Geographical Analysis of the Physical Aspect of Gashaka-Gumti National Park, North East Nigeria

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Abstract

In this paper, the use of geospatial techniques for geographical analysis of the physical aspects of Gashaka-Gumti National Park (GGNP) in Nigeria was carried out. Shuttle Radar Topography Mission (SRTM) was acquired and processed in ArcGIS 10.5 to produce the relief and rivers /streams within the park, while the names of the identified rivers and streams were obtained from topographical maps. Landsat 5 TM of 1991 and 2003 as well as Landsat OLI 8 of 2021 were obtained online to map the vegetation pattern of each year using NDVI indices. Changes in vegetation within the three-year study period were detected using the area calculation module in ArcGIS 10.5. Mean annual rainfall and temperature of fifty years were obtained online from Diva GIS which were interpolated to generate the spatial pattern of rainfall and mean temperature within the park. The results show that the relief of the national ranges from 286 to 2419 m, with Chapal Wadi mountain as the highest elevation of 2419 m above sea level. River Yim has the largest drainage basin of 1862.22 km^2, while River Kam is the longest with 93.7 km. Mean annual rainfall ranges from 1349.9 in the north to 1717.9 mm in the south. Mean temperature from 26.2 to 36.6°C. There are four geologic units in the park, but Porphroblastic Gneiss covers the largest area of 4588.03 km^2. Among the seven existing soil units, Leptosols alone covered 65.09% of the park. Forest areas that gained a total land area of 91.43km^2 between 1991 and 2003, lost 70.88km^2 between 2003 and 2021, while non-vegetation which decreased in size to 209.09km^2 between 1991 and 2003, increased to 241km^2 between 2003 and 2021. It was recommended that the management of Gashaka Gumti National Park should be more proactive in the preservation of the park to minimize the rate of vegetation depletion within the park.

Keywords: *Gashaka-Gumti National Park, geospatial techniques, geographical analysis, vegetation depletion.*

Introduction

There are seven National Parks in Nigeria: Chad Basin (Borno State), Cross River, Gashaka-Gumti (Adamawa/Taraba States), Kainji (Kwara/Niger States), Kamuku (Kaduna State), Okomu (Edo State) and Old Oyo (Kwara/Oyo States). Among all these, Kainji Lake National Park was the first to be established in 1979 during the military rule of General Olusegun Obasanjo.

All the National Parks in Nigeria are managed by the Nigeria National Park Service (NNPS) which is responsible for preserving, enhancing, protecting and managing vegetation and wild animals in the National Parks of Nigeria. GGNP along with Chad Basin, Cross River and Old Oyo National Park were established in 1991. The variations in the land areas as previously quoted were mainly due to estimation or reliance on manual measurements, coupled with the numerous conflicting existing boundaries of the park in most of the existing literature.

Despite all the importance of GGNP to the people and economy of Nigeria, not much documentation especially on the physical aspect of the park in a single document has been carried out. There is a need to map and analyze the physical aspect of important places like the Gashaka Gumti National Park in Nigeria for research and documentary purposes and most importantly for data provision for comprehensive conservation of the park and also for military operations at the face of the current security challenges in the country especially in the park's environment where accessibility is minimal due to the ruggedness of the area.

Numerous works have been carried out by various scholars such as Mubi (2010), Chapman (2014), Oruonye et al. (2017), Yamduma et al. (2019) on the description of the physical aspects of the National Park. However, the relief for instance, was shallowly described without showing the actual positions and heights of some important highlands and hills Mubi (2010), Chapman (2014), Zaku et al. (2022), and Kwesaba et al. (2023a). While, only the four important rivers (Yim, Kam, Gashaka and Gamgam were frequently described without showing the locations, lengths and sizes of the large basins within the park.

Furthermore, rainfall and temperature of Gembu which is outside the park were often used to describe the climate within the park (Mubi, 2010; Kwesaba et al., 2023b). In this paper, the topography as well as most of the rivers and streams within the park were

identified, mapped and well-labeled. Most of the descriptions of the climate in GGNP were without maps to show the spatial patterns. Therefore, the main objectives of the study are to: (i) apply geospatial techniques to map and analyze the relief, drainage, climatic variables (rainfall, temperature and relative humidity) vegetation, geology and soils of Gahaka Gumpti National Park, (ii) generate and analyze the spatial patterns of the important climatic variables (rainfall, temperature and relative humidity within the park.

The Study Area

GGNP is located between latitudes 6° 56′ 16.116″ N and 8° 5′ 22.341″ N of the Equator, and longitudes 11° 11′ 15. 859″ E and 12° 13′ 14.087″ E of the Meridian. The Park occupied some parts of two states in Nigeria that is, Taraba and Adamawa States at the southern and northern parts of the park respectively.

GNNP is bounded in the East by Cameroon, South by Mambilla Plateau, North by Adamawa State and West by the central part of Gashaka LGA. GGNP occupied a total land area of 6205.4 km2. Out of this total land area, 3954.68 km2 (64.66%) are in Taraba State while the remaining 2161.11 km2 (34.34%) are in Adamawa State. While the Toungo sector of the park within Adamawa state was found in only Toungo Local Government Area, major parts (3768.52 km2) which is about 95.29% of the park within Taraba, falls in Gashaka LGA. The remaining 186.16 km2 (4.71%) falls in Sardauna LGA of Taraba State.

GGNP was created by the merging of Gashaka Game Reserve with that of Gumti Game Reserve (Andrew, 1999). GGNP is the largest park in Nigeria with a land coverage of about 6205.40 km2 as digitally calculated in this study. Though, several land areas have been cited by many authors such as 6731 km2 (Andrew 1999, Oruonye et al., 2017).), 6400 km2 (Ogunjemite, 2010), 6,671 km2 (Kwaga et al., 2019). Today, the plain and grassland of the northern side is referred to as Gumti Sector while the mountainous side in the southern park is called the Gashaka sector.

