers and streams in the extreme south flow southwards from the central plateau. The foot of the plateau was also found to contain only few rivers/streams as shown in Fig. 6

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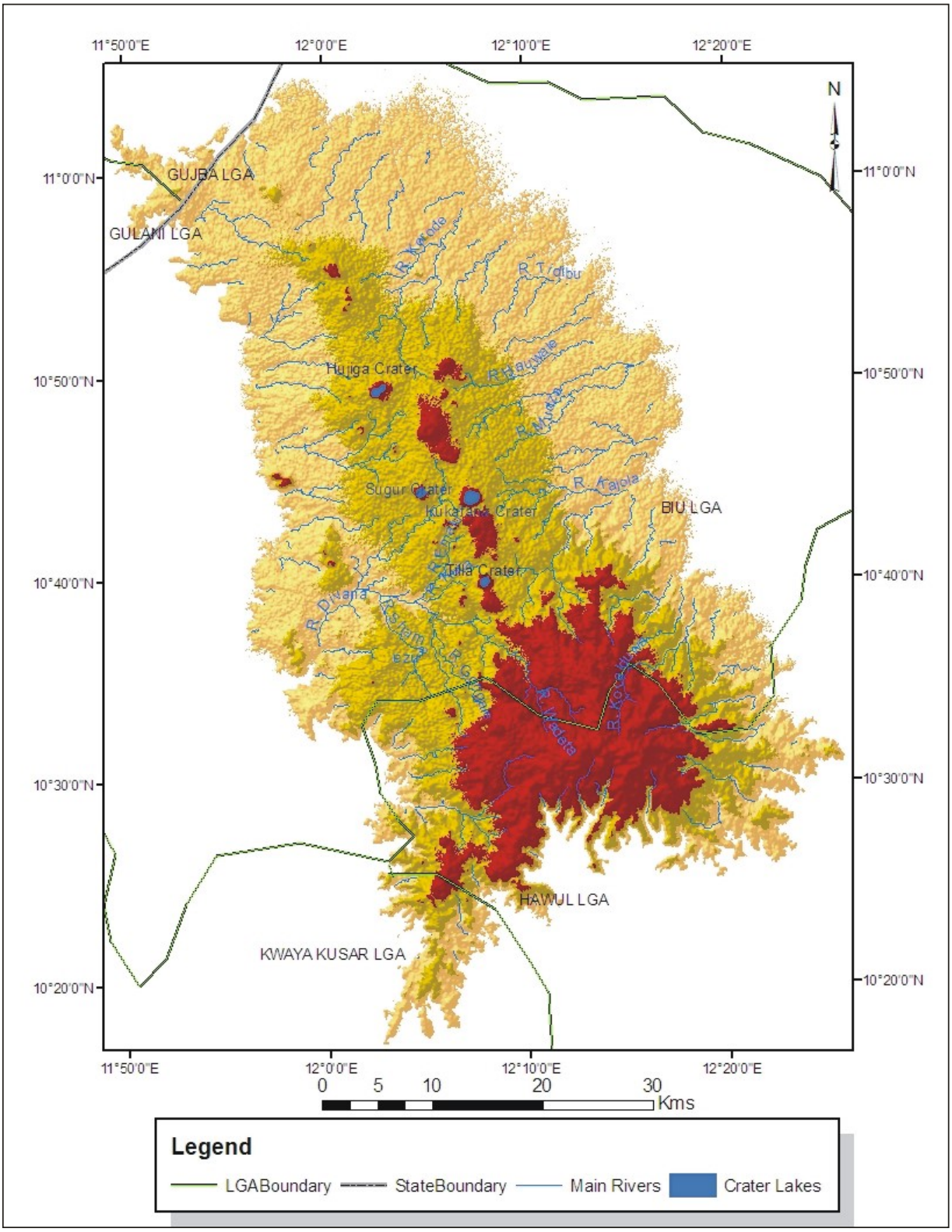

Fig. 6. Drainage of Biu plateau

According to [4], only four craters (Hujiga, Kukafana, Tila and Sugur) out of the thirteen identified craters in Biu plateau have crater lakes. The land area and the shape of each of the four crater lakes were assessed in this study as presented in Table 3 and Fig.7 respectively.

