

Analysis of the Spatial Distribution of Geology and Pedologic Formations in Gombe State, North Eastern Nigeria

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Abstract

This paper focused on the mapping and analysis of the spatial distribution of the geology and soils in Gombe State. The ever rapid rise in population of the country has called for the need for expansion of agricultural activities which necessitates an in-depth knowledge of the spatial location of soil types for agricultural related activities. There is also the need to explore the environment for possible endowments of mineral resources which can be exploited to meet the economic demands of the populace. The soil and geology maps of Gombe State were extracted from existing soil and geology maps of Nigeria, obtained from Food and Agricultural Organization (FAO)/United Nations Education, Scientific and Cultural Organization (UNESCO)/International Soil Reference and Information Center (ISRIC) and Nigeria Geological Survey Agency (NGSA) respectively. The soil and geology types were digitized as polygon, while other important features such as LGA boundaries, state boundaries were also digitized and overlain on the two generated maps (soils and geology). The clip sub module of the ArcGIS was used to delineate each of the LGAs in both maps, that is, extraction of each LGA as well as the soil and geology units in each of the LGAs. The area in square kilometers of the soils and geology units in the entire state and in each LGA were obtained through the use of the area calculation module of the ArcGIS. The result of the study revealed that Gombe State consists of fourteen (14) geologic units. Among them, the KerriKerri which comprised of sandstone, shale and clay geologic unit covers almost half (42.75%) of the State. Limestone and Shale of the Pindiga formation which are principally used for cement making are found mainly in Funakaye LGA which is the home of Ashaka Cement. It was also found out that there are eleven soil units in the state with Nitisols almost covering half of the state. It was recommended that the generated soil and geologic maps of the State are expected to be considered for mineral exploration and crop suitability assessments in order to reduce time, cost and energy that would likely be incurred if the entire state is assessed.

Keywords: mapping and analysis, spatial distribution, Gombe State

1. Introduction

The importance of the study of the soils and geology of any place cannot be overemphasized. For instance, in the case of geology, (Rhodes & Perlman, 2001) reported that almost everything we utilize in our lives has something to do with earth and that, although, the sun is the ultimate energy source of earth, we rely on "earth" energy sources for our daily energy requirements like oil, carbon, nuclear energy obtained from uranium, among others. Geology science is of paramount importance to locate those earth energy sources, how to extract them from earth more efficiently and at a lower cost, and with the smallest impact on the environment. Water, an important natural resource, is scarce in many parts of the world. The study of geology can help to find underground water resources to reduce the impact of water scarcity of people and civilization. Moreover, the spatial distribution of the geology of an area also helps in the assessments, monitoring and prediction of possible environmental hazards in the area. Among these hazards are floods, soil erosion, droughts earthquake among others. The knowledge of geology can help by estimating where earthquakes are most likely to occur (known as fault lines) and to recommend the type of technology to be used in the construction of buildings in these vulnerable areas (Rhodes & Perlman, 2001). Finally, most countries of the world depend heavily on the available mineral resources in their domain for their growth and development. The endowments of these mineral resources largely depend on the geology and the soil types of the area.

Soil is one of the most important natural resources that are available in almost everywhere. It is normally the major determinant of so many human activities. For instance, farmers consider its types, fertility and texture among others for site suitability for their various crops production, civil engineers relate soil types to residential development, the availability of some mineral resources also largely depend on the soil types. Soil Science Society of America (2017) stated that soil is a vital part of the natural environment, and it is just as important as plants, animals, rocks, landforms, lochs and rivers. It influences the distribution of plant species and provides a habitat for a wide range of organisms. It controls the flow of water and chemical substances between the atmosphere and the earth, and acts as both a source and store for gases (like oxygen and carbon dioxide) in the atmosphere. Soils not only reflect natural processes but also record human activities both at present and in the past. They are therefore part of our cultural heritage. According to FAO (2002), a better understanding of the linkages between soil life and ecosystem function and the impact of human interventions will enable the reduction of negative impacts and the more effective capture of the benefits of soil biological activity for sustainable and productive agriculture. Hence, spatial distribution of soil is very important to so many disciplines that rely on such spatial data for decision making.

Existing comprehensive research on the soils and geology of Gombe State is very scanty. Most of the existing works are either on North East Nigeria as a region, or former Bauchi State; the region and State respectively which Gombe State belonged until 1996 when it was made a state. Other existing ones are based on the geographical regions like Benue Basin, Upper Benue Basin or Gongola Basin (Udo, 1978) where Gombe State is located. Being one of the most recent States that was created in Nigeria, expectedly, existing research on such states cannot be as much as those that have existed for long. There has been recent works on the physical aspects of the State especially since the advent of security challenges in the entire North East region of Nigeria which necessitated the study of the topography of the State (Ikusemoran et al., 2017). The ever rapid rise in population of the country has also called for the need for expansion of agricultural activities which necessitates an in-depth knowledge of the soil types for agricultural related studies such as suitability study for crop production among others. There is also the need to explore the environment for possible endowments of mineral resources which can be exploited to meet the demands of the populace. Hence the need for the study of the spatial distributions of the soil and geology of a young state like Gombe state becomes very necessary.

Moreover, most existing maps are on the entire country or at best on States especially the old regions and States, and hence making it difficult for people in a country where Geographical Information System (GIS) techniques is relatively new (Surveyor General of the Federation (OSGOF) 2012) to delineate or extract smaller areas of interest like LGAs from the existing maps. Finally, a recent publication on the terrain of Gombe state (Ikusemoran et al., 2016) contains a comprehensive analysis of the topography, drainage, vegetation, transportation and settlements of the state. The Soils and Geology of the State were not discussed in the publication resulting to several calls by stake holders to work on the two missing features for the benefit of the general public. It is based on this background that this paper was set to map and analyze the spatial distribution of soil and geology in Gombe State. The main objectives are therefore, to: (i) Generate digital maps and analysis of the spatial distribution of the soils and geology of Gombe State. (ii) Delineate and analyze the spatial distribution of the soils and geology in each of the Local Government Areas of Gombe State.

2. The Study Area

According to (Ikusemoran et al., 2016) Gombe State which is popularly referred to as the 'Jewel in the Savannah' was carved out from the former Bauchi State by the Federal Military Government of Nigeria on 1st October, 1996. The State shares boundaries with Yobe State to the north, Adamawa and Taraba States to the south, Borno State to the east, and Bauchi State to the west (Fig.1). The following tribes are also found in the State: Tangale, Waja, Fulani, Tula, Cham, Dadiya, Hausa. In (Gombe State Official Website. 2013), the topography of Gombe State is made up of mainly mountainous, undulating and hilly to the south-east and flat opens plains in the western part of the State. (Gombe State Tourism Board. 2013) also described the hills of Gombe State as having beautiful dome-shaped rock formations with fascinating scenery which are ideal for climbing and camping. The Famous Tangale dome shaped rock/hill formation, Tula Hills, the Bima hills as well as Filiya – Dadiya hills and the Ndinijam Kargo hill are some of the hills in these mountainous region.

In the study of (Ikusemoran et al., 2016), most parts of the State are located within the valley of River Gongola and on some highlands and mountain ranges. The river basin is a generally lowland area with altitudes ranging from 184 to 351m heights above sea level. They concluded that more than 33% of the land of Gombe State lies within the Gongola valley. This River Gongola valley formed an east-west narrow land area in Dukku and Nafada LGA at the extreme northern part of the State, and except the intrusion of Kulani-Degri-Likkar hills in the southern part of the state, the entire western border of the state comprised the river basin.

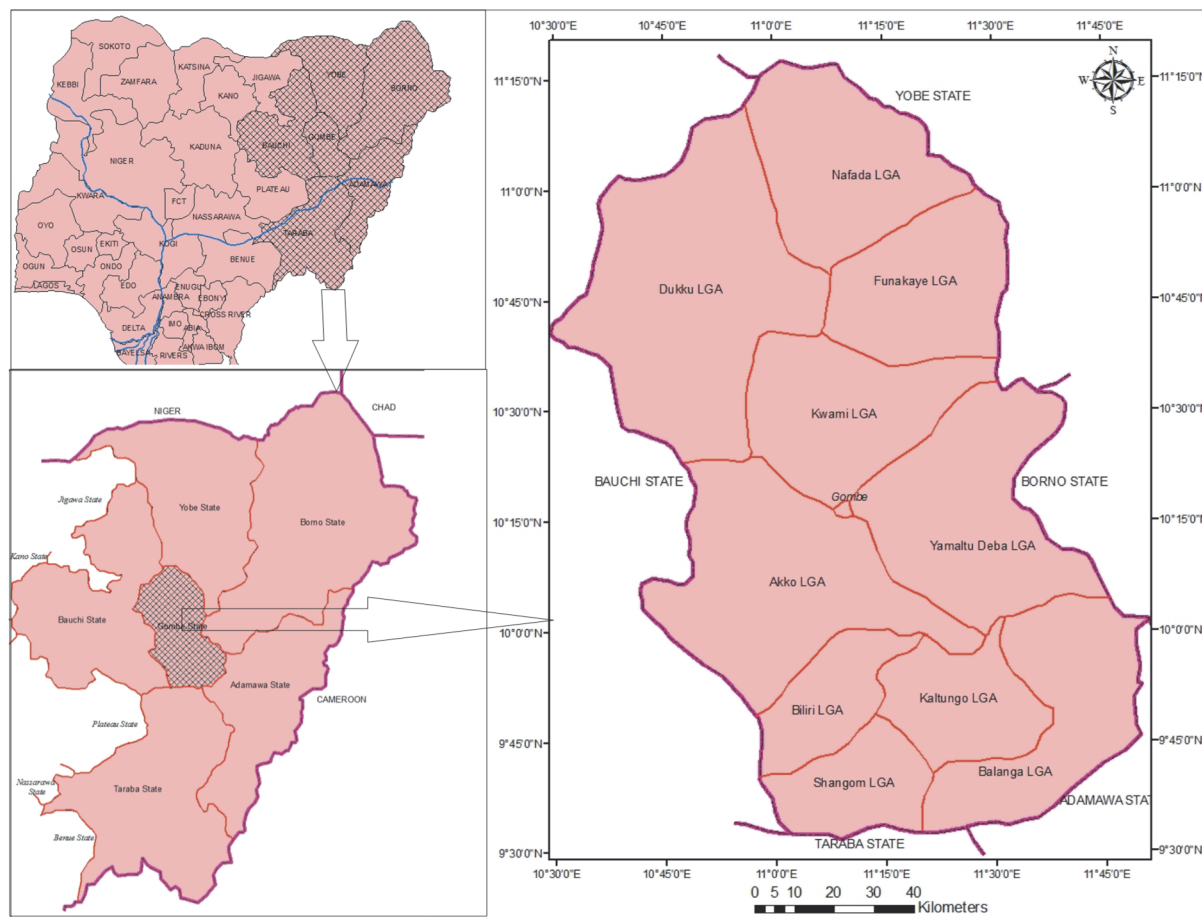


Figure 1. The Study Area

The northern part of Dukku LGA, the central portion of Nafada LGA, the western part of Funakaye and Kwami LGAs, major parts of Yamaltu LGA and the north and southern parts of Balanga LGA are all located in the valley of River Gongola (Fig.2). The highest peak of the highlands in Gombe State is Kilang hill in Shangom LGA with altitude of 1158m above the sea level. Only 5.8% of the land areas of Gombe State are of highlands, with Kaltungo, Balanga and Shangom LGAs having more than 10% of their land area as highlands. Some of the highlands/hills in the state with their maximum heights as derived from the Digital Elevation Models (DEM) in Fig. 2 are shown in Table 1.

Table 1. Highlands/Hills and their maximum peaks in Gombe State

S/N	Highlands/Hills	LGAs	Highest Peak (m)
1	Kilang	Shangom	1158
2	Filiya	Shangom	1062
3	Dadiya	Balanga	1029
4	Nwona	Balanga	913
5	Kilani-Degil-Jikkani	Balanga	891
6	Bima	Yamaltu Deba	885
7	Tangale	Biliri	882
8	Dogon Dutse	Kaltungo	845
9	Tula	Kaltungo	840
10	Nappe	Akko	729
11	Chabbal	Akko	678
12	Pindiga	Akko	663
13	Bworo	Nafada	525

River Gongola is the largest and the most important river in the State. The River enters the State in the north-west through Bauchi State and flows eastward through Dukku, and Nafada LGAs. At Nafada, the Gongola bends in a loop southward forming natural boundary between the state and Borno and Adamawa states in the eastern parts before it joins River Benue at Numan, outside the state (Ikusemoran et al., 2016). According to (Abubakar, 2013), Gombe state has two distinct climates, the dry season (November–March) and the rainy season (April–October) with an average rainfall of 850mm. The mean annual temperature is about 32°C, while the vegetation of the state is that of savanna woodland comprising scattered shrubs and trees such as *Butyrospermum*, *paradoxum*, *Tamarin indica*, *Parkia biglibosa*, *Aflexia Africana* and grasses. The National Population and Housing Census of Nigeria (National Population Commission. 2006) put the total population of the State as 2,365,040 people out of which 1,244,228 were males and 1,120,802 were females. (Mohammed, 2011) reported that the main occupation of the people in the state is small-scale farming and the major crops grown include rice, maize, cowpea and vegetables.