Among the distinguishing features of GGNP from other parks are: it is the largest National Park in Nigeria (Yaduma et al., 2019), it is the only park where enclaves (settlements) are legally allowed among all the other National Parks in Nigeria (Andrew 1999), its unique biodiversity comprising woodland, grassland, forest, mountainous (Mambilla section) and wide plains of Benue Basin

(Andrew 1999), the highest mountain in Nigeria (Chappal Waddi Hills) which is about 2419 m above sea level is located within the park (Oruonye et al., 2017). Diverse flora and fauna of the national park (Andrew 1999): the largest population of chimpanzees in Nigeria (Ogunjemite et al., 2010), It is also the only park in Nigeria that has a subtemperate climate (Andrew 1999).

Among the challenges of the park are: poaching by inhabitants and animal grazers, landslide because of the sedimentary nature of the rock, annual bush burning which is degrading the grasses and the woodlands, rugged topography which impedes easy accessibility, security challenges from illegal loggers, herders and bandits; some rangers have lost their lives to these set of people (Kabir, 2019).

The Jibu, Dakka, Ndoro, Tigun, Gbaya, Tiv, Mambilla, Kaka and Fulani are the main ethnic groups in the southern part of the park, while the Chamba, Kutim Potopore, Fulani, Dakka, Nyamnyam and Koma are found in the Toungo sector. Though settlements are not legally allowed within parks, GGNP has some settlements known as enclaves within the park. Andrew (1999) defined enclaves in the park as "areas of land inside the park set aside for livestock grazing and farming, controlled zones where traditional livelihoods are protected and supported". The communities on the mountains at the central part of the park comprising Shirgu, Nyumti, and Hunde are enclaves which are mainly pastoral communities predominantly by the Fulanis (Andrew, 1999).

Other existing enclaves within the park include Gumti, Chappal Delam, Filinga and Mayo Sabere. Most of the other settlements that are not enclaves are found at the fringe of the park among which is Gashaka (Fig. 1). Jakuba village is the most popular among the illegal settlements within the park. The major occupations of the people in the area are farming, livestock husbandry, hunting and fishing. Maize, groundnut, millet, guinea corn, beans, soya beans, rice, yams, sugar cane, and cassava are some of the major crops that are grown in the area (Oruonye et al., 2017).

The main road from Tougo through Serti to Gembu is the major access road to both sectors of the park. No major roads are found within the park as the Gashaka sector is accessible through a secondary road from Serti to Gashaka village and southward through Mai Idanu to Gembu. Access minor road to Toungo sector is from Mayo Yim to Labare (Fig.1).

Materials and Methods

The materials that were used in this study include hardware (Hp intel core15 8th Gen. Laptop, GPS Germin 76), software (ArcGIS 10.5, Microsoft Excel), satellite climatic data (Diva GIS, NASA climatic data), satellite images (Landsat 5, 7 & 8), Digital Elevation Model Data (Shuttle Radar Topography Mission (SRTM DEM Data)), Topographical Sheets (Dau, Filinga, Gashaka & Serti). Other materials include Soils and Geology maps. The description, sources and methods of each data are presented in Table 1.

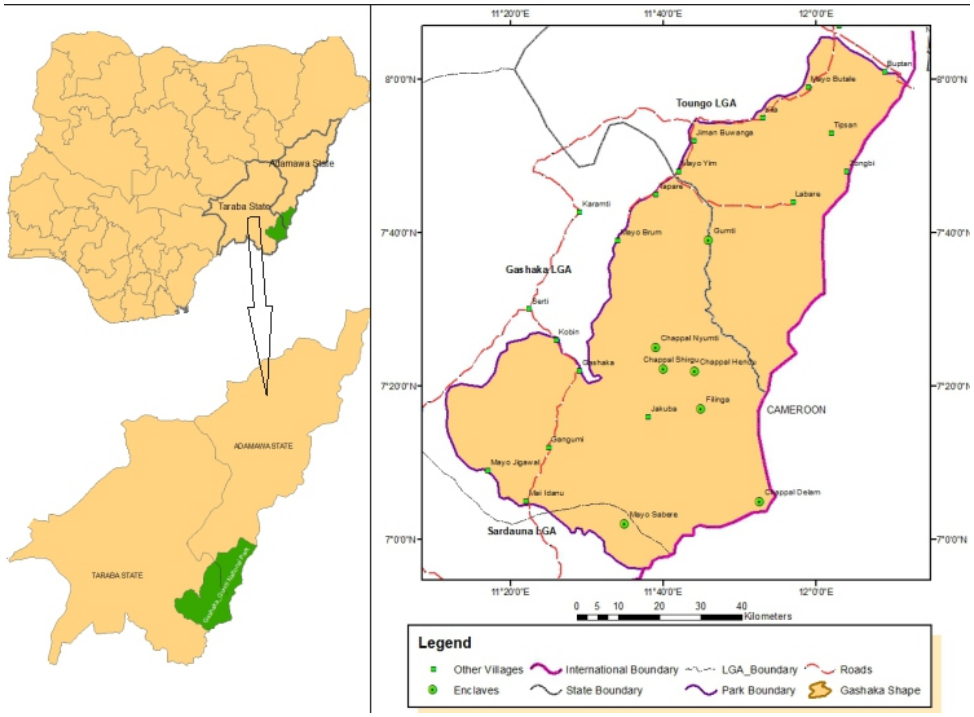

Figure 1. The Study Area
Source: Digitized from Gashaka Primate Project
(Gashaka Gumti National Park in conjunction with the
Department of Anthropology, University College, London (2019)

Materials and Methods

Table 1. Sources, purposes and methods of the utilization of the materials for the study