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Table 3. Area of the Crater Lakes on Biu plateau

S/N	Crater Lakes	Area (Hectares)
1	Hujiga	58.40
2	Kukafana	55.65
3	Tila	14.42
4	Sugur	22.92

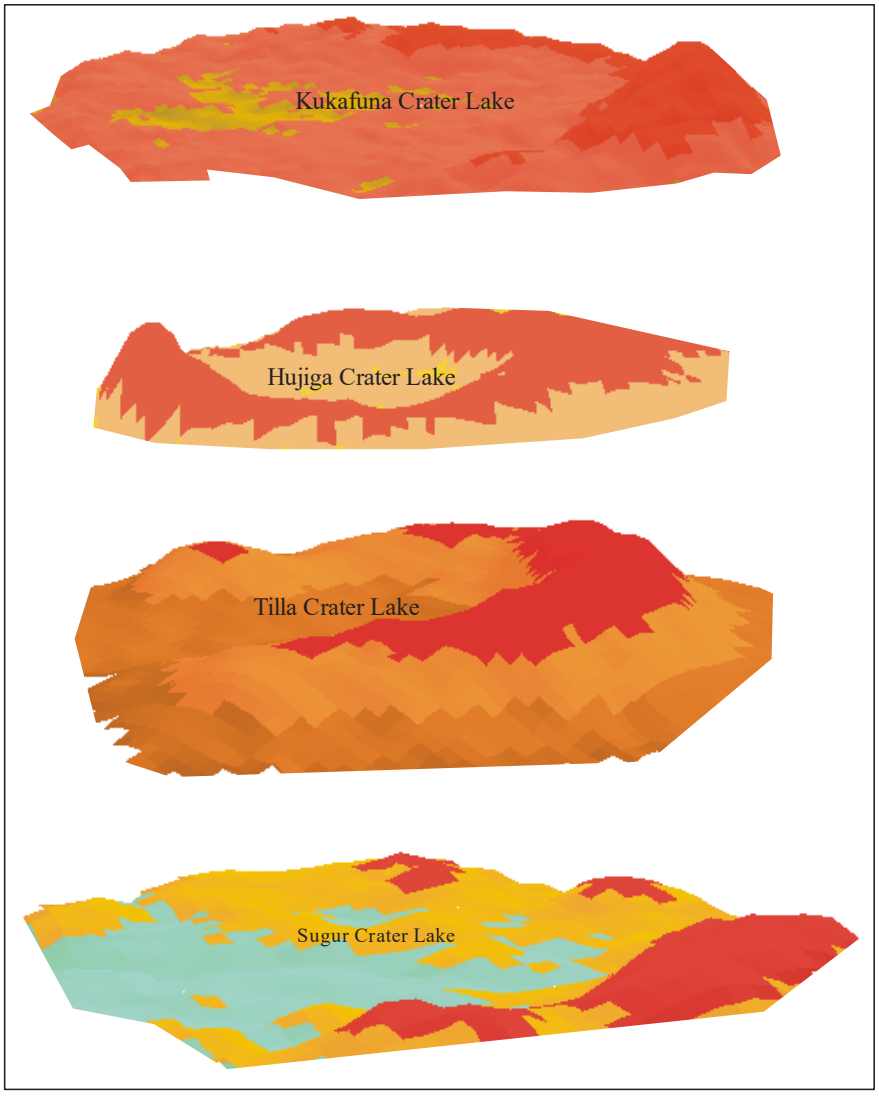

Fig. 7. Shapes of the crater lakes on Biu plateau

Table 3 shows that Kukafana crater lake covered the largest area landmass with 55.65 hectares while Tila crater lakes is the smallest in terms of land area coverage among the four crater lakes with only 14.42 hectares. Some of the crater lakes are being used for resort and recreation activities. For instance, [15] reported that Government is currently developing the Lake Tilla as a holiday resort and that the chalets and restaurants have already been provided for the comfort of guests.

In analyzing the hydrology of the plateau, only five drainage characteristics were examined: drainage pattern, drainage density, stream order, number of streams and stream lengths as shown in Table 4.

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Table 4. Stream Characteristics of Biu Plateau

Stream Order	Number of Streams (Nu)	Stream Length (Lu)
1	9814	2402.34
2	3783	2384.32
3	837	1185.16
4	193	595.21
5	35	235.11
6	9	77.36
Total	14671	6879.5

Drainage Pattern

The drainage pattern of the plateau is dendretic as the shape look like a tree with several branches (Fig. 6). According to [14] it is the most common drainage pattern, and tends to occur on flat land with uniform, non-porous bedrock. Straller's pattern of stream order was also adopted to assess the stream order of the plateau. The results revealed that the highest stream order of Biu plateau is 6^{th} Order. [14] concluded that the dendretic drainage pattern reflects the uniform nature of the soil and geology while homogenous rock structure accounts for the evolution of dendritic drainage pattern.