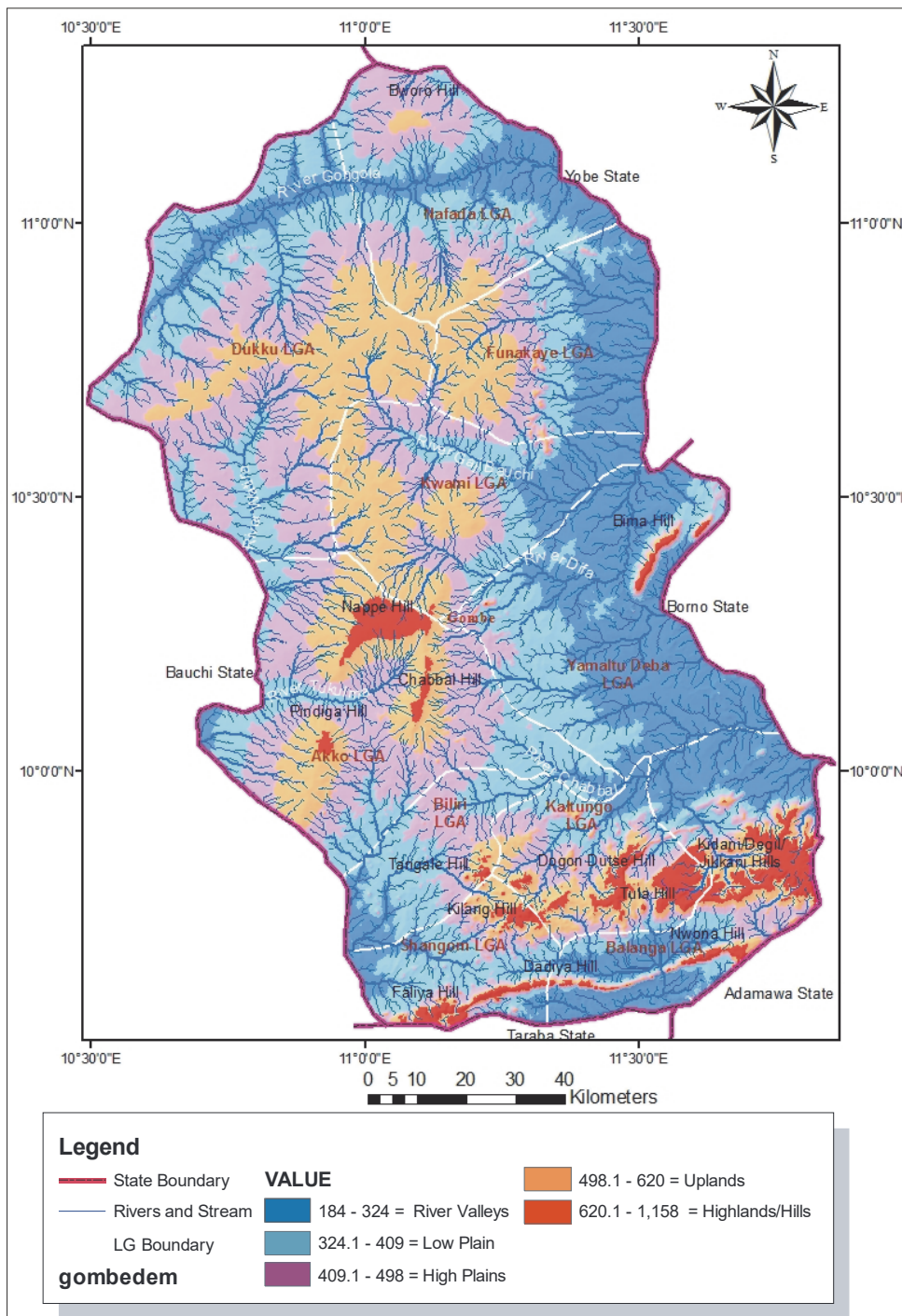


Figure 2. Relief and Drainage of Gombe State

3. Materials and Methods

Table 2 shows the acquired, sources and the usefulness of the data for this paper.

Table 2. Types, sources and importance of acquired data

Data	Sources	Importance
Soil Map of Nigeria	FAO* and UNESCO*/ISRIC* (1996)	Base map for extraction of the Soil map of Gombe State
Geology Map of Nigeria	NGSA* (2009)	Base map for extraction of the Geology map of Gombe State
Political Map of Gombe State	Dada et al (2007) Nigeria Geological Survey Agency (NGSA) (2009)	To generate Gombe State map showing the LGAs boundaries for extraction of each of the LGAs
Settlements in Gombe State	GPS and World Atlas of the Encarta Premium (2009)	To link with the generated maps in order to see the location of some settlements in each LGAs of the State

*Food and Agricultural Organization (FAO), *United Nations Education, Scientific and Cultural Organization (UNESCO), *International Soil Reference and Information Center (ISRIC), *Nigeria Geological Survey Agency (NGSA)

The acquired soils and geology maps of Nigeria were separately georeferenced using the World's WGS 1984 projection system, with some selected settlements as tie points. Gombe State political map was also referenced to the georeferenced soils and geology maps of Nigeria. Each of the LGAs in the State was digitized using the complete polygon module after the first digitized polygon (LGA) was done as new. The soil and geology types were digitized as polygon, while other important features such as LGA boundaries, state boundaries were also digitized and overlain on the two generated maps (soils and geology) as shown in Figs 3 and 5. The clip sub module of the ArcGIS was used to delineate each of the LGAs in both maps, that is, extraction of each LGA as well as the soil and geology units in each of the LGAs as shown in Figs. 4a-4k and 6a -6k. The area in square kilometers of the soils and geology units in the entire state and in each LGA was obtained through the use of the area calculation module of the ArcGIS. The results were used to prepare Tables 3 and 4.

4. Spatial Analysis of the Geology of Gombe State

Gombe State consists of fourteen (14) geological units: (i) Alluvium (ii) Basalt (iii) Coarse Porphyritic Homblende Granite (iv) Undifferentiated Granite, Migmatite & Granite Gneis (v) Migmatite and Granite Gneis (vi) Porphyritic Granite (vii) Coarse Porphyritic Biotite (viii) Shale and Minor Sandstone (ix) Older Basalt (x) Shale Sandstone and Limestone (xi) Sandstone, Siltstone and Shale (xii) Shale, Limestone and Sandstone (xiii) Shale and Mudstone (xiv) Sandstone, Siltstone, Shale, Coal and Ironstone. All these geologic units belonged to twelve rock formations (NGSA) as classified in Table 2.

Table 3. Rock formations, age and the geologic units in Gombe State

Formation	Age	Geologic Units
Alluvium		Alluvium
Basalt	Cretaceous*	Basalt
Basement Complex	Pre Cambrian *	Coarse Porphyritic Homblende Granite Undifferentiated Granite, Migmatite and Granite Gneis Porphyritic Granite, Coarse Porphyritic Biotite
Jessu	Upper Turonian **	Shale and Minor Sandstone
Longuda Basalt	Tertiary – Recent Volcanics **	Older Basalt
Pindiga	Turonian-Coniacian ***	Shale Sandstone and Limestone
Bima	Albian to Early Cenomanian *	Sandstone, Siltstone and Shale
Yolde	Late Albian - Late Cenomanian *	Shale, Limestone and Sandstone
Fika	Late Cretaceous ****	Shale and Mudstone
Gongila	Turonian-Coniacian ***	Limestone and Shale

Gombe Sandstone	Maastrichtian age *	Sandstone, Siltstone, Shale, Coal and Ironstone
KerriKerri	Post-Cretaceous *	Sandstone, Shale, and Clay

* (Ahmed, 2007)

** (Carter et al., 1963)

*** (Akande et al., 1998)

**** (Portland Cement. 2017)

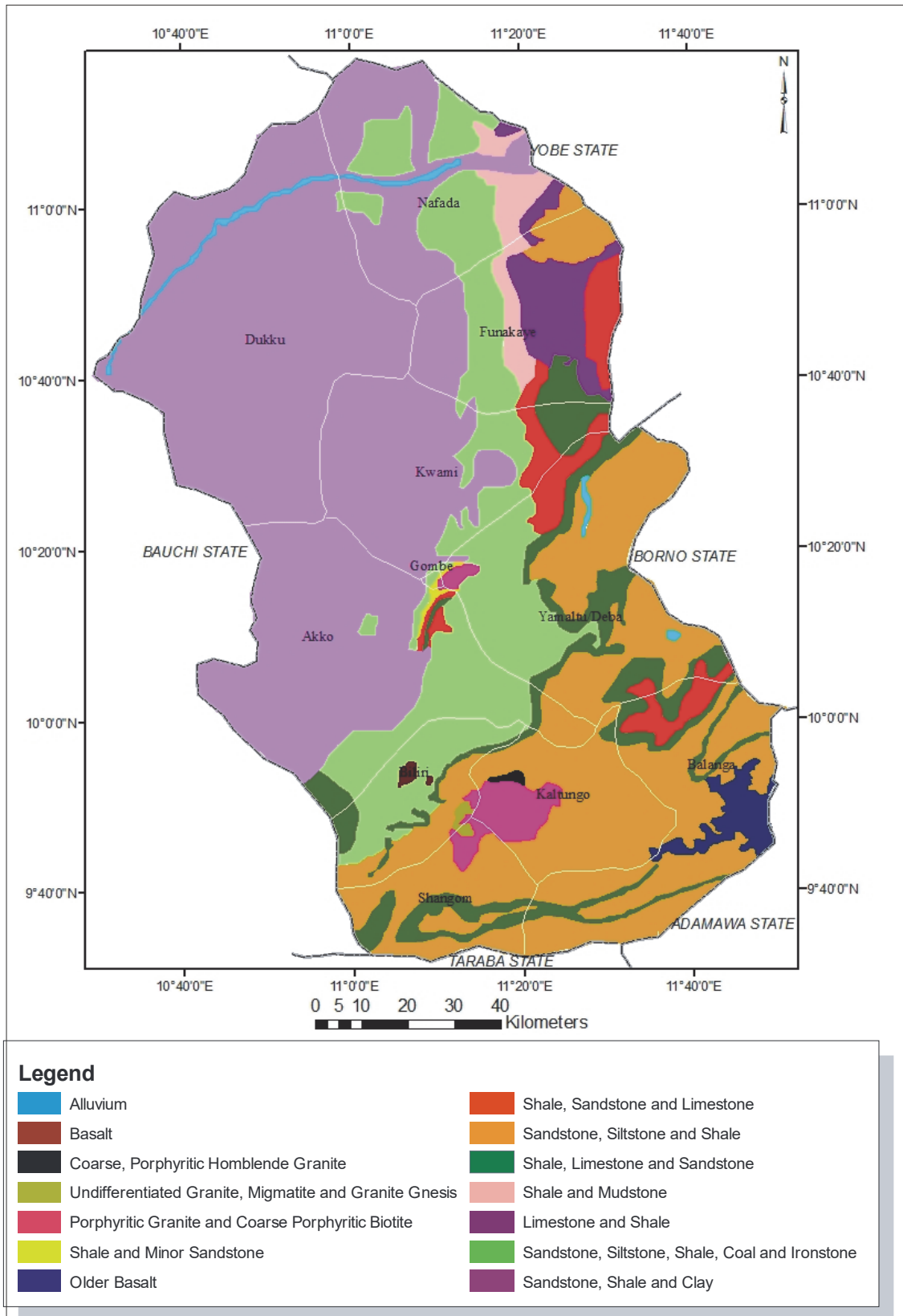


Figure 3. Geologic Units in Gombe State

Gombe State is known for cement production following the presence of limestone deposit in the State. Fig. 3 revealed that there are three geologic units that contain limestone which is principally used for cement production

in the State; Limestone and Shale of the Pindiga formation, Shale limestone and Sandstone of the Yolde formation as well as Shale, Sandstone and Limestone of the Pindiga formation. These three geological units are found in the north eastern region of the state. While Limestone and Shale of the Pindiga formation are mainly found in Funakaye LGA (with little extension to Nafada LGA), the other two formations are situated in Balanga, Funakaye, Nafada, Kwami and Yamaltu Deba LGAs.

The most common rock types used in cement production are: limestone which supplies the bulk of the lime and clay, marl or shale which supplies the bulk of the silica, alumina and ferric oxide Portland Cement (2017). The extensive endowment of Limestone and Shale in Funakaye LGA was no doubt the main reason of the siting of Ashaka Cement factory in Ashaka in Funakaye LGA in Gombe State. Therefore, villages like Jillahi, Zagaina, Zadawa and Madekiri, Ungwan Yeyaro in Funakaye LGA and Jombor and western Manawashi in Nafada LGA are all situated in Limestone region.