Materials	Description	Sources	Purpose	Methods
Shuttle Radar Topography Mission (SRTM)	It has 90m spatial resolution	National Aeronautics and Space Administration (NASA)	(i). For mapping the relief of the National Park (ii). For generating the rivers and stream within the park. (iii). For generation of the sub-basins within the park	(i). With shape file of the park, the park was delineated from the DEM and classified into four terrain classes. (ii). The delineated DEM was processed using the hydrology modules of ArcGIS 10.5 (iii). Using the basin module of ArcGIS 10.5, each of the four important basins within the park were generated.
Landsat 5 TM (1991)		earthexplorer.usgs.gov	For mapping the vegetation pattern of 1991 using NDVI	Using NDVI (IR-Red)/(IR + Red)
Landsat 7 ETM+ (2003)		earthexplorer.usgs.gov	For mapping the vegetation pattern of 2003 using NDVI	Using NDVI (IR-Red)/(IR + Red). Classifications of the result into four
Landsat 8 OLI (2021)		earthexplorer.usgs.gov	For mapping the vegetation pattern of 2021 using NDVI	Using NDVI (IR-Red)/(IR + Red). Classifications of the result into four
Topographical Maps	SERTI SHEET 256. 1:100,000 DAU SHEET 257. 1:100,000 GASHAKA SHEET 276. 1:100,000 FILINGA SHEET 277. 1:100,000	Department of Geography, MAU, Department of Geology, MAU.	For identifications of names of rivers, villages, rivers and streams	Names of features like rivers/streams or places of interest were extracted from the Topographical maps
Diva GIS Rainfall and Temperature Data	50 years mean rainfall and temperature (1950 -2000)	Online (Diva GIS)	For mapping the spatial patterns of rainfall and temperature in the park	100 equal distance points over GGNP area were generated using the fishnet method in ArcGIS 10.5. The rainfall and temperature values of each of the points were extracted in Diva GIS environment. Kriging method was applied to interpolate the values.
Soil/Geology map	(i) Dominant soils of Nigeria (ii) Geology of Nigeria	i. FAO/UNESCO/ISRC (1996). ii. Nigeria Geological Survey Agency (2009)	For mapping the spatial of soil and geologic units in the park	The shape file of the park was used to extract the units in vector, the vector polygons were calculated in ArcGIS environment
Satellite Climatic Data	Rainfall data (1981-2023)	National Aeronautics & Space Administration (NASA)	For generating rainfall trend In GGNP	The mean annual rainfall from 1981-2023 were used to generate the rainfall trends in Filinga & Bodel using Microsoft Excel

Source: Compiled by the Researchers (2021)

In order to ensure the use of an authentic map of GNPP as the base map for this study, the map of GGNP that was generated by the Gashaka Primate Project (Gashaka Gumti National Park in conjunction with the Department of Anthropology, University College, London was personally obtained from the headquarters of GGNP at Serti in 2019. The choice of irregular period, that is, 1991-2003 which is thirteen years and 2003-2021; a period of nineteen years, was due to the unavailability of clean Landsat images from 2004 to 2014. Therefore, available images were considered for the choice of the study periods. The numbers of scenes with their paths and rows numbers as well as the dates of acquisition are shown in Table 2.

Table 2. Characteristics of the acquired images

Landsat Image	Year	Path	Row	Date
Landsat 5 TM	1991	186	055	20/12/1991
		186	054	19/12/1991
		185	055	17/12/1991
		185	054	17/12/1991
Landsat 5 TM	2003	186	055	10/01/2003
		186	054	20/02/2003
		185	055	19/01/2003
		185	054	19/01/2003
Landsat 8	2021	186	055	04/02/2021
		186	054	04/02/2021
		185	055	16/01/2021
		185	054	28/01/2021

Source: earthexplorer.usgs.gov

The change in the vegetation between one study period and the other was computed as:

(I) Magnitude of change: Differences between the land area of vegetation type in period A and that of period B. For instance between 1991 and 2003 or 2003 and 2021.

(ii) Percentage change: Total land area of landcover type in period B minus that of period A divided by period A and multiplied by 100. That is, A-B/A*100.

(iii) Annual rate of change: Percentage change of each landcover type divided by the number of years within the study period in each landcover type, that is, thirteen (13) years between 1991 and 2003 and nineteen (19) years between 2003 and 2021.

Vegetation depletion within the park has been attributed to climate change (Tagowa and Buba 2012, Yaduma *et al.,* 2019). Since rainfall is the most climatic element in vegetation, online monthly rainfall data (1981-2017) of Filinga (Latitude 7° 25′ and Longitude 11° 25′) in the southern part of Gashaka section and Bodel (Latitude 7° 75′ and Longitude 11° 25′) at the northern part of Gumti in Gumti section (Fig. 3) were obtained to generate the trends of rainfall in the park within the period.

The online data was obtained from power.larc.nasa.gov. The essence of the rainfall trends was to assess whether rainfall is decreasing or increasing within the park and their effects on vegetation depletion. The labelling style of the rivers as carried out in

this paper was considered the best option to clearly show the names of the numerous rivers regardless of the lengths and clumsiness which could be difficult if not impossible if the names are written on individual rivers.

Discussion of Results

In this section, a discussion of the delineated maps on the physical aspects of GGNP and the analysis of the results were carried out.

Relief

The relief of the park was classified into four terrain classes as shown in Fig. 2. They include Mountains/Hills, Highlands, Uplands and Plains. The relief classes and ranges, total land areas percentage land area and description of each of the relief classes are shown in Table 3.