Drainage Density

According to [16], drainage density looks at the relationship between the total length of all the rivers and streams in a drainage basin (km) and the total area of a drainage basin (km^2). If an area has a high density, it means that precipitation gets into streams quicker, but if an area has a low drainage density, it means that more precipitation has to travel by surface run-off, through flow and base flow. They concluded that drainage densities are usually higher on steep land because there is less infiltration and often less vegetation (depending on aspect), higher on impermeable surfaces because of low infiltration, and vegetation increases interception and reduces drainage density. The nature of Biu plateau confirmed the aforementioned factors because the drainage density of the plateau can be said to be low (2.61) because the slope (Fig 2b) is not steep in most part of the plateau, while 82.7% of the plateau are covered with vegetation; that is either with forest (11.62%), woodland (28.72%) and grassland/shrubs (42.66%) as shown in Table 6.

Soil of Biu Plateau

The five major soil types that were identified based on Food and Agriculture Organization classifications on the plateau are: arenosols, gleysols, leptosols, luvisols and phaeozems. The area coverage, percentages and spatial location of the soil types are presented in Fig 8.

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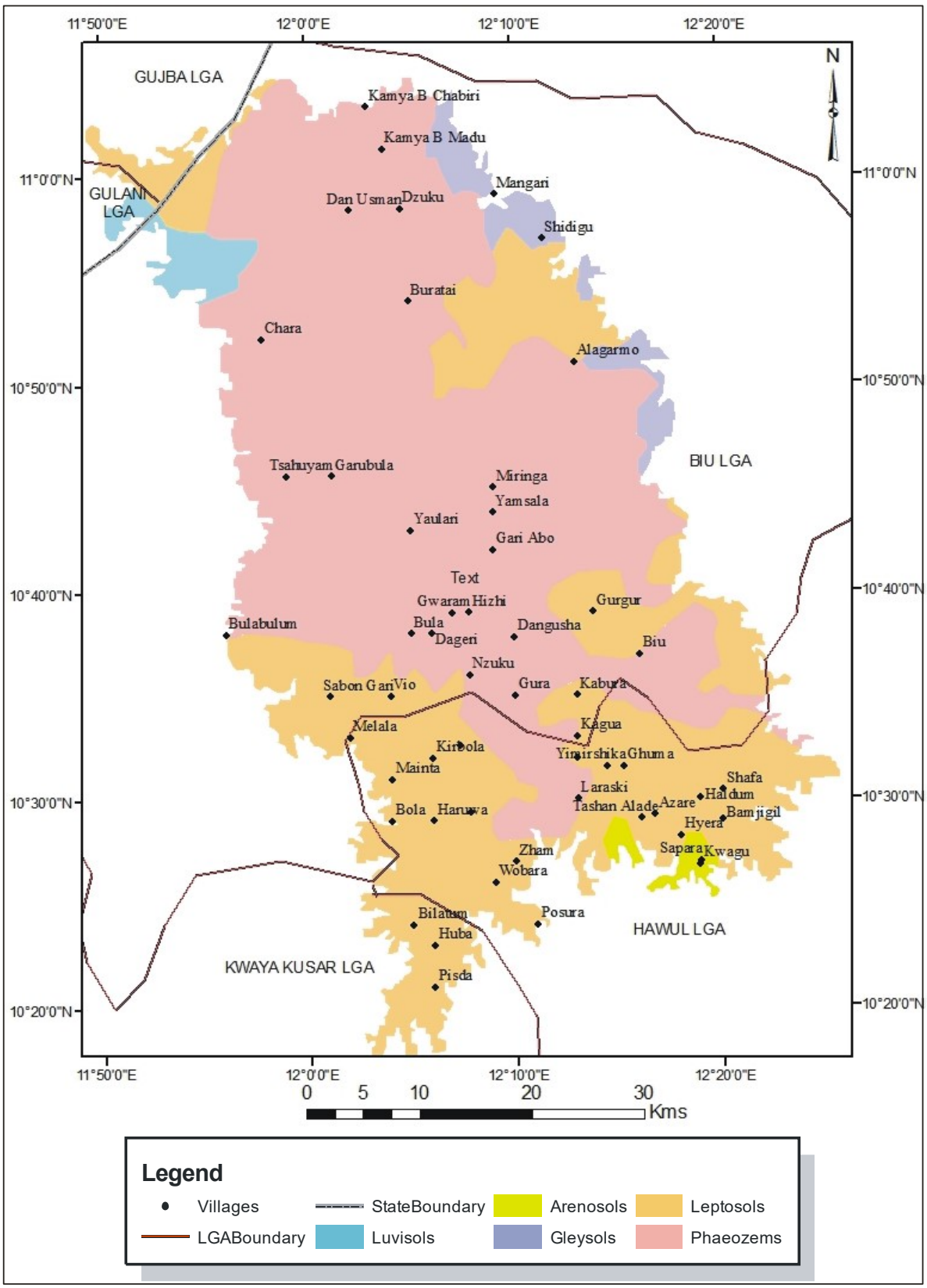