Table 4. Spatial Distribution of the Geologic Units in each LGA in Gombe State

LGA	Alluvium	Basalt	Coarse PHG*	UndiffGMG*	PorphyrGCPB*	Shale & Minor Sandstone	Older Basalt	Shale Sandstone & Limestone	Sandstone Siltstone & Shale	Shale, Limestone & Sandstone	Shale & Mudstone	Limestone & Shale	Sandstone, Siltstone, Shale, Coal & Ironstone	Sandstone, Shale & Clay
	Alluvium Formation	Basalt Formation	Basement Complex Formation			Jessu Formation	Longuda Basalt Formation	Pindiga Formation	Bima Formation	Yolde Formation	Fika Formation	Gongola Formation	Gombe Formation	Kerikeri Formation
Akko	-	-	-	-	-	13.69	-	34.19	86.56	90.99	-	-	601.36	1726.78
2553.57	-	-	-	-	-	0.54%	-	1.34%	3.39%	3.56%	-	-	23.55%	67.62%
Balanga	-	-	-	-	-	-	216.01	114.56	1041.31	294.92	-	-	-	-
1666.48	-	-	-	-	-	-	12.96%	6.87%	62.47%	17.69%	-	-	-	-
Biliri	-	18.77	-	13.89	12.3	-	-	-	237.24	97.73	-	-	394.09	-
774.02	-	2.43%	-	1.79%	1.59%	-	-	-	30.65%	12.63%	-	-	50.91%	-
Dukku	-	-	-	-	-	-	-	-	-	-	-	-	6.87	3357.61
3364.48	-	-	-	-	-	-	-	-	-	-	-	-	0.20%	99.80%
Funakaye	-	-	-	-	-	-	-	191.34	153.38	84.8	131.19	364.9	287.36	262.71
1475.68	-	-	-	-	-	-	-	12.97%	10.40%	5.75%	8.89%	24.73%	19.47%	17.80%
Gombe	-	-	-	-	1.56	3.23	-	-	-	-	-	-	6.56	2.44
13.79	-	-	-	-	11.31%	23.42%	-	-	-	-	-	-	47.57%	17.69%
Kaltungo	-	-	14.41	-	182.5	-	3.15	-	772.17	25.43	-	-	-	-
997.66	-	-	1.44%	-	18.29%	-	0.32%	-	77.40%	2.55%	-	-	-	-
Kwami	-	-	-	-	-	-	-	94.63	-	105.81	-	-	269.36	1162.69
1632.49	-	-	-	-	-	-	-	5.80%	-	6.48%	-	-	16.50%	71.22%
Nafada	30.34	-	-	-	-	-	-	-	38.5	-	167	62.44	610.3	857.97
1766.55	1.72%	-	-	-	-	-	-	-	2.18%	-	9.45%	3.53%	34.55%	48.57%
Shangom	-	-	-	8.1	48.43	-	-	-	494.05	268.3	-	-	-	-
818.88	-	-	-	0.99%	5.91%	-	-	-	60.33%	32.76%	-	-	-	-
Y/Deba	20.81	-	-	-	27.15	6.29	-	-	157.77	952.05	449.69	-	573.94	7.3
2195	0.95%	-	-	-	1.24%	0.29%	-	-	7.99%	43.37%	20.49%	-	26.15%	0.33%
Total	51.15	18.77	14.41	21.99	271.94	23.21	219.16	592.49	3775.26	1417.67	298.19	427.34	2749.84	7377.5
G/Total	0.11%	0.08%	0.13%	1.58%	0.13%	1.27%	3.43%	21.87%	8.21%	1.73%	2.48%	15.93%	17258.9	42.75%
Total	0.30%													100%
G/Total														

*Coarse PHG = Coarse Porphyritic Homblende Granite, *UndiffGMG = Undifferentiated Granite, Migmatite & Granite Gneis, *PorphyrGCPB*= Porphyritic Granite, Coarse Porphyritic Biotite

Among all these rock formations, the KerriKerri which comprised of sandstone, shale and clay geologic unit covers almost half (42.75%) of the State as revealed in Fig. 4 and Table 4 which is very similar to the report of (Gombe State Official Website. 2013) that half of Gombe State is underlain by the early tertiary KerriKerri Formation. The western part of the state, that is, 99.8% of Dukku LGA, more than half of the land areas of Akko and Kwami LGAs (62.67% and 71.22% respectively). Two other geological units, that is, Sandstone, Siltstone and Shale of Bima formation as well as Sandstone, Shale, Coal and Ironstone of Gombe formation also cover large areas of the State with 21.87% and 15.93% respectively. According to Klinkenberg (1967), Yolde Formation gives rise to a subdued topography often with sparse vegetation cover and is poorly exposed in most part of the Gongola basin. The Yolde Formation is indeed a transitional sequence between the continental Bima Group and the marine deposits of the lower part of the Pindiga Formation which is noticeable in Balanga, Funakaye, Nafada, Yamaltu Deba and other parts of the state as shown Fig. 3. (Suleiman et al., 2015) also reported that the exposed stratigraphic succession in the Ashaka area begins with the Bima Sandstone. It also forms the floor of the Ashaka Cement Quarry section and is separated from the overlying Pindiga Formation (Kanawa Member) by a thin ferruginous crust without the transitional Yolde Formation. The Yolde Formation is almost absent in the Ashaka area.

The spatial distribution of the geologic units in each LGA of the State was quantified as presented in Table 4, while the spatial distribution of the geology in each of the eleven LGAs are also presented in Figs. 4a to Figs. 4k.