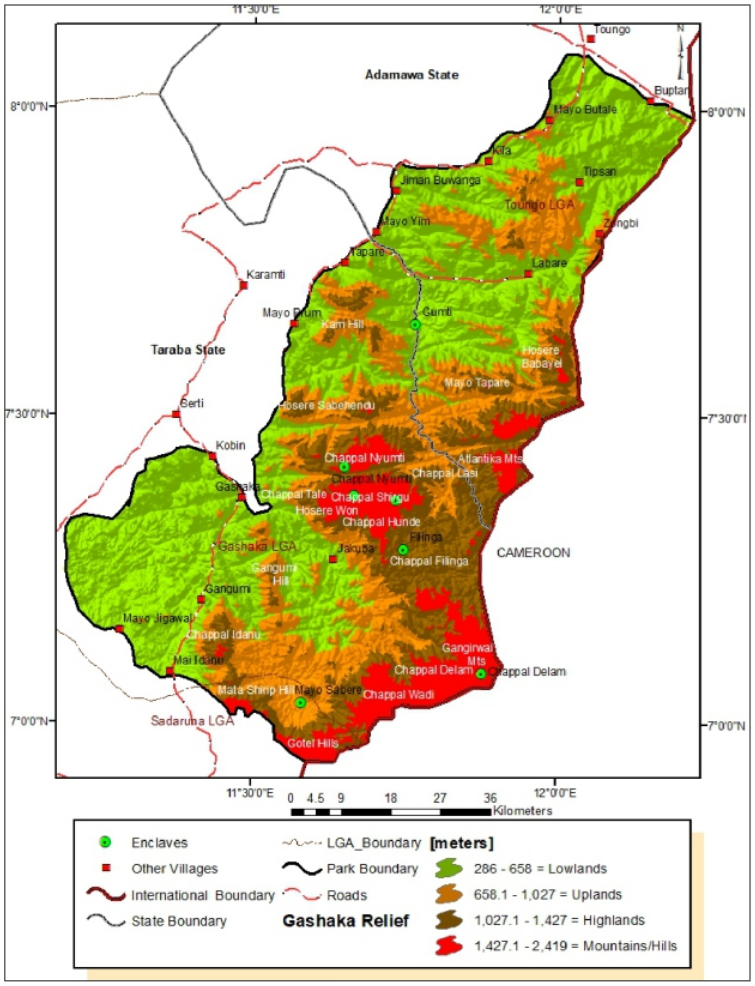

Figure 2. The Relief of GGNP

Table 3. Relief classes, ranges and land areas of GGNP

Relief Classes	Altitude (Ranges in Meters)	Area (km^2)	Area%	Description of the relief classes
Mountains/Hills	1427.1-2419	609.25	9.82	The highest point (2419m) is located in Sardauna LGA
Highlands	1027.1-1427	1100.04	17.73	The highland areas envelop the hills and mountains. They are mainly found at the border between Nigeria and Cameroon. The rugged nature of the highland areas prevents settlements as only Filinga was on the highland areas within the park.
Uplands	658.1-1027	1454.66	23.44	The Uplands are the transition zones between the plains and the highland areas. Only few settlements are found in this terrain class: Walur Gadaru, Forum Gabti in Toungo LGA of Adamawa State and Mayo Sabere in Sardauna LGA of Taraba State.
Plains	286-658	3041.45	49.01	The plains cover the largest part of the park (more than half of the land area). Most of the settlements within the park such as Gumti, Gangumi, Tipsan, among others are all located in the plains.
Total		**6205.40**	**100**	

Source: Extracted and calculated from SRTM DEM Data (2000)

The names of some mountains and hills are shown in Fig. 2, while the elevations of the peaks of the identified mountains and hills are shown in Table. 4.

Table 4. Important mountains/hills and their peaks within Gashaka-Gumti Park

	Mountains/Hills	Sector	State	LGA	Highest Peak (m)
`1	Chappal Wadi	Gashaka	Taraba	Gashaka	2419
2	Gangirwal/Chappal Dela	Gashaka	Taraba	Gashaka	2215
3	Chappal Hunde	Gashaka	Taraba	Gashaka	2028
4	Chappal Shirgu	Gashaka	Taraba	Gashaka	1819
5	Gotel Hills (Gashaka Extension)	Gashaka	Taraba	Sardauna	1832
6	Hosere Won	Gashaka	Taraba	Gashaka	1807
7	Atlantika Mountains	Gumti	Adamawa	Toungo	1740
8	Filinga	Gashaka	Taraba	Gashaka	1732
9	Chappal Nyumti	Gashaka	Taraba	Gashaka	1722
10	Mata Shirip Hill	Gashaka	Taraba	Sardauna	1634
11	Idanu	Gashaka	Taraba	Gashaka	1595
12	Mayo Tapare	Gashaka	Taraba	Gashaka	1545
13	Hosere Babayel	Gumti	Adamawa	Toungo	1517
14	Chappal Tale	Gashaka	Taraba	Gashaka	1373
15	Hosere Sabehendu	Gashaka	Taraba	Gashaka	1355
16	Gangumi	Gashaka	Taraba	Gashaka	1342
17	Chappal Lasi	Gumti	Adamawa	Toungo	1252
18	Kam Hill	Gashaka	Taraba	Gashaka	1231

Source: Extracted from SRTM DEM Data (2000)

Drainage

Fig. 3 shows the Rivers and streams as well as most of their names within Gashaka Gumti National Park. The five most important rivers within the park are Yim, Kam, Gashaka, GamGam and Ngiti (Fig. 3). Table 5 shows the features of the five rivers.