Fig. 8. Spatial distribution of soil types on Biu Plateau

The area coverage and the percentages as well as the villages that are found in each of the soil types regions are presented in Table 5.

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Table 5. Soil types, area coverage and villages in each soil type area on Biu Plateau

Soil Types	Area Coverage (km^2)	Percentage	Villages/Description of the location of the Soil Type Areas
Arenosols	22.68	0.86	Kwagu and Sapara in Hawul LGA
Gleysols	86.39	3.28	Shidigu and Mangari in Biu LGA
Leptosols	905.81	34.37	Shaffa, Teshan Alade, Yimirshika, Hyera, Ghuma, Pisda, Bilatum, Kwaya Bura, etc in Hawul LGA and Vio, Gurgur in Biu LGA.
Luvisols	51.19	1.94	North-West of Chara Village
Phaeozems	1556.08	59.05	Biu, Buratai, Miringa, Garubula etc in Biu LGA; and Nzuku, Gura, Laraski etc in Hawul LGA
Total	2635.12	100	

The description of each of the soil types by [17] was adopted in this paper. [17] reported that **Phaeozem** are characterized by a humus-rich surface layer covered in the natural state with abundant grass or deciduous forest vegetation. They are highly arable soils and are used for growing wheat, soybeans, and pasture for cattle, as well as for wood and fuel production (which are all produced on the plateau). They also reported that phaeozems have a high content of available calcium ions bound to soil particles, resulting in a very permeable, well-aggregated structure. This high permeability of the soil is a confirmation of the low drainage density in the plateau (section 4.3 ii).

Arenosols exhibits only a partially formed surface horizon (uppermost layer) that is low in humus, and they are bereft of subsurface clay accumulation. Given their excessive permeability and low nutrient content, agricultural use of these soils requires careful management [17].

Gleysols are formed under waterlogged conditions produced by rising groundwater. In the tropics and subtropics they are cultivated for rice or, after drainage, for field crops and trees [17]

Leptosols are soils with a very shallow profile depth (indicating little influence of soil-forming processes), and they often contain large amounts of gravel. They typically remain under natural vegetation, being especially susceptible to erosion, desiccation, or water logging, depending on climate and topography [17]. **Leptosols** are approximately equally distributed among high mountain areas, deserts, and boreal or polar regions, where soil formation is limited by severe climatic conditions. The mixed mineralogy, high nutrient content, and good drainage of these soils make them suitable for a wide range of agriculture, from grains to orchards to vineyards [17]. **Luvisols** form on flat or gently sloping landscapes under climatic regimes that range from cool temperate to warm Mediterranean [17].

Settlements on Biu Plateau

The settlements distribution in Figs 3 and 7 shows that the settlements on Biu plateau is a scattered type of settlements. The spatial distribution of the settlements on the plateau also revealed that settlements are more clustered in the southern part of the plateau than the northern counterpart. Most of the settlements are rural types except Biu town which is the second largest settlements in the state and Azare the Hawul LGA headquarters.

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Land Use and Land Cover

The classified landsat image of the plateau revealed farmland and settlements as the main landuse types, while bare surface, woodland, forest, open water and grasslands/shrubs were the identified landcover types. It was also revealed that some parts of the grassland/shrub areas are used for animal grazing [3] and [8]. The seven classified landuse and landcover types are presented in Fig 9 and analyzed in Table 6.