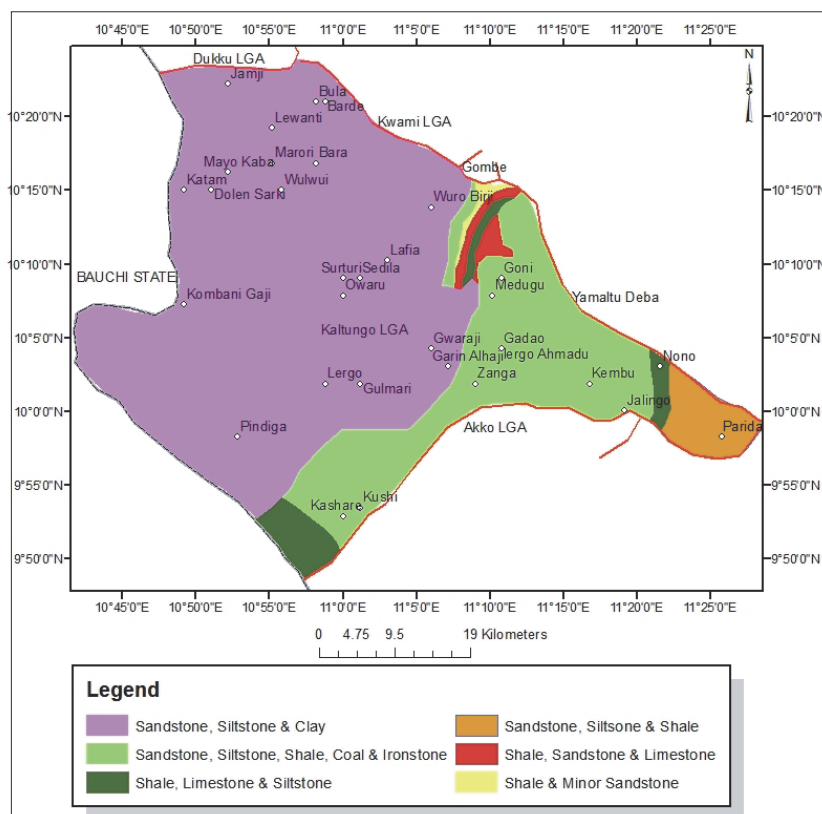


Fig. 4a. Geology of Akko LGA

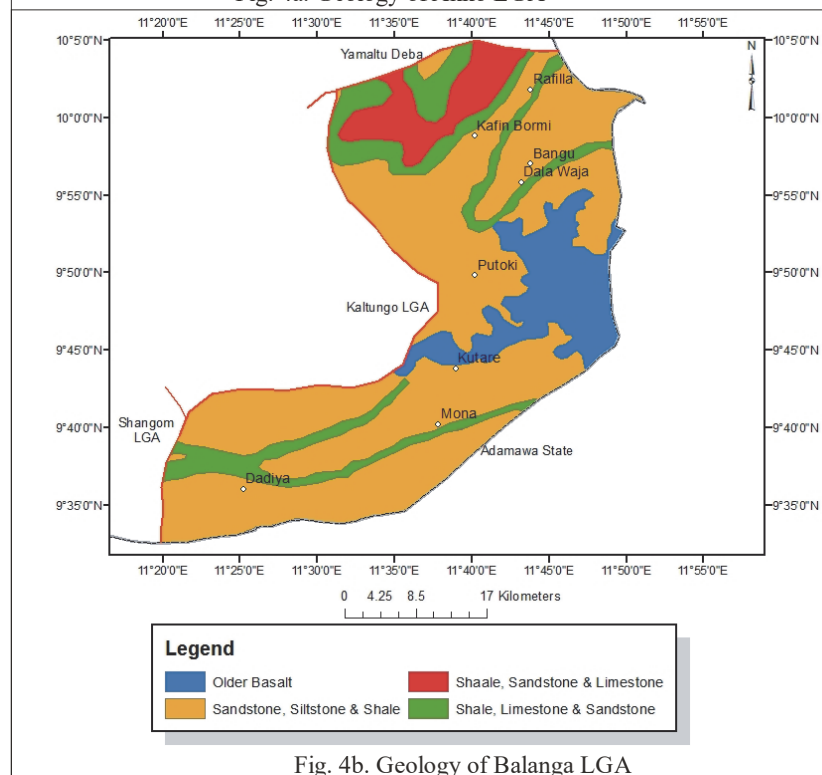


Fig. 4b. Geology of Balanga LGA

Figure 4a&4b. Geology of Akko & Balanga LGAs

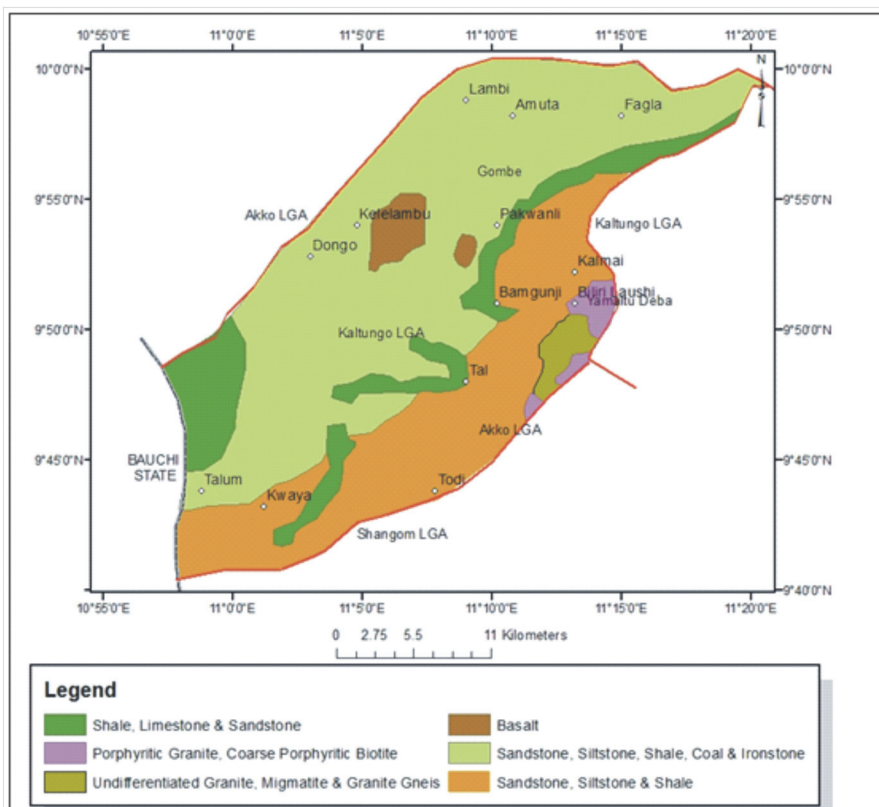


Fig. 4c: Geology of Bilin LGA

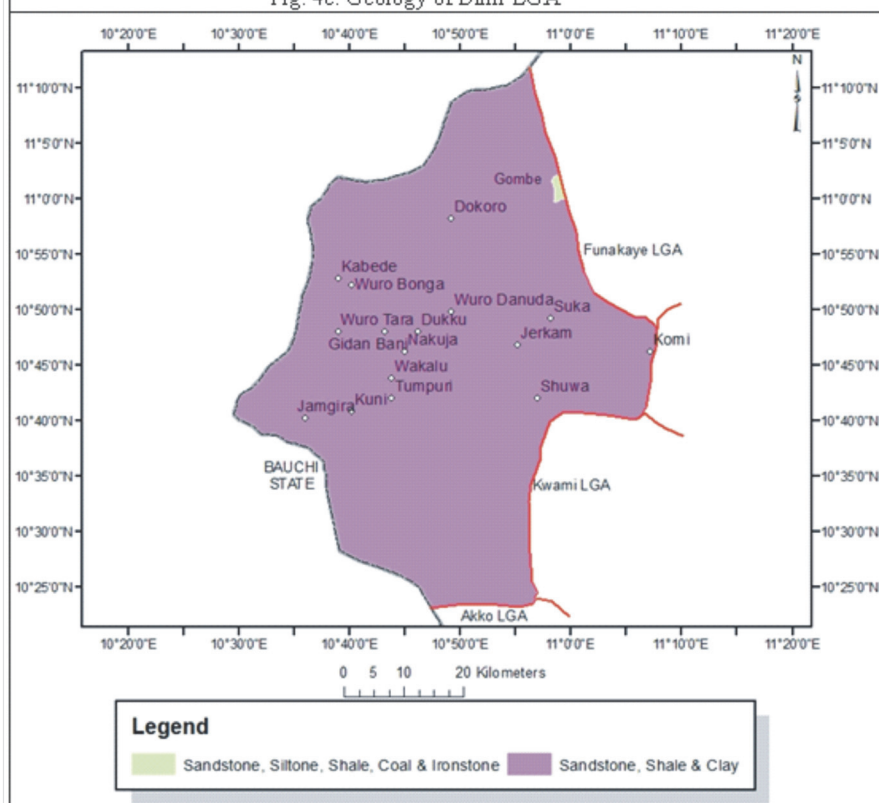


Fig. 4d: Geology of Dukku LGA

Figure 4c&4d. Geology of Biliri & Dukku LGAs

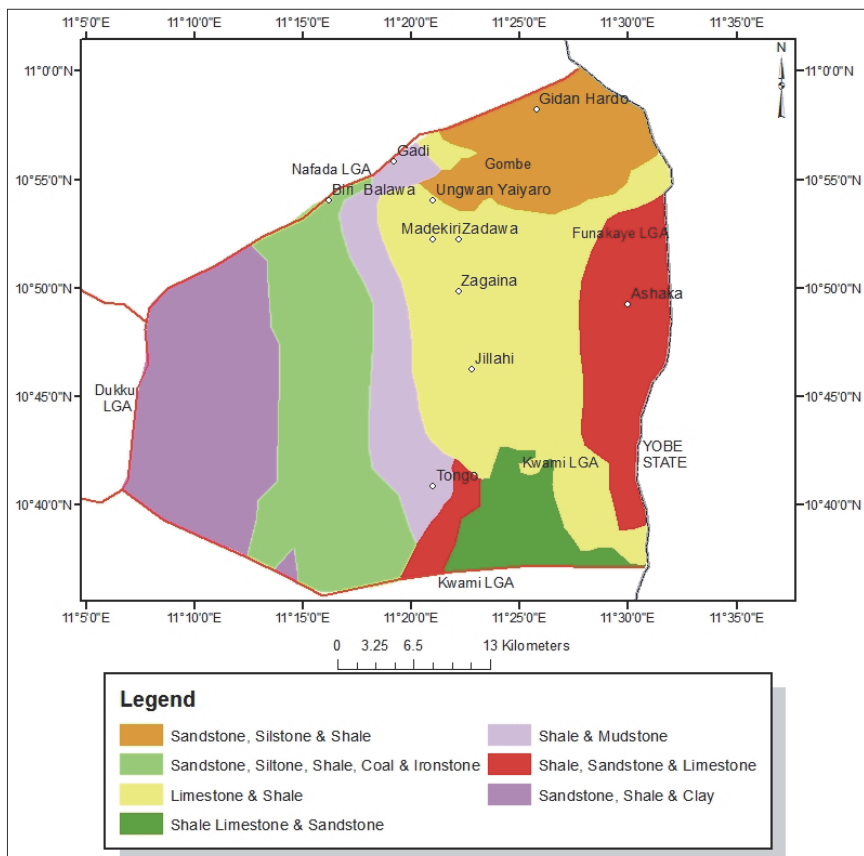


Fig. 4c: Geology of Funakaye LGA

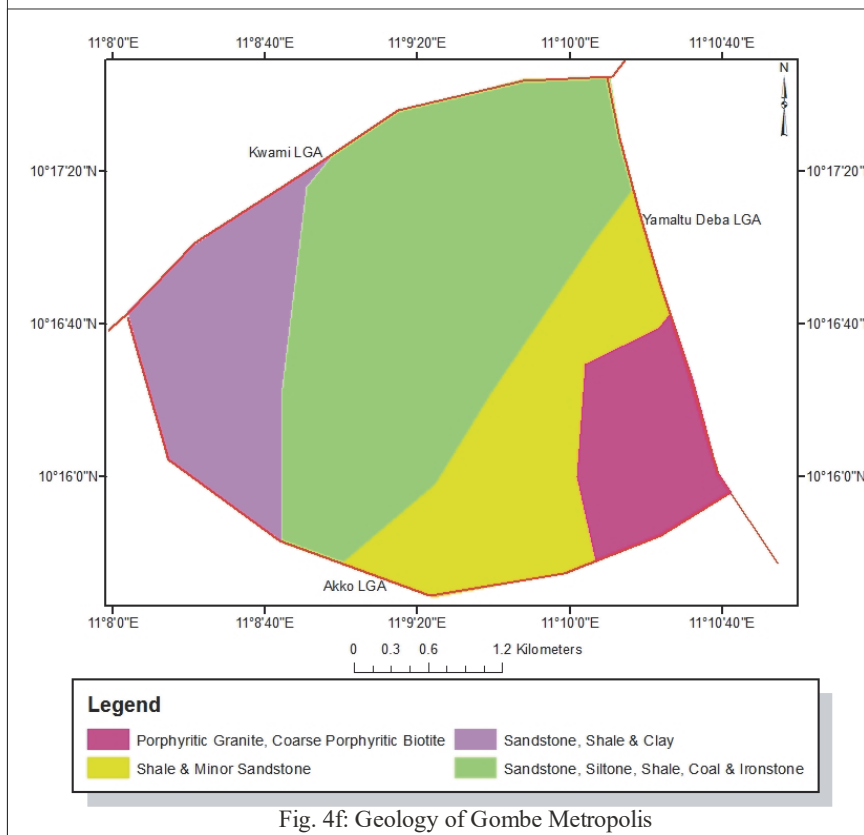


Fig. 4f: Geology of Gombe Metropolis

Figure 4e&4f. Geology of Funakaye & Gombe Metropolis

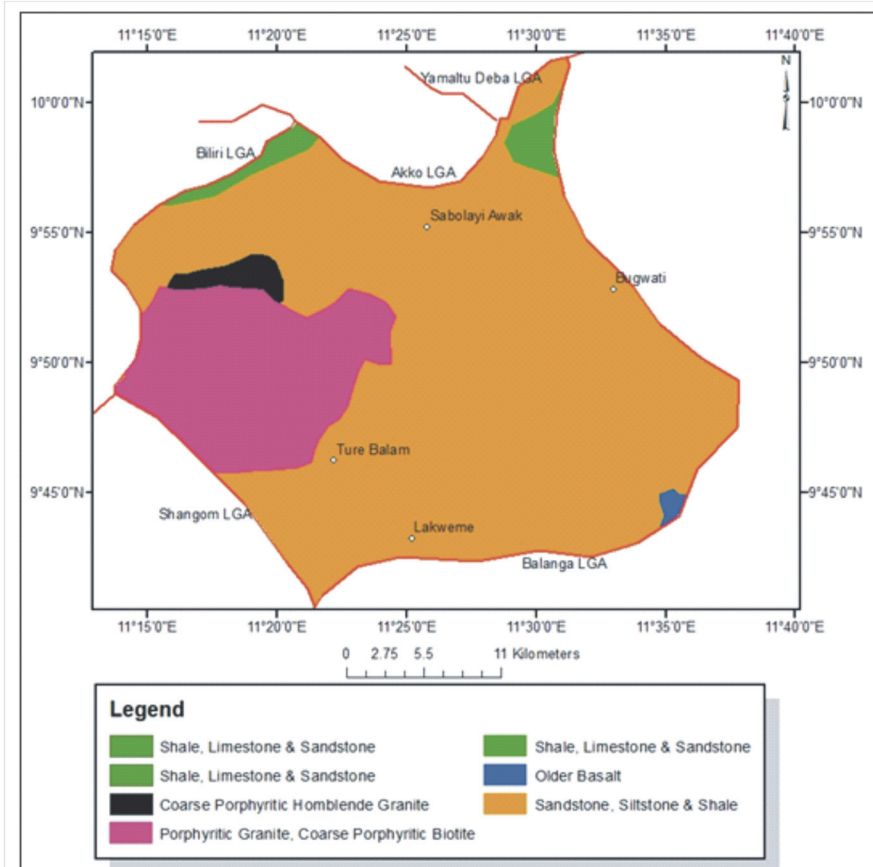


Fig. 4g: Geology of Kaltungo

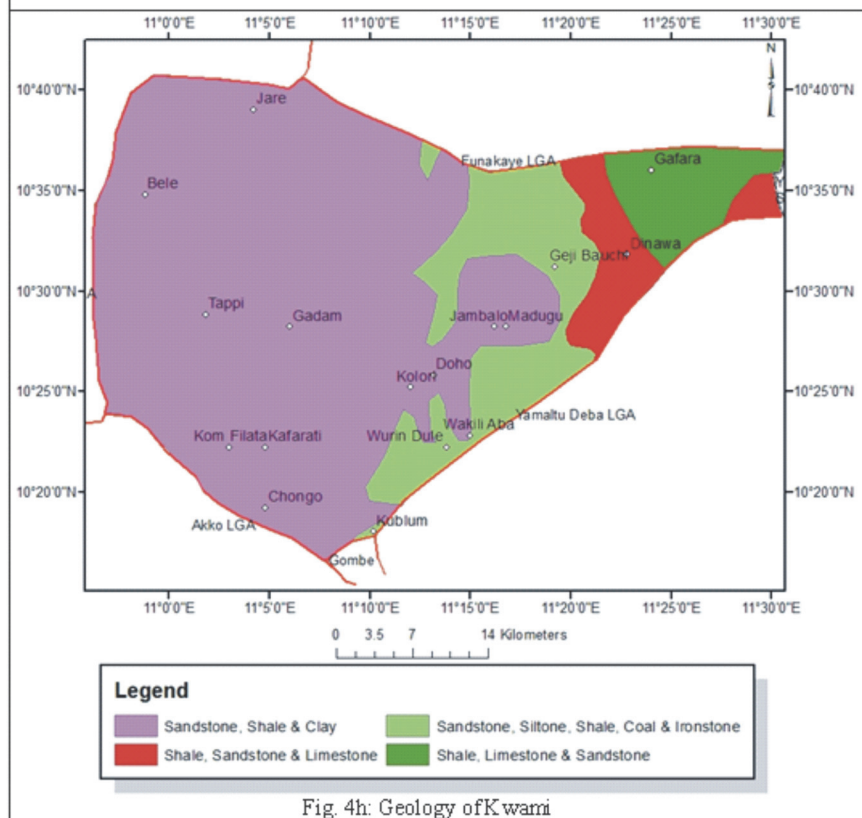


Fig. 4h: Geology of Kwami

Figure 4g&4h. Geology of Kaltungo & Kwami LGAs

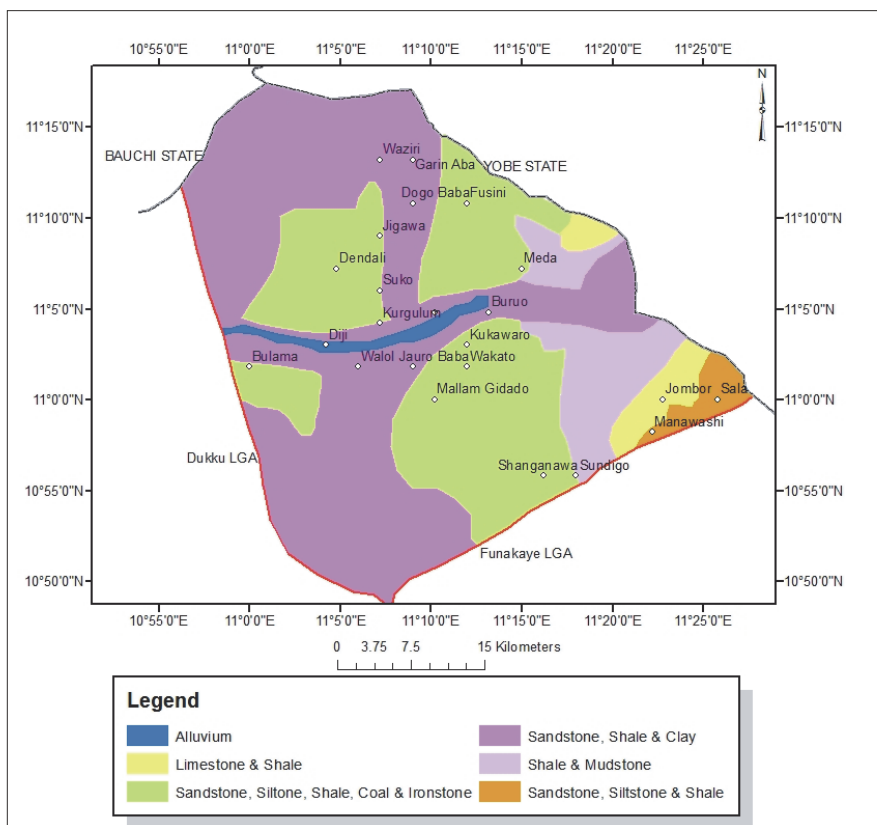


Fig.4i: Geology of Nafada LGA

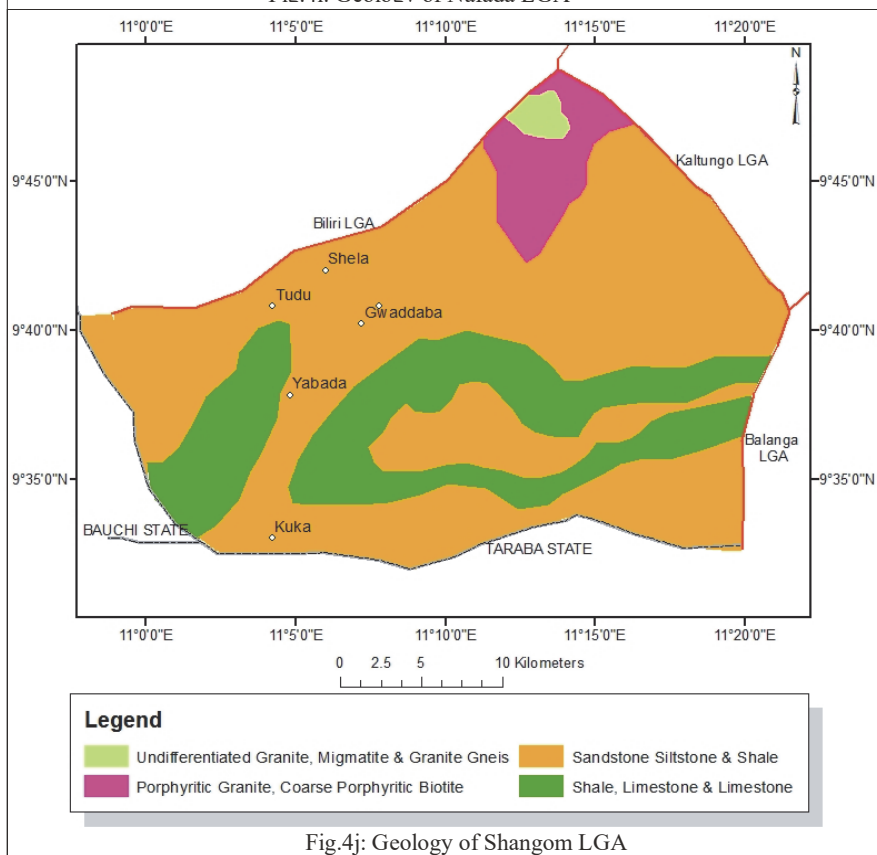


Fig.4j: Geology of Shangom LGA

Figure 4i&4j. Geology of Nafada & Shangom LGAs

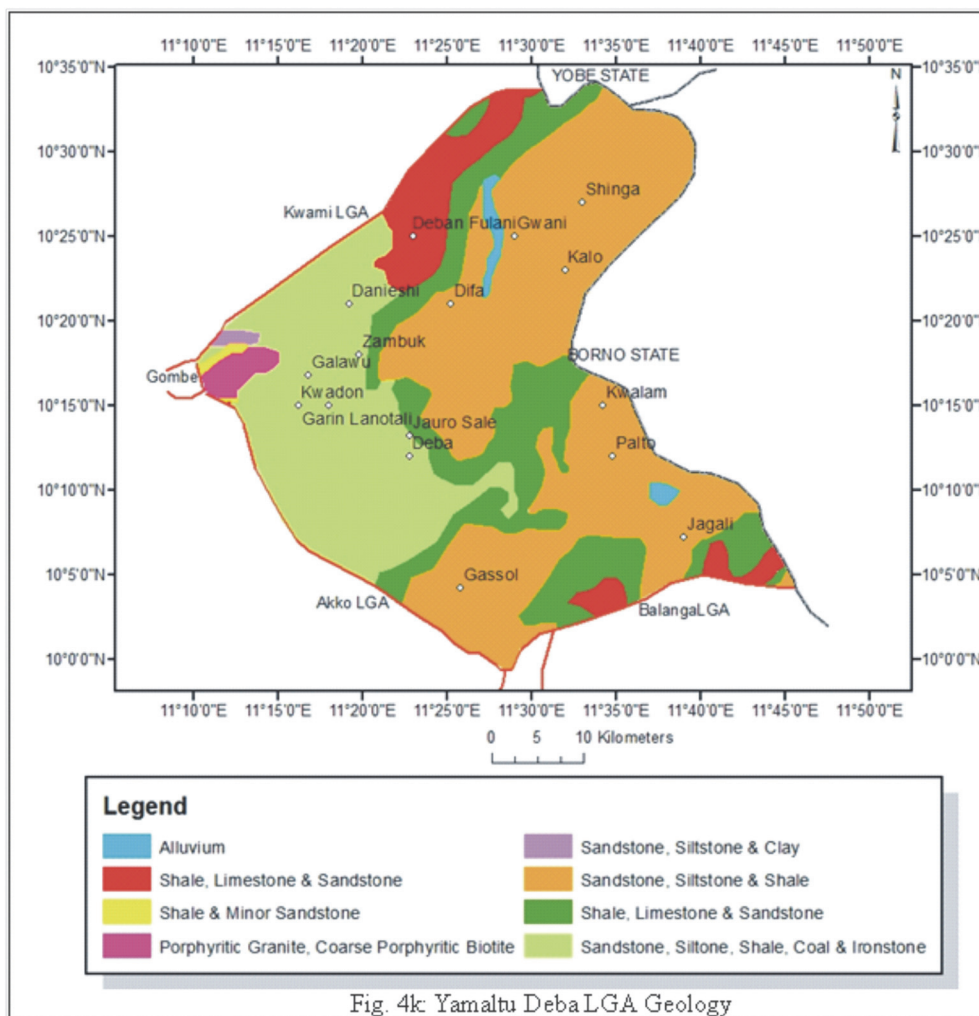


Figure 4k. Geology of Yamaltu Deba LGA

4. Spatial Analysis of the Soils of Gombe State

There are eleven soil units in Gombe state. That is, (i) Fluvisols (ii) Leptosols (iii) Nitisols, (iv) Regosols (v) Leptosols (vi) Cambisols and Luvisols (vii) Regosols and Cambisols (viii) Leptosols and Regosols (ix) Luvisols and Leptosols (x) Luvisols and Cambisols and (xi) Luvisols and Vertisols. Out of these eleven units, six are combinations of different soil units. Cambisols was discovered to be the only soil unit that do not stand alone but was mixed with other soil units such as Luvisols and Regosols.

Nitisols was found to cover almost half of the State (41.99%) as revealed from Fig. 3 and Table 4. Nitisols are found mainly on higher altitudes, no wonder Nitisols is found in the western part of the state that is mainly dominated by Dukku hills. They are perhaps the most inherently fertile of the tropical soils because of their high nutrient content and deep, permeable structure. They are exploited widely for plantation agriculture. The suitability of Nitisols for plantation agriculture might have contributed to the establishment of two out of the three most important forest reserves within the Nitisols soil unit; that is, Wawa forest Reserve which lies in Dukku and Nafada LGAs as well as Lembi Forest Reserve in Akko LGA (Lazarus, 2016).