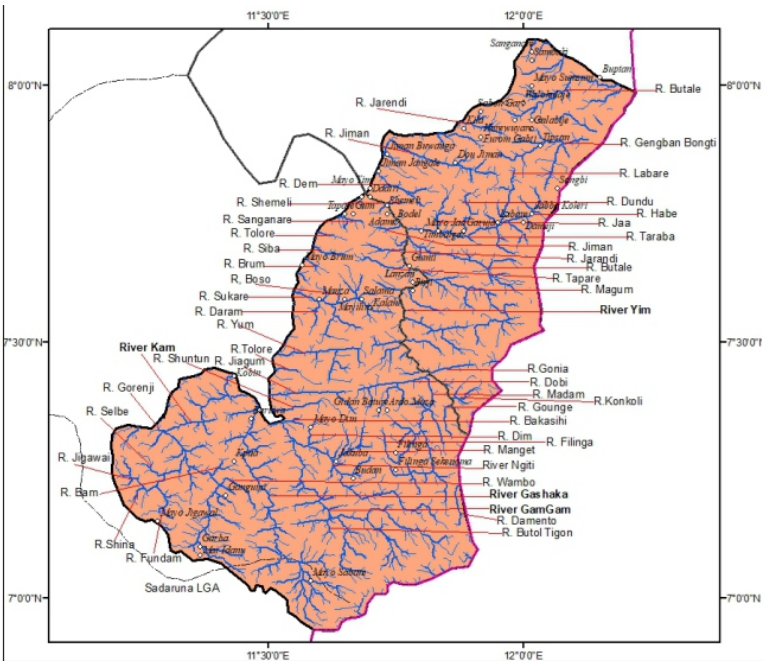

Figure 3. The Drainage of GGNP

Table 5. Sources and lengths of the major rivers in Gashaka-Gumti National Park

Rivers	Source	Basin Area (km^2)	Length (km)	Remark
Yim	Gangirwal Mountains	1862.22	82.46	River Yim forms a natural boundary between Adamawa and Taraba State. It flows through Gumti with numerous tributaries which drain the entire Toungo and some parts of Gashaka sectors.
Gamgam	Chappal Wadi	366.65	55.25	Gamgam Basin which includes R.Ngiti drains the depression (surrounded by Chappal Hunde, Won, Tale, Filinga and Gangumi Hills) at the central part of Gashaka sector
Ngiti	Chappal Wadi	508.79	55.06	River Ngiti is the largest tributary to River GamGam.
Kam	Mata Shirip Hill	770.64	93.75	River Kam is the longest river not the largest within the park, but the largest basin within Gashaka sector.
Gashaka	Chappal Wadi	572.44	61.75	It is located betwe en River Kam and the Gam -Gam Rivers and flow northwards.

Source: Extracted and calculated from SRTM DEM data (2000)

Climate

Among the various climatic elements, only rainfall and temperature were discussed in this paper. The spatial distribution of rainfall as well as that of mean temperature is shown in Figs. 4a and 4b.

Rainfall

The spatial pattern of rainfall in GGNP reduces from south to north and also higher on mountain tops. Therefore, the rainfall pattern in the park is controlled by both the latitudes and relief which has also been observed by Yaduma *et al.,* (2019) that "the high rainfall (in the park) is aided by the mountains of the area".

Mean annual rainfall ranges from 1345.9 to 1720 mm (Fig. 4a). This rainfall figure is similar to that of Dada *et al.,* (2006) with a range of 1400 to 1600 mm. April to November are the wet season periods while the dry season lasts from December to March (Kwaga *et al.,* 2019).

The extreme southern part of the park including Mayo Sabere and Chappal Delam as well as the mountain tops of Chappal Shirgu, Hunde and Filinga have the highest amount of rainfall (1626.5 – 1720 mm). The extreme northern part of the park covering about half of Gumti sector has the least amount of rainfall. Gumti, Mayo Brum, Labare, Zongbi, Tipsan, Kila among others are located within the least rainfall area (Fig. 4a).

Temperature

The spatial pattern of mean temperature within the park is almost the reverse of that of rainfall as the places with the highest rainfall such as the extreme south and mountainous areas had least temperature and vice versa (Fig. 4b). Mean temperature ranges from 26.1 to 36.7°C (Fig. 4b) which is similar to that of Akinola (2019).

However, Kwaga *et al.,* (2019) opined that night temperature is as low as 10-15°C in December, which might be high ranging from 40°-43°C between March and April. Temperature can be much cooler at higher altitudes and during the harmattan period that occurs from November to March.

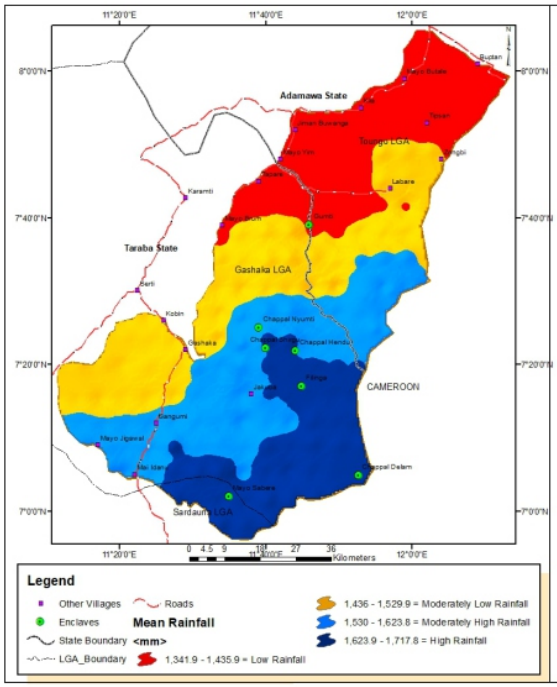

Figure 4a. Spatial pattern of mean rainfall in GGNP

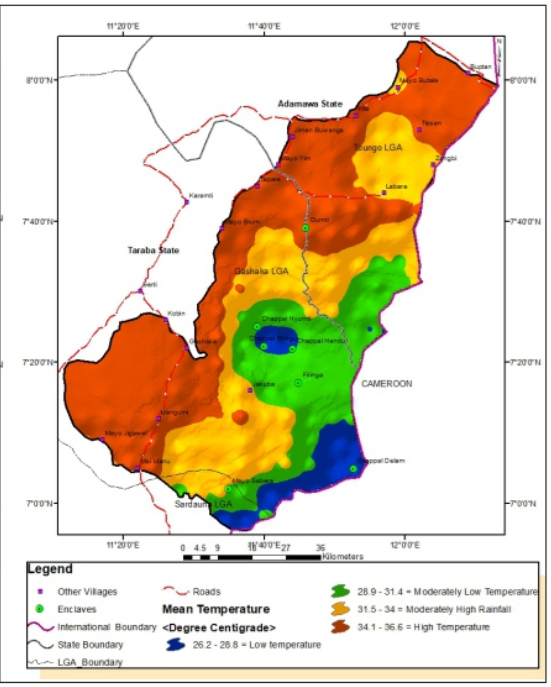

Figure 4b. Spatial pattern of mean temperature in GGNP

Geology

There are four geologic units within the park: sandstone, young basalt, porphroblastic gneiss and undifferentiated granite, migmatite granite, gneiss older granite and migmatite porphroblastic. Fig. 5a shows the spatial pattern of the four geologic units within the park, while Table 6 shows the area coverage, percentage, formation, age and description of the geologic units within GGNP.