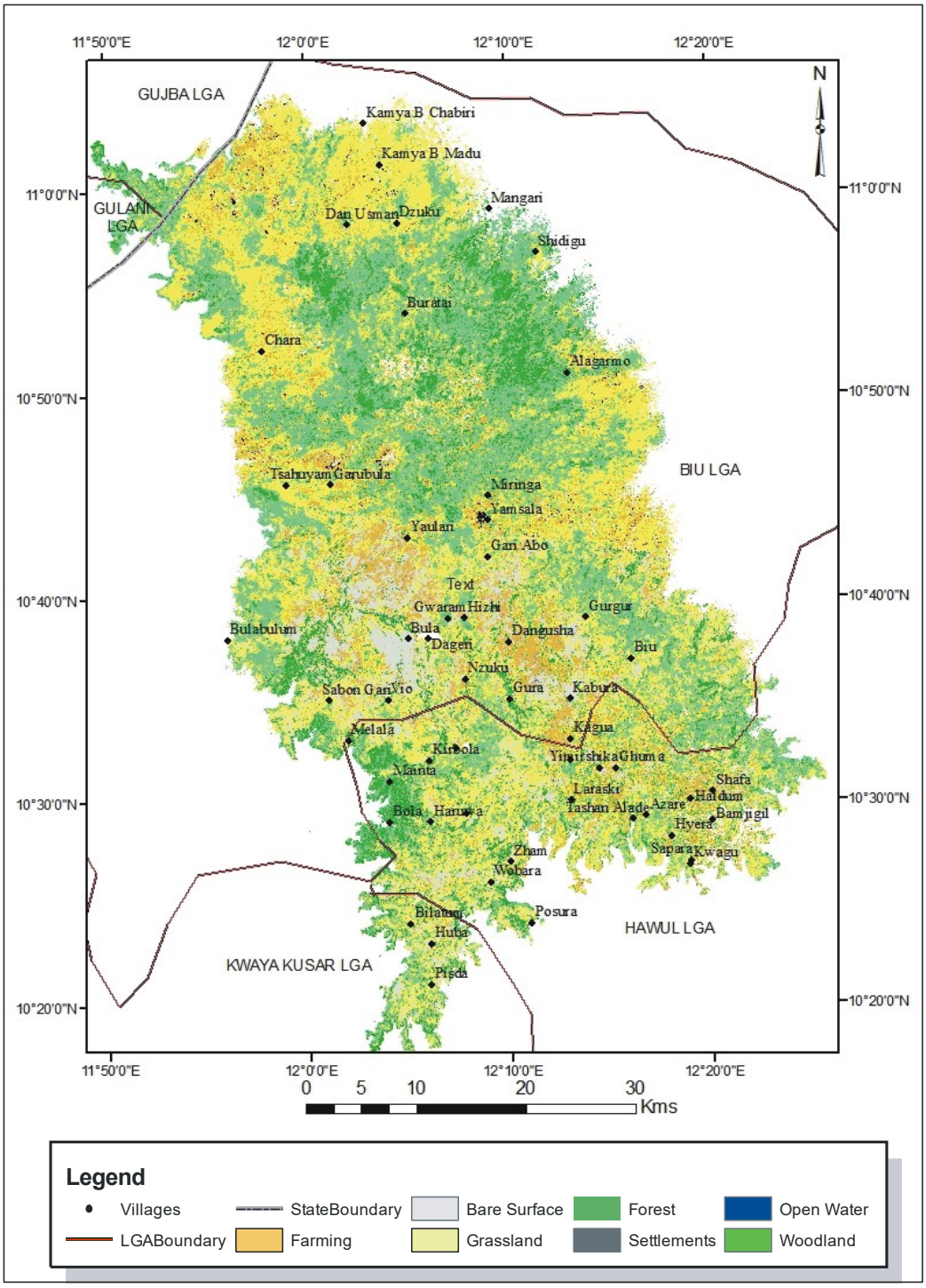

Fig. 9. Landuse and Landcover of Biu Plateau

The land area and the percentages of each of the classified landuse and landcover on the plateau is shown on Table 6.