In terms of area land mass, Leptosols is the second largest soil unit in Gombe State. According to Food and Agricultural Organization FAO (2017) Leptosols are soils with a very shallow profile depth 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. Leptosols are approximately equally distributed among high mountain areas. The mountainous southern part of Gombe State especially Balanga, Shangom and Kaltungo LGAs are mainly covered by Leptosol soil unit. The ever soil erosion prone areas in Akko LGA is also covered by the soil unit.

The cement producing area of Funakaye LGA is mainly covered by Luvisols, Cambisolssols or a combination of both. Regosols are young, mineral soils (Burl et al., 2016). Regosols are extensive in eroding lands, in particular in arid and semi-arid areas and in mountain regions. The mixed mineralogy, high nutrient content, and good drainage of these soils make them suitable for a wide range of agriculture, mixed clay accumulation that has high levels of available nutrient ions comprising calcium, magnesium, sodium, or potassium. Luvisols are often associated with Cambisols. Fluvisols are found on alluvial plains. Under natural conditions periodical flooding is fairly common.

Gombe is the largest grower of cotton in Nigeria with an output of 500,000 metric tonnes per annum Voice of Gombe (2013). This largely depend on the suitable soil types for crop production in State. For instance, (Ikusemoran & Tammi, 2009), opined that Cambisols, Vertisols and Fluvisols are suitable for cotton production. These soil types cover some parts of Yamaltu Deba, Akko and Gombe which also reflects the area where cotton production in Gombe State is prominent. The spatial coverage of each of the soil units in Gombe State and in each of the LGAs is presented in Figs. 6a to 6k and Table 4.