Soils

There are five main soil units within GNP: Acrisols, Ferrasols, Fluvisols, Luvisols and Leptosols, Mixture of Leptosols and Luvisols as well as Leptosols and Ferrasols are also found in some parts of the park. The spatial distribution of soil units in the park is shown in Fig. 5b Table 7 shows the sizes of each of the soil units within the park. Leptosols cover major parts of the park (Fig. 5b and Table 7) which agrees with the findings of Mubi (2010) that Leptosols cover mainly the undulating high plains of the southwestern and central parts of the southern sector.

The northern part of Gumti sector is covered by Leptosols and Luvisols which also confirms the report of Mubi (2010) that the northern sector of the park is covered with Leptosols and Luvisols soil.

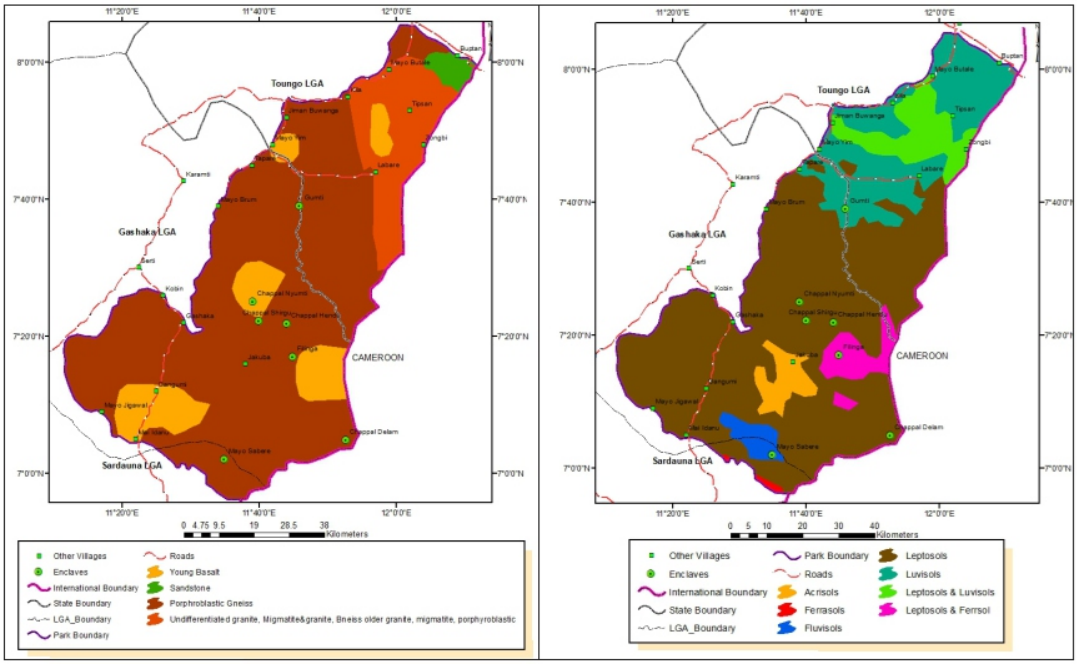

Figure 5a. Spatial pattern of the Geology in GGNP

Figure 5b. Spatial pattern of soils in GGNP

Table 6. Spatial Patterns of the Geologic units in GGNP

Geologic Units	Area (Km^2)	%	Age	Formation	Description of Geologic units	Location of Geologic Units
Sandstone	95.30	1.54	Albian Calominian	Yola – Bima - Yolde	Sandstone geologic unit is generally located in areas with little or no vegetation cover, loose soil structure and high water flow velocity. Soil erosion is a sure end result of the areas with these characteristics which could lead to removal of a large amount of sediment (Zhishui, *et al,* (2019).	Sandstone is found at the extreme northeastern part of the Toungo sector of the park. It is the soil type around Butale village.
Porphroblastic Gneiss	4588.03	73.93	Pre-Cambian to Cambian	Migmatite – Gneiss Complex	This type of rock has been described as a large mineral crystal in a metamorphic rock.	This geologic unit covers most parts of the park, especially the Gashaka sector
Young Basalt	713.63	11.50	Tertiary to Recent Volcanics	New Basalt	Basalt is dark in colour but fine - grained igneous rock mostly forms as extrusive rock. Basalt rocks are crushed for road construction (Hobart 2021).	Mainly on mountains , e.g central highlands of Chappal Shirgu, Hunde and Nyumti, and also Filinga and Idanu mountains
Undifferentiated Granite, Migmatite & Granite, Gneiss Older Granite, Migmatite, Porphyroblastic	808.44	13.03	Jurassic	Pan-African Older Granitoids	Granites are coarse or medium - grained intrusive rock that is rich in quartz and feldspar. It is formed through the cooling of magma (FAO, 2021)	Granite rocks are found in the plains of the Gumti section of the park covering Zongbi, Labare, Mayo Butale, Tipsan and Kila communities.
	6205.40	100				

Source: GGNP geologic units extracted and digitized from the Nigeria Geological Survey Agency (2009)