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Table 6. Areas and Percentages of Landuse and Landcover types in Biu Plateua

Landuse and Landcover Types	Area (km^2)	Percentages
Bare Surface	204.22	7.75
Farming	238.03	9.03
Forest	306.33	11.62
Grassland/Shrub	1116.28	42.36
Open Water	2.96	0.11
Settlements	10.49	0.40
Woodland	756.81	28.72
Total	2635.12	100

Table 6 revealed that grassland/shrub covered the largest portion of the plateau (42.36%). It was also revealed that despite being a plateau, 40.34% of the plateau was covered with forest (11.62%) and woodland (28.72%). This findings show that major parts of the plateau are covered with vegetation as reported by [7] that the plateau is covered by Sudan savanna type of vegetation which consists mainly of scrub vegetation interspersed with tall trees and woodland; the vegetation type has been greatly modified in most parts by over-cultivation and overgrazing.

Fig 6 also revealed that bare surface areas were found mainly in southern Biu LGA especially in areas where rocks are exposed and where farming activities are extensively carried out, hence some places around Bula, Vio, Kagua, Biu among others were bare surface (Fig.6). Moreover, the widest areas where bare surface were found (between Yaulari in the north and Vio in the south) have long been a cattle grazing reserve [18]. The grazing activities in this area have turned some parts of the area into bare surface. Some parts of Shaffa, Yimirshika, Azare and other areas in Hawul LGA were also places where farming activities were carried out. Forest and woodland areas are found especially at the central towards the western parts of Biu LGA. A large area bounded by Miringa in the south, Alagarmo and Shidigu in the north-east and Buratai in the west commonly refered to as Alagarmo forest. Alagarmo forest has been reported by [19] to be the spiritual power base of the insurgents in north-eastern Nigeria, the base that was dislodged on 31st March, 2016. The extended portions of the plateau into Yobe State (Gulani and Gujba LGAs) are mainly forest or woodland areas. Grassland/shubs areas are found almost everywhere on the plateau except the Alagarmo forest region. The grassland areas are usually home to animal grazing as reported by [3] that Miringa in Biu LGA is known as a veritable livestock rearing area with the highest concentration of livestock population, especially cattle. The popular Demsikari Forest Reserve which is located between Biu and Gurgur [18] is also conspicuously shown as a forest and woodland areas on the classified image

The settlements types are mostly rural which are difficult to be discerned with naked eyes on the image (except when zoomed in), while open water has the least land area. Following the fact that the image was captured in November when most of the rivers must have dried off as reported by [8] that water supplies are poor on Biu plateau which has been heavily dissected by numerous streams, most of which contain no water during the dry season.

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CONCLUSION

The position and size, topography and relief, drainage and hydrology, soils, settlements and landuse and landcover of Biu Plateau has been analyzed in this paper using geospatial techniques. The adopted method was found to be more accurate and reliable especially in the assessments of the shapes, sizes, heights and depths of some features on the plateau than the previous studies that were carried out using manual methods. The plateau was found to mainly occupy Biu and Hawul LGAs in Borno state, but this study revealed that little parts of the plateau extended to Kwaya Kusar in Borno State as well as into Gulani and Gujba LGA in Yobe State. The total land area of the plateau that has been hitherto quoted as more than 5,000 km^2 was discovered in this study to occupy only a land area of 2635.12 km^2. The actual locations of some important features especially craters and crater lakes on Biu plateau were also generated in this study. The generated depth, heights and area coverage of the craters and crater lakes can be used for the classifications of these features based on the obtained values of their area, depth and heights. The main soil type of the plateau is Phaeozem which are highly arable soils and are used for growing wheat, soyabeans, and pasture for cattle, as well as for wood and fuel production; all of which are carried out on the plateau. From the many landuse and landcover types, the plateau was covered mainly by grasslands and shrubs. Geospatial techniques can also be used for the assessments and analysis of other important natural endowed features such as vegetation, plains, troughs, deserts and other plateaus and highlands in the country in future studies.

RECOMMENDATIONS

This study has revealed some important facts about the Biu Plateau environment and the techniques used in the study. On the basis of these findings the following recommendations are made.

1. Geospatial techniques should be adopted in the assessment and documentation of important natural endowments in Nigeria because of its high accuracy, reliability and easy documentations
2. The study area can be harnessed for tourism because of the presence of attractive natural features like plateau, craters and crater lakes.
3. Since the plateau was also found to contain much grasslands and shrubs, the federal and Borno State government can make the plateau a good site for animal grazing like the Obudu cattle ranch in southern Nigeria.

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