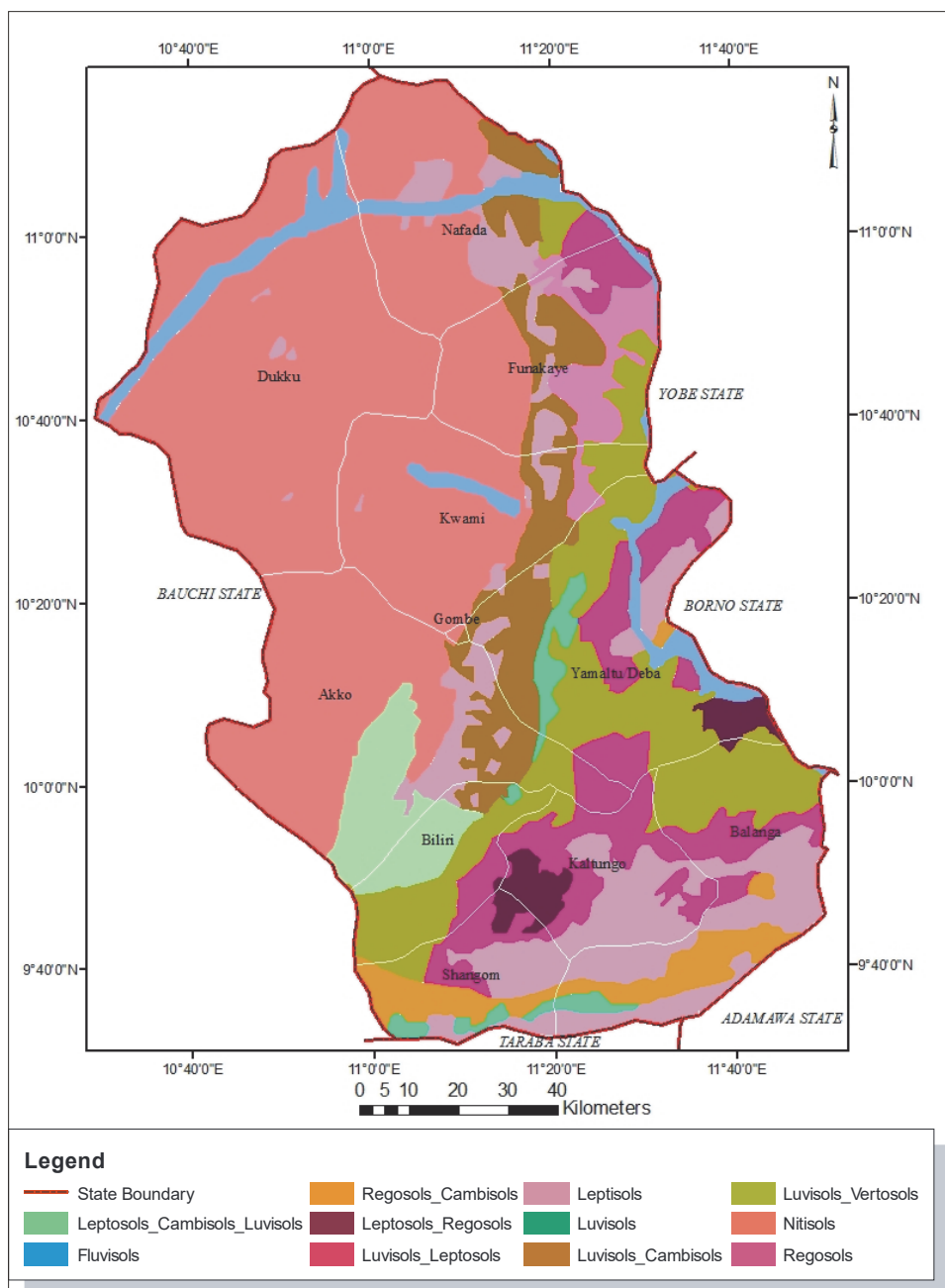


Figure 5. Soil Units in Gombe State

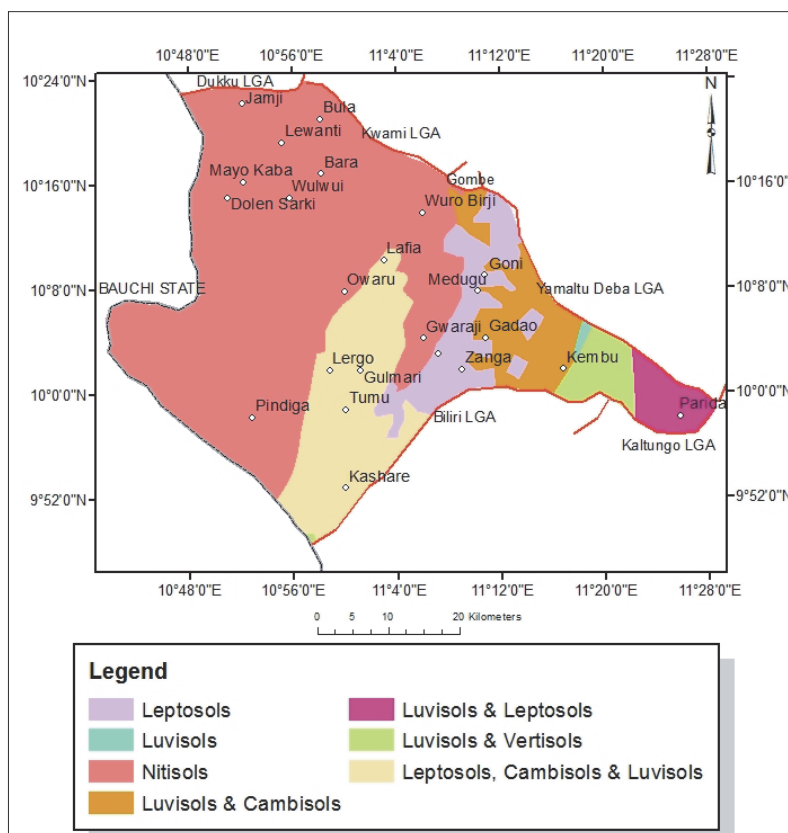


Fig. 6a. Akko LGA Soils

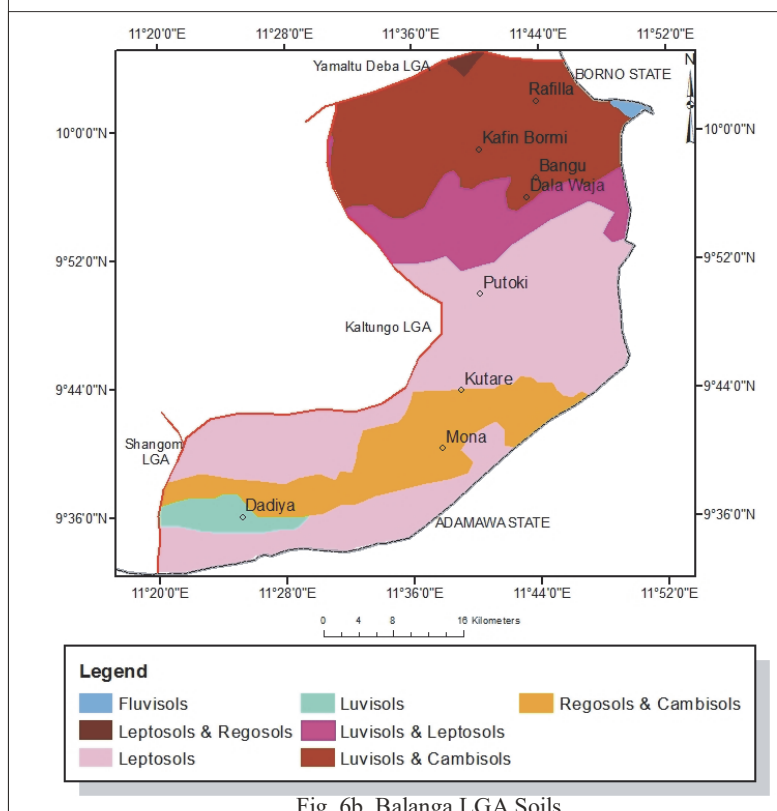


Fig. 6b. Balanga LGA Soils

Figure 6a&6b. Soils of Akko & Balanga LGAs

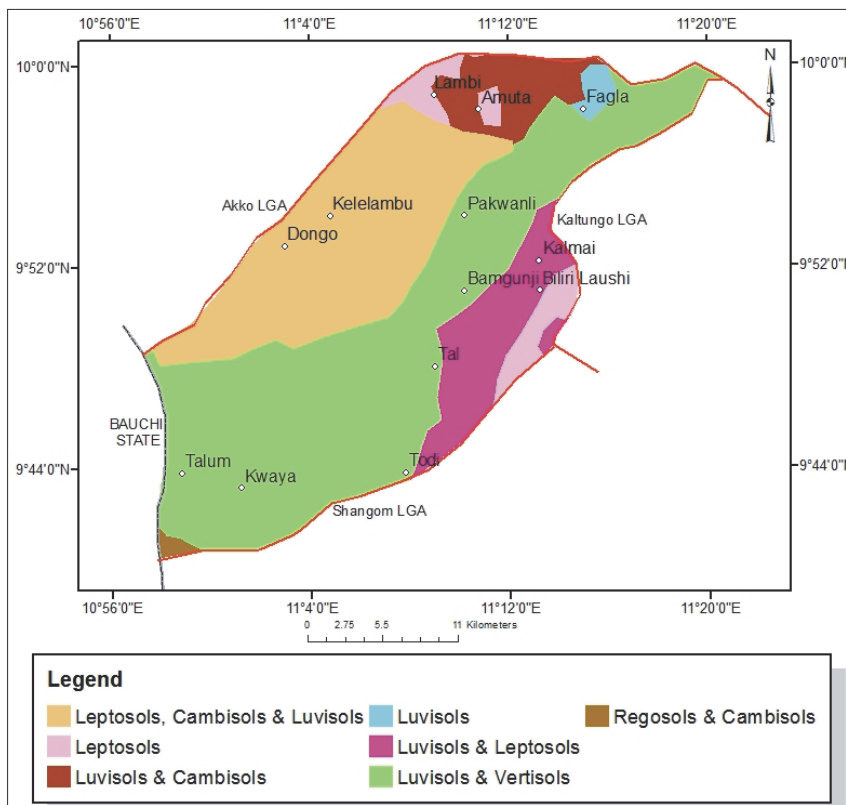


Fig. 6c. Biliri LGA Soils

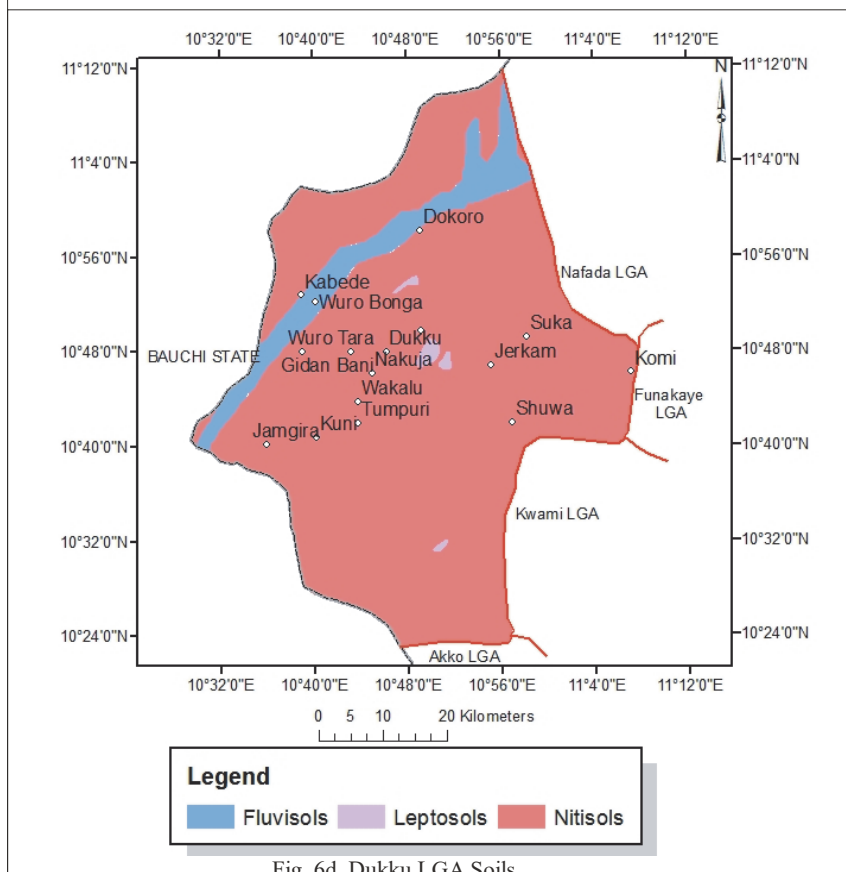


Fig. 6d. Dukku LGA Soils

Figure 6c&6d. Soils of Biliri & Dukku LGAs

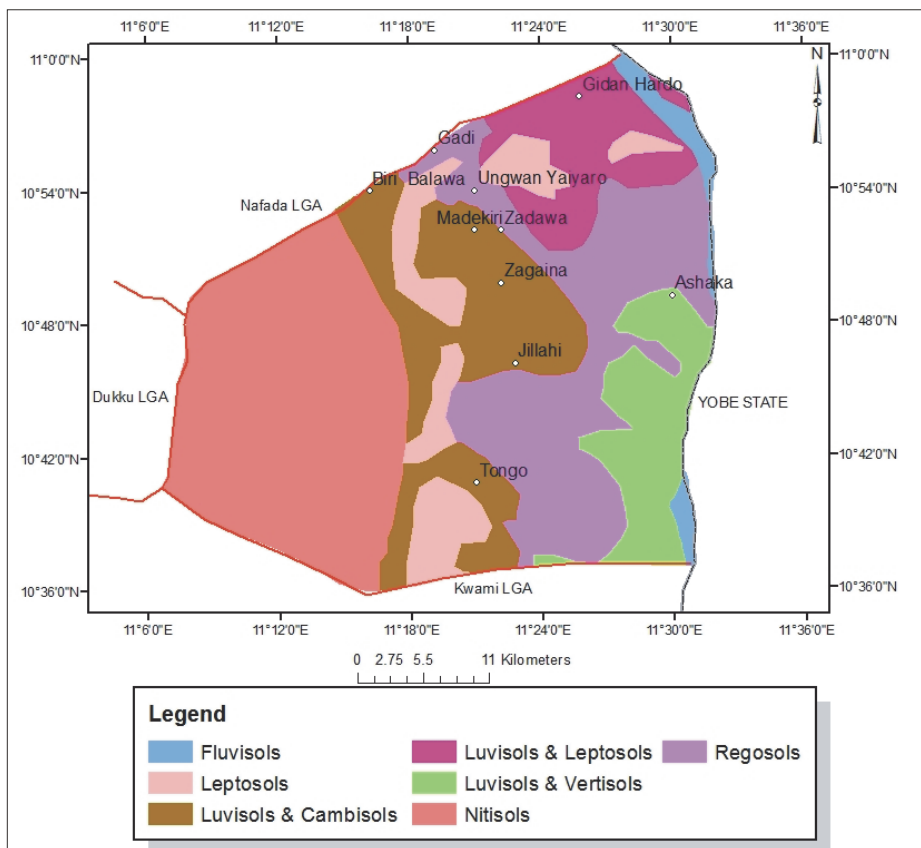


Fig. 6e. Funakaye LGA Soils

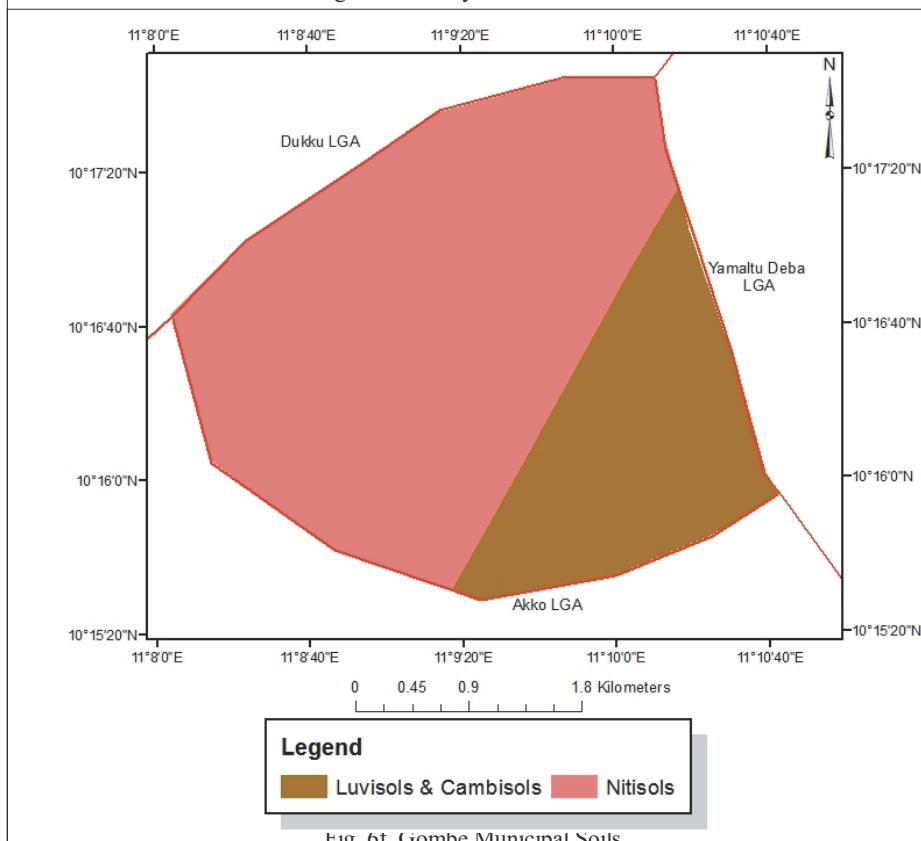


Fig. 6f. Gombe Municipal Soils

Figure 6e&6f. Soils of Funakaye LGA & Gombe Municipal

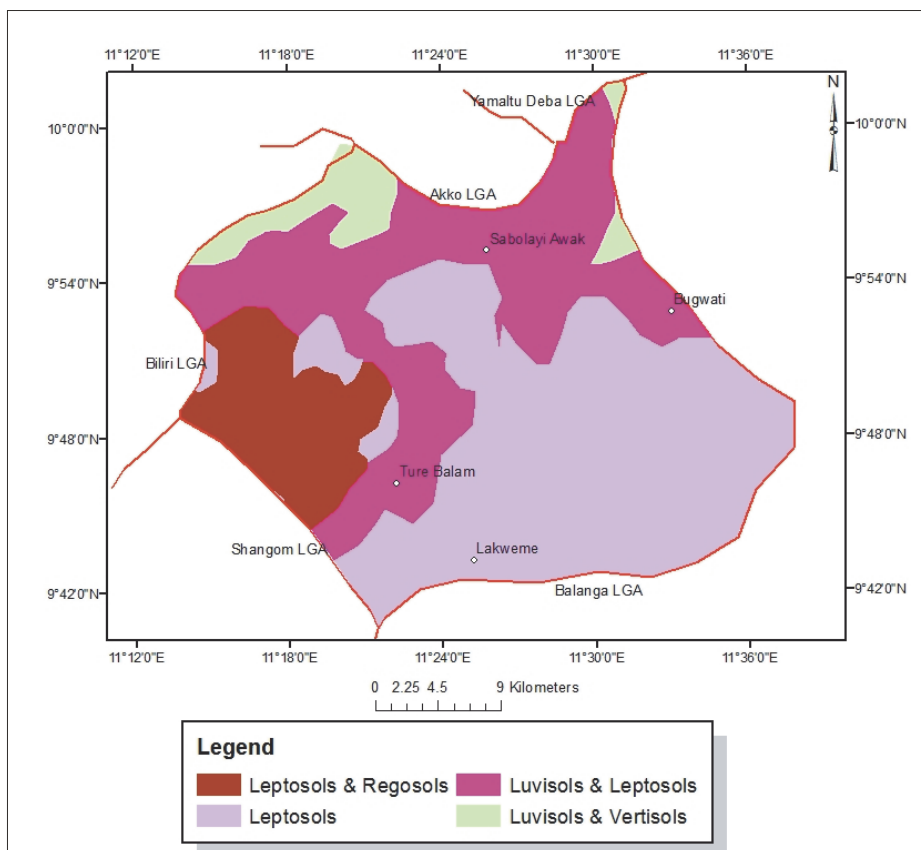


Fig. 6g. Kaltungo LGA Soils

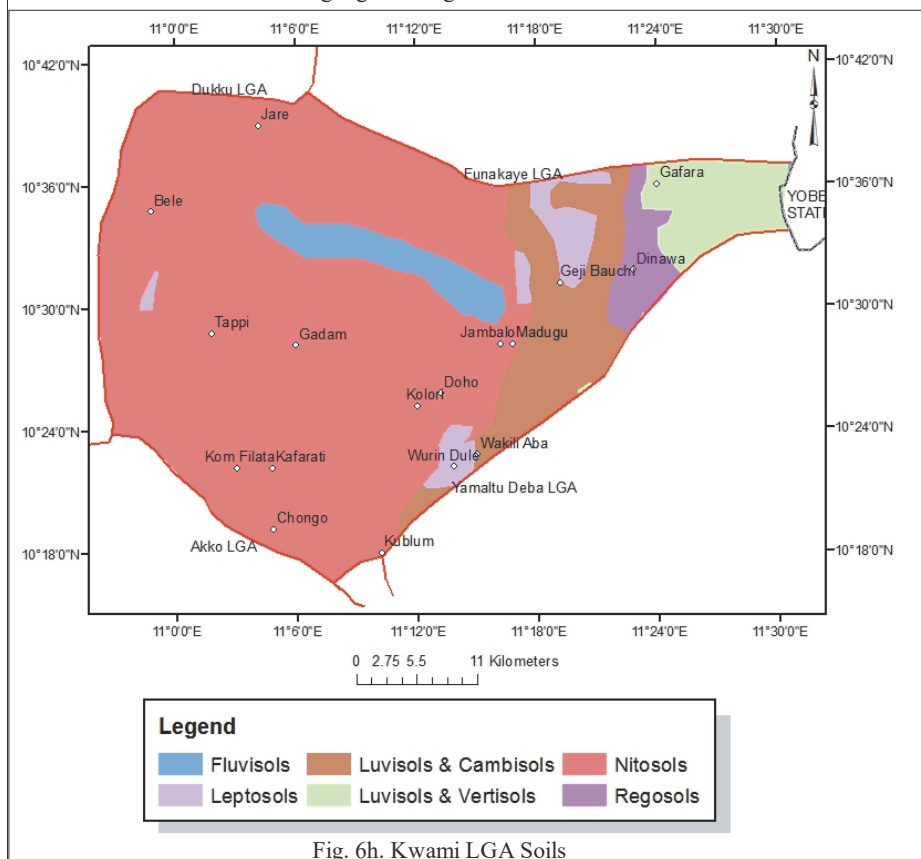


Fig. 6h. Kwami LGA Soils

Figure 6g&6h. Soils of Kaltungo & Kwami LGAs

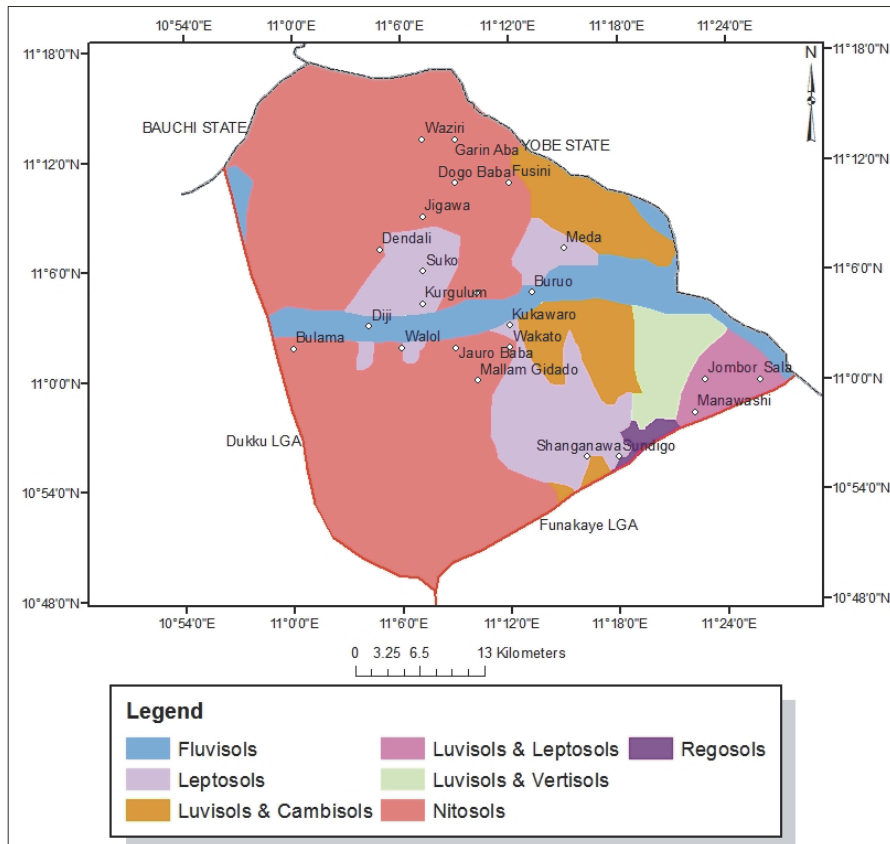


Fig. 6i. Nafada LGA Soils

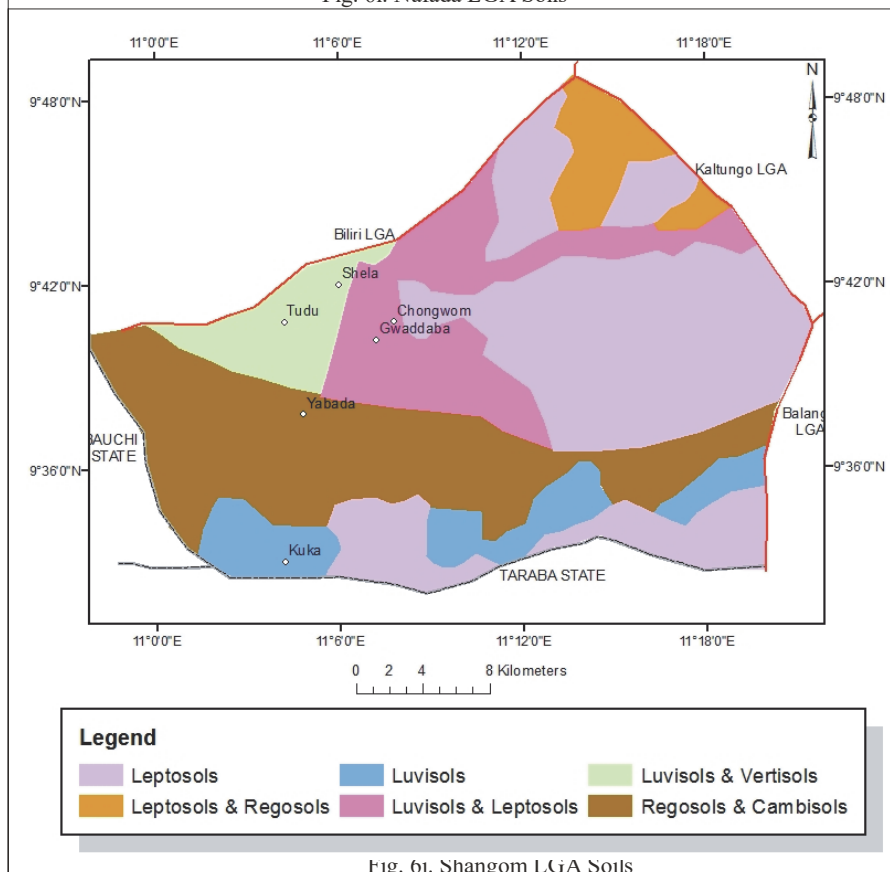


Fig. 6j. Shangom LGA Soils

Figure 6i&6j. Soils of Nafada & Shangom LGAs

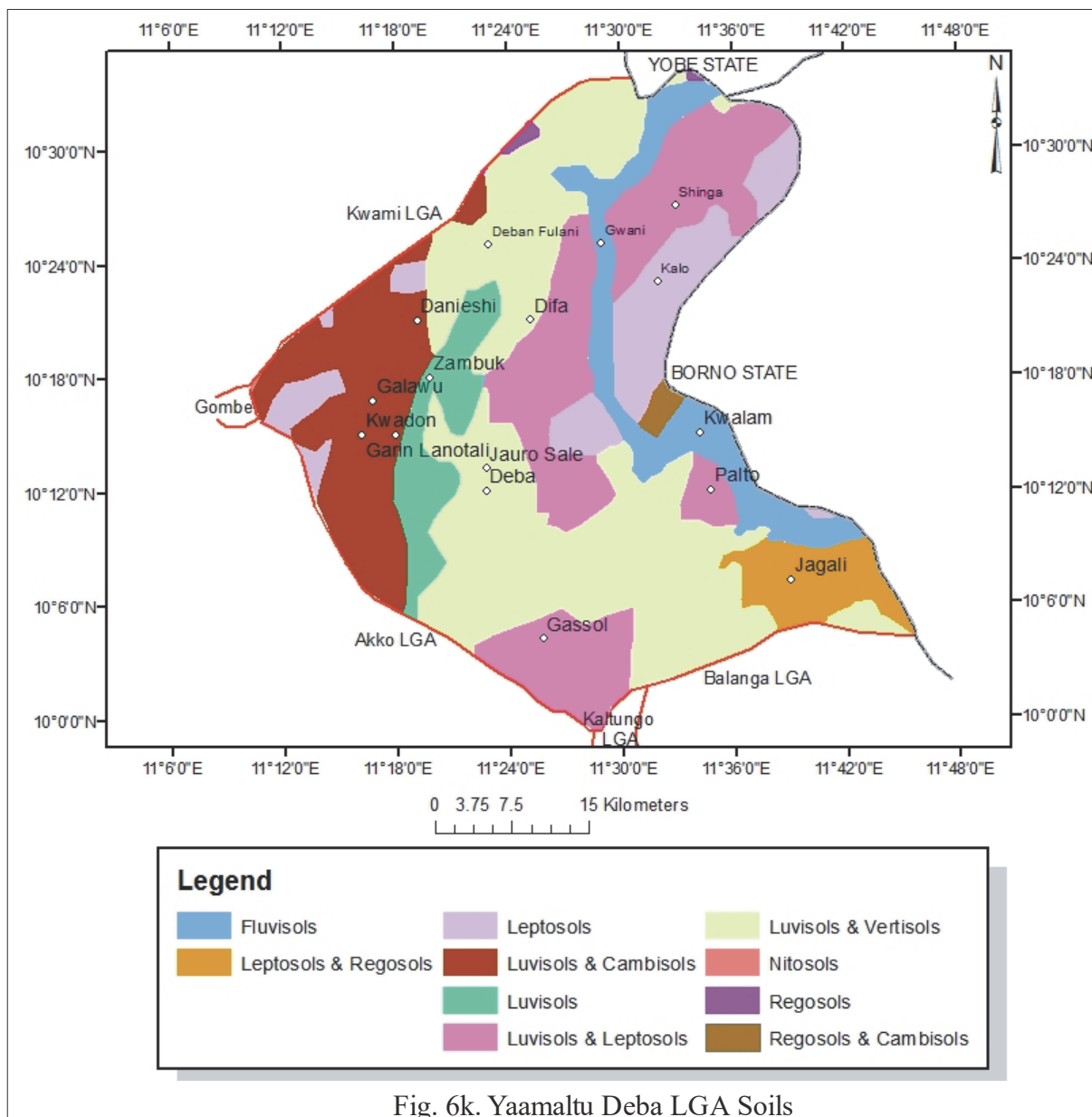


Fig. 6k. Yamaltu Deba LGA Soils

Figure 6k. Soils of Yamaltu Deba LGA

Table 5. Spatial Distribution of the Soil Units in each LGA in Gombe State

LGAs	Fluvisols	Leptosols	Luvisols	Nitisols	Regosols	Leptosols, Cambisols & Luvisols	Regosols & Cambisols	Leptosols & Regosols	Luvisols & Leptosols	Luvisols & Cambisols	Luvisols & Vertosols
Akko	-	229.1	5.56	1536.67	-	427.77	-	-	84.63	182.53	87.31
2553.57k m ²		8.97%	0.22%	60.18%		16.75%			3.31%	7.15%	3.42%
Balanga	4.91	633.82	49.51	-	-	-	290.72	6.29	227.96	-	453.27
1666.48 km ²	0.29%	38.03%	2.97%				17.45%	0.37%	13.68%		27.20%
Biliri	-	36.54	8.76	-	-	213.81	4.09	-	87.54	36.43	386.85
774.02		4.72	1.13%			27.62%	0.53%		11.31%	4.71%	49.99%
Dukku	272.72	20.09	-	3071.67	-	-	-	-	-	-	-
3364.48 km ²	8.11%	0.60%		91.30%							
Funakaye	34.31	137.31	-	456.37	351.35	-	-	-	133.95	219.56	142.83
1475.68 km ²	2.33%	9.30%		30.93%	23.81%				9.08%	14.88%	9.68%
Gombe	-	-	-	9.88	-	-	-	-	-	3.91	-
13.79 km ²				71.65%						28.35%	
Kaltungo	-	387.66	-	-	-	-	-	126.69	422.57	-	60.74
997.66 km ²		38.86%						12.70%	42.36%		6.09%
Kwami	70.09	58.83	-	1168.64	53.41	-	-	-	-	187.75	93.77
1632.49 km ²	4.29%	3.60%		71.59%	3.27%					11.50%	5.74%