Table 7. Spatial Patterns of the Soil units in GGNP

Soil Units	Area (Km^2)	%	Description of soil units	Location of soil units
Acrisols	177.82	2.87	Acrisols is a clay-rich subsoil with woodland as natural vegetation but in most areas have been degraded by constant bush burning The extensive leaching of these soils have led to low levels of plant nutrients, and high erodibility.	located at the south western part of the park as well as the south central depression around Jakuba and Budan villages.
Ferrasols,	16.96	0.27	Fine reddish/orange color soil with exposures of rock outcrop and bare surfaces (Mubi & Tukur, 2012).	Extension of Waddi hills from Mambilla hills into the park
Fluvisols,	122.78	1.98	Fluvisols are found typically on level topography flooded periodically by surface waters or rising groundwater, as in river floodplains, deltas and coastal lowlands (Ikusemoran *et al.,* (2018)	The upland areas surrounding the south central depression around Mayo Sabere village
Luvisols	1205.34	19.42	Luvisols are formed on flat or gently sloping landscapes overlying an extensively leached layer that is nearly devoid of clay and iron - bearing minerals (FAO, 2021).	At the plains in the northern part of the park, that is, in Toungo LGA of Adamawa State
Leptosols,	4039.33	65.09	Leptosols are soils with a very shallow profile depth, that is, little influence of soil forming processes. They often contain large amounts of gravel but remain under natural vegetation, susceptible to erosion, desiccation, or water logging, depending on climate and topography. The high nutrient content and good drainage of these soils make them suitable for a wide range of agriculture (FAO, 2021).	Leptosols covered the largest part of the park especially the Taraba section of the park.
Leptosols & Ferrasols	222.58	3.59		It is found at the Filinga highland region at the south eastern part of the park.
Leptosols & Luvisols	420.59	6.78	Alluvium along riparian and fine/coarse sand on the plains (Mubi & Tukur, 2012).	It is the soil of the upland area at the extreme northern part of the park.

Source: GGNP soil units extracted and digitized from Dominant Soils of Nigeria, (FAO/UNESCO/ISRC, 1996).

Vegetation

The pattern of vegetation cover in GGNP from 1991 when the park was established to 2021 (the year of this study) is shown in Fig. 6.

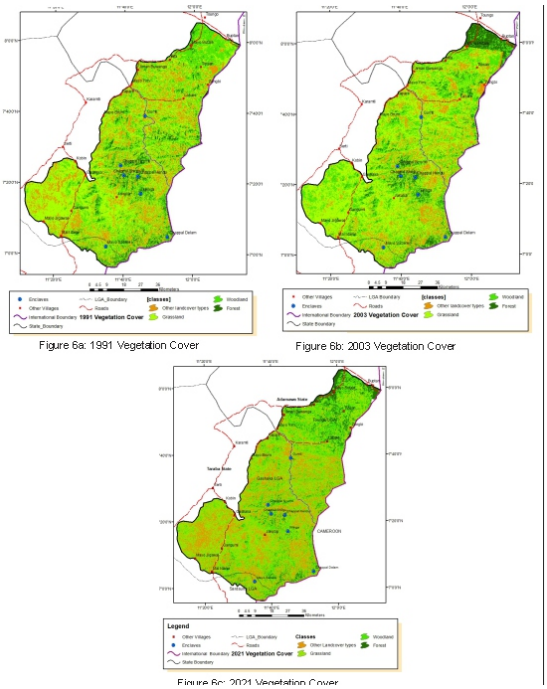

Figure 6a,b & c: Vegetation cover from 1991 to 2021.

The vegetation of GGNP has been described as diverting habitat types with grassland (lowland and montane), woodlands and montane forests. The changes in the vegetation within the park from 1991 to 2021 are shown in Fig. 6. The forests were dominated by mostly tall trees with large foliage which are too thick to allow undergrowth of grasses (Tagowa & Buba 2012).

Chapman and Chapman (2010) in Kwaga *et al.,(2019)* identified lowland rainforest, montane rainforest, montane grassland and savannah woodland as the four main vegetation types within the park. According to Andrew (1999), each of these vegetation types provides a habitat for a community of plants and animals. For instance, Chimpanzees, Giant Forest Hog, Leopard, Yellow-Backed Duiker, Golden Cat Among others are found in the forest, while the woodlands are home to Buffalo, Lion, Elephant, Wild Dog, Antelopes, Waterbuck, Roan Antelope, Kob, and Hartebeest.

The Montane forest harbours black and white colobus Monkeys, Baboons, Warthog, Oribi, and Klipspringer. The Rivers are homes to hippos, crocodiles, otters and a wide variety of fishes.

Table 8: Magnitude, percentage and annual rate of changes of forest (1991 to 2021).

Landuse & Landcover	Vegetation Changes from 1991-2003					Vegetation Changes from 2003-2021				
	1991	2003	Mag. of Change	% Change	Annual Rate of Change	2003	2021	Mag. of Change	% Change	Annual Rate of Change
Forest	380.74	472.17	+91.43	24.01	1.85	472.17	401.29	-70.88	-15.01	-0.79
Woodland	1696.09	1765.27	+69.18	4.08	0.31	1765.27	1727.13	-38.14	-2.16	-0.11
Grassland	2816.38	2964.85	+148.47	5.27	0.41	2964.85	2732.75	-232.10	-7.83	-0.41
Non-Vegetation	1312.19	1103.10	-209.09	-15.93	-1.22	1103.10	1344.23	+241.13	21.86	1.15
Total	**6205.40**	**6205.40**				**6205.40**	**6205.40**			

Source: Extracted from the NDVI images of the Park in 1991, 2003 and 2021.

Table 8 revealed that between 1991when the park was established and 2003; thirteen years after the park's establishment, all the vegetation types (forest, woodland and grassland) were increasing in land area while non-vegetated areas (built-up, bare surface, bare rocks among others) decreased.

Within this period, forest recorded the highest percentage change per annum. The increase in the vegetation within this period has also been reported by Yaduma *et al.,* (2019) that between 1991 and 2001, derived savanna, montane forest and gallery forest recorded 5.17%, 14.49% and 9.47% respectively.

Furthermore, Chapman *et al.,* (2004) in their findings stated that "overall forest area has not changed greatly (negatively) since the 1970s, and no evidence to suggest that any tree species has become extinct". All these findings are clear evidence that the vegetation within the park was stable within this study period (1991-2003) which could be attributed to the proactive activities of the GGNP in the monitoring and protection of the park at the early stage of its establishment.