Nafada	173.1	254.84	-	1002.19	14.54	-	-	-	59.4	186.63	75.85
1766.55 km ²	9.8	14.42		56.73	0.82				3.36	10.56	4.29
Shangom	-	289.79	74.27	-	-	-	207.18	45.92	150.23	-	51.49
818.88 km ²		35.39%	9.07%				25.30%	5.61%	18.35%		6.29%
Y/Deba	191.73	216.72	123.01	1.31	8.15	-	14.46	102.57	478.41	296.8	761.84
2195 km ²	8.73%	9.87%	5.60%	0.06%	0.37		0.66	4.67	21.8	13.52	34.71
Total	746.86	2264.7	261.11	7246.73	427.45	641.58	516.45	281.47	1644.69	1113.61	2113.95
G/Total											17258.6
Total	4.33%	13.12%	1.51%	41.99%	2.48%	3.71%	2.99%	1.63%	9.53%	6.45%	12.25%
G/Total											100%

Some of the settlements in each of the soils and geologic units are presented in Figs. 7a and 7b for easy identification of the settlements in each geologic or soils.

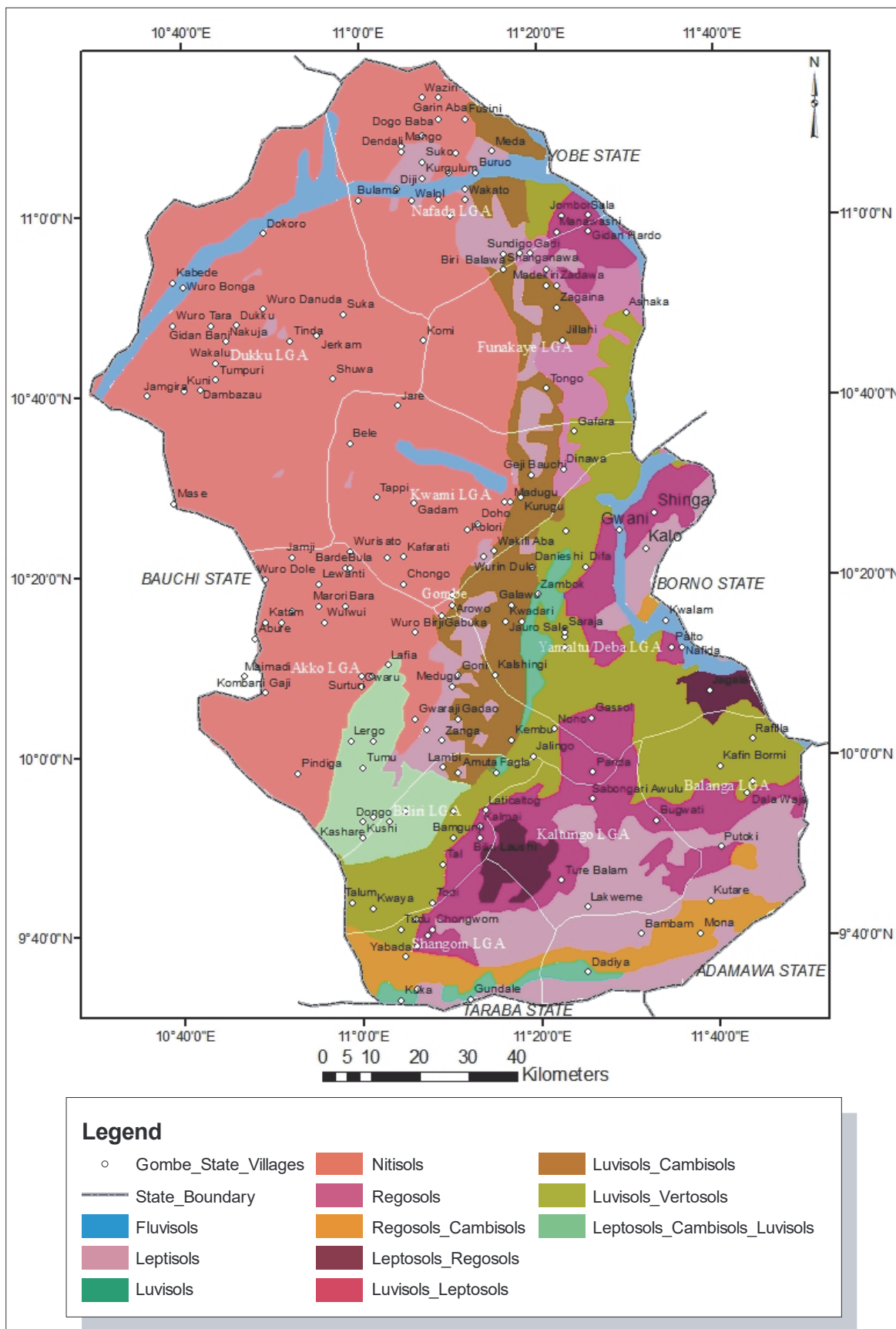


Figure 7a. Some Settlements on the Soils of Gombe State

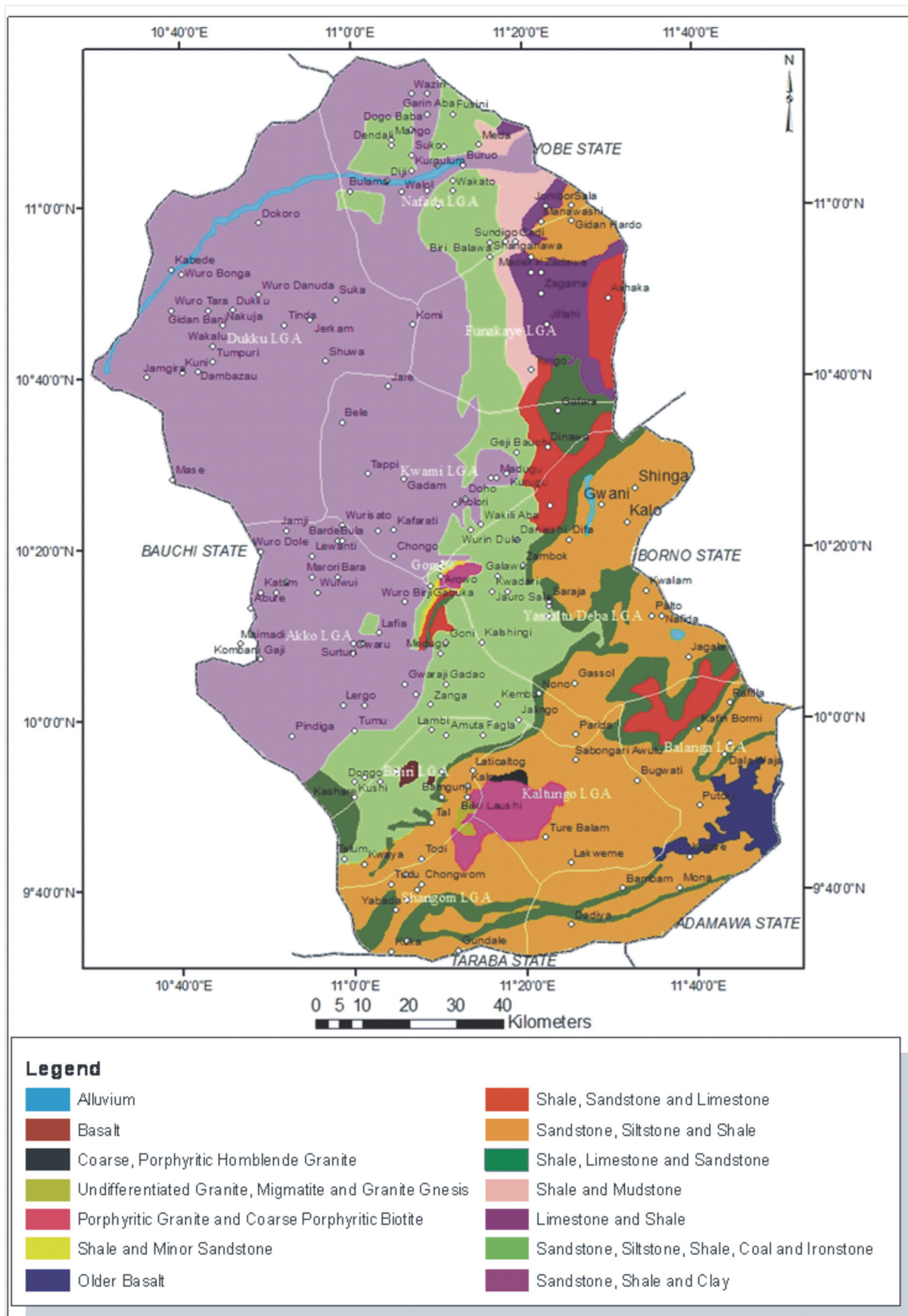


Figure 7b. Some Settlements on the Geology of Gombe State

5. Conclusion

The spatial distributions of the soils and geologic units in Gombe State in general and in each of the LGAs in the State have been demonstrated in this paper. The quantity of the spatial coverage of each unit in the soils and geology in the State and in each LGAs have also been carried out. It is hoped that researchers and other stakeholders who are interested in using spatial distribution of the soil and geology of smaller units like LGAs in the State will find this work very useful. The result of the study revealed similarity between the spatial distribution of the geologic and soil units in the State. For instance, the western part of the State is covered by only one soil (Nitisols) or geologic (Sandstone, Shale and Clay) units while the eastern and southern parts contain the other soil and geological units. The result also shows that Gombe State has fourteen (14) geologic units. However, out of the 14 geologic units, almost half of the State (41.75%) is covered by Sandstone, Shale and Clay unit, while eleven soil units exist in the State with Sandstone, Shale and Clay unit alone covering 41.99% of the State. The use of geospatial techniques for spatial assessments and quantification in this paper has also proven to be better, faster and more accurate than the manual methods. It could have been very difficult to map, delineate and calculate the soils and geologic units with accuracy of spatial locations of other features like settlements and political boundaries if manual techniques were used. The major limitation of this paper is the use of already made soil and geology maps which considered some areas as having several units such luvisols and vertisols in soil or shale and mudstone in the geologic unit.

This paper is also expected to minimize the time, cost and energy on mineral exploration and site suitability for crop production activities in the State because once the suitable geology or soils for a particular mineral or crop is identified on the map, it will limit the exploration or suitability study to only the areas where such geologic unit or soil is endowed. Though the sources of the maps were highly reliable, but it could have been better if the maps were generated using geospatial techniques. It is therefore suggested that further studies should be carried out on geospatial techniques for mapping soil and geologic units in the State. Delineation and mapping of the soils, relief, drainage, geology etc. of the agricultural and mining zones in the State to serve as data bank for further researchers or other users in general.

6. Recommendations

From the results and findings of this study, the following recommendations are made:

- (i) Geospatial mapping of the soils and geology of the agricultural zones of Gombe state should be carried out so as to ease the problems of delineation and extraction of the zones from the available entire Gombe state.
- (ii) Generation of maps of the agricultural and mining zones in the state comprising of major features like soil, geology, relief, drainage, population density, transport, settlement among others to serve as data bank
- (iii) Further research should also be carried to actually delineate the areas that are considered to comprise more than a unit except where those units are actual mixed
- (iv) The generated soil and geologic maps of the State are expected to be considered for mineral exploration and crop suitability assessments in order to reduce time, cost and energy that would be incurred if the entire state is assessed.

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