Between 2003 and 2021, the reverse of the condition of the vegetation cover within the park took place. All three vegetation types decreased in land area coverage, while the non-vegetal areas increased. The high rate of the percentage change as well as the annual rate of change of the no-vegetal areas as revealed in this section becomes more worrisome especially when the quality of the future of the Park is taken into consideration.

Some factors that lead to the degradation of vegetation within the park in recent times have been highlighted by many authors (Chapman *et al.,* 2004, Nzeda and Nformi 2012, Akinsoji 2016, Yaduma *et al.,* 2019). Among the factors are: initially many of the steep slopes within the park were inaccessible, but recently, some of the slopes have been denuded by the timber industry,

creating accessibility to the park for logging and other anthropogenic activities, especially farming.

Secondly, large populations of immigrants with "little means of survival other than targeting the natural resources" have moved into the park. Furthermore, many illegal settlements have sprung up within the park in recent years which also depend on the park resources for survival.

For instance, Chapman *et al.,* 2004 reported that "in January 2002 there was an influx of more Fulani and their cattle following land rights disputes between the Fulani and Mambilla people living on Mambilla Plateau" which led to an increase in population and more pressure on the environment. The vegetation of the park has also been frequently subjected to burning and overgrazing, burning because of the inability to protect the large park and most importantly because of no clear-cut identifiable boundaries of the park.

Lastly, natural factors like climatic influences and land degradation through soil erosion, that is cattle-induced soil erosion and compaction, especially pronounced in gullies and along cattle tracks.

Climatic factors have also been said to be one of the contributing factors to vegetation depletion in GGNP (Tagowa & Buba 2012, Yaduma *et al.,* 2019). The rainfall trends as shown in Figs. 7a and 7b depicts the decreasing rainfall amount at both sections (Gashaka and Gumti) within the thirty-six years of study (1981-2017). At Filinga, in the southern section of the park with high rainfall (Fig. 4a) the rainfall trend shows a decreasing trend with -12.154.

Bodel in the northern Gumti section with low rainfall (Fig. 4a) also recorded a decreasing trend of -13.084. This general decreasing trend in rainfall within the park could affect plant growth and regeneration which could contribute to the vegetation degradation within the park.

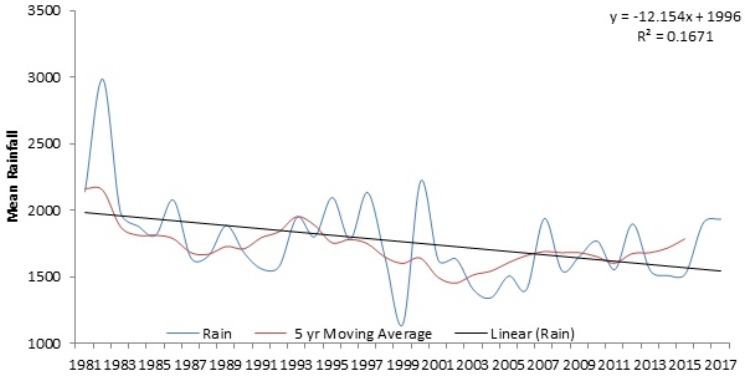

Figure 7a. Rainfall trend of Filinga, southern part of GGNP

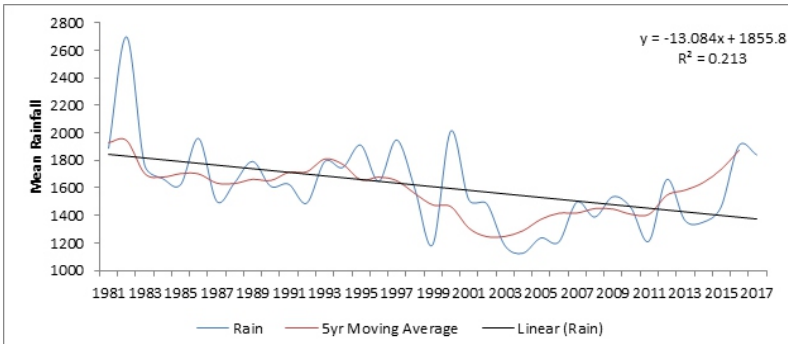

Figure 7b. Rainfall trend of Bodel, northern part of GGNP

Conclusion

Geospatial techniques have been successfully applied to the assessment of the physical aspect of GGNP taking into consideration the relief, drainage, geology, soil, climatic elements and vegetation. It was revealed that geospatial techniques were highly effective in the derivation, mapping and analysis of the spatial patterns of the physical elements within the park.

Some activities that could be very difficult or impossible to achieve like mapping of the rivers and streams, identifications of peak heights of mountains and hills, spatial patterns of climatic elements and vegetation change detection, if manual methods are used are effectively achieved in this paper using geospatial techniques.

The vegetation within the GGNP was well conserved within the first two decades of the establishment after which degradation has taken place for about two decades now. The causes of the vegetation degradation have been attributed to; population increase among the enclaves within the park, influx of more migrants into the park, anthropogenic activities such as farming and grazing, and natural factors especially climatic effects and soil erosion.

The management of the park has recently found it difficult to protect and conserve the park due to: the inability to control the legal and illegal inhabitants of the park, leading to constant attack on the rangers and the difficulty in the identification of the actual boundary of the park. A Geospatial technique for assessment of socio-economic activities within the park is suggested for further studies.

Recommendations

Based on the findings in this study, the following recommendations were proffered.

(I) The management of Gashaka Gumti National Park should be more

proactive in the preservation of the park to minimize the rate of vegetation depletion within the park.

(ii) Awareness of the acquisition and use of online climatic data should be created to fill the gap between unavailable and the unreliability of existing ones in most places, especially in developing countries like Nigeria.

(iii) Regulations of influx of migrants into the parks as well as the springing of new settlements within the park by the park authority to reduce the pressure on the resources in the park.

(iv) Enactment of new stringent measures and implementation of such measures against the accessibility and unlawful acquisition or utilization of the park's resources.

(v) Proper demarcation of the park's boundary that will be conspicuous with durable materials such as concretes and irons.

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