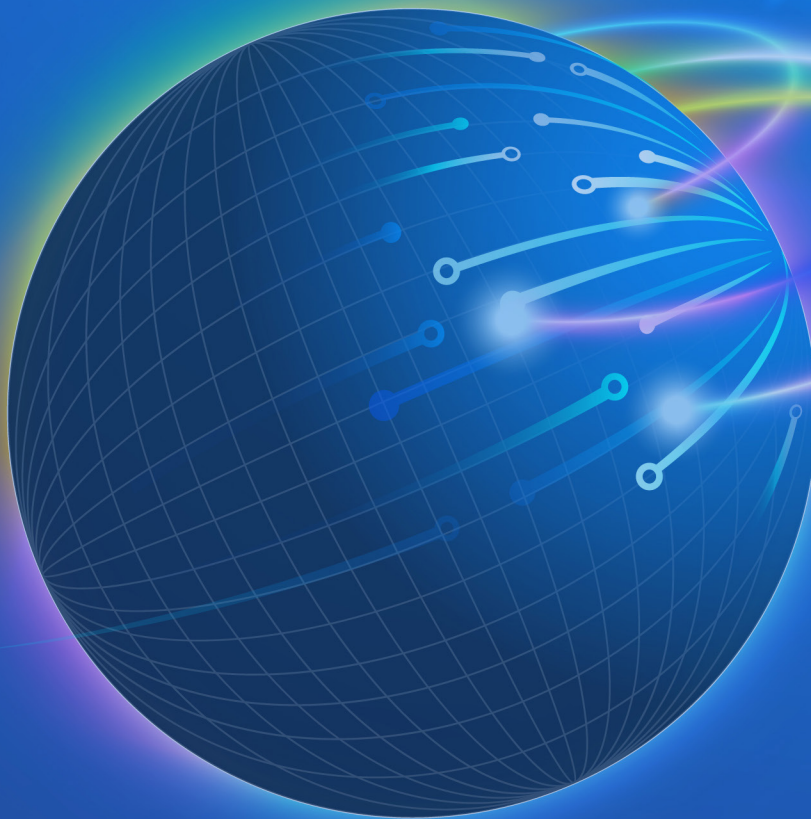




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An in-depth analysis of the Terrorists Activities on Land Use and Land Cover (LULC) Change of Sambisa Forest of Nigeria

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ABSTRACT

This study analyzed terrorists activities on land use and land cover change of Sambisa Forest of Nigeria. Land use and land cover change was employed to determine the rate of change in Sambisa Forest as a result of Boko Haram activities. GIS and remote sensing was employed in the course of this study. Secondary types and sources of data were used and they include data on the vegetation cover of Sambisa Forest before and during the emergence of Boko Haram and data on the land use/land cover. The data for the vegetation analysis of this study were obtained using satellite imageries of the study area from 1994, 1999, 2004, 2009, 2014 and 2019. The Landsat images of each year was independently classified with supervised classification technique. Each analysis carried out was subjected to different formular for deducing each of the variables. Maximum likelihood classifier algorithm was applied to classify the LULC types in QGIS 3.8.2 software. The result from satellite imagery analysis for land use land cover of Sambisa forest for the year 1994 revealed that marshland constitutes 13.4% amounting to 63.4km² on the satellite image. Vegetation measurement on the satellite image covers an area of 222.38km² representing 46.9%. Bare surface covers an area of 84.01km² representing 17.7% of the imagery. Built-up accounts for 21.2% covering an area of 100.6km², such settlements include; Masba, Dalwa, Dalori, Bama, Konduga, Tateri, Kuka Kowa, among others. Water (lakes, ponds, streams, etc.) amounted to 0.76% covering an area of 3.61km². The year 2009 witnessed the beginning of the vicious cycle of violence starting from Borno State, around the Sambisa forest northern corridor of Konduga, Bama Dalori and ultimately Maiduguri. From the analysis, the result experienced a fluctuating dip and rise with water bodies accounting for 0.66% of the total landcover with an area coverage of 3.12km² comparing this result with that of 2004 which was 0.5% (2.17km²), this simply means that there was a slight increase by 0.16% which accounted for the rise. Bare surface cover in the area was 20.6% representing 97.6km² precisely areas around Konduga. Marshland in the area accounted for 19.1% representing 90.7km². There was an increase in the vegetation of the study from 104.13 the previous year to 201.5 in 2009. Land use land cover analysis for 2019 yielded another interesting result leaving little to doubt from the previous years. From the analysis, Water occupied 0.39% representing 1.86km², vegetation within the area had 11.61% which is a drop from the 28.5% in the previous year. Marshland covered 32.7%, translating to 155km²; Bare surface accounted for 32.1%, covering an area of 152.10km², while Built-up had a drastic increase of 23.2%, representing 110.3km² of the total area. This is a clear indication of Boko Haram activities and Military counter insurgency on Sambisa forest. From the findings, it is recommended that the military should stop Boko Haram activities and force them out of the forest and the area will regenerate and the soil remediated.

INTRODUCTION

Using a land change approach, land use represents the interaction between humans and their environment and is used as a conceptual platform upon which to determine both the causes and consequence of land use change and to investigate the influence and potential success of land management decisions. Analyzing land use change requires a time series of land use maps and remote sensing classification is the primary tool used to acquire such data. There are many advantages of using remote sensing classification tools to map land use such as, it allows efficient access to otherwise inaccessible or remote locations and it provides time series information at a scale meaningful for regional decision making. Szabo *et al.* (2016) opined that remote sensing techniques provide a great possibility to analyze the environmental processes

in local or global scale. Satellite images provide a wide range of possibilities of monitoring the environment in a fast way, especially on areas which are unavailable for a field survey due to the topography, dense vegetation or other local factors.

Terrorist activity is a particularly dangerous form of criminal activity that poses a threat to all mankind, along with environmental disasters and wars. Global terrorism is a rapidly growing threat to world security and increases the risk of bioterrorism (Green *et al.*, 2019). There are environmental implications of wars, terrorists' activities and the use of bombs on the environment. Indirect impacts are many and varied and are often long lasting than the direct impacts. They include the construction of various camps although ephemeral, camps cause impairment of soil and vegetation through trampling by

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personnel and vehicles and the disposal of waste materials (Ukah *et al.*, 2021). War also inevitably entails destruction, resulting in widespread toxic substances, dead wildlife, and an atmosphere choked with fumes. McCarthy (2022) noted that there three (3) key facts about how war impacts the climate crisis and the environment. Firstly, militaries consume enormous amounts of fossil fuels, which contributes directly to global warming. Secondly, bombings and other methods of modern warfare directly harm wildlife and biodiversity. And lastly, pollution of the environment.

LULC was employed to determine the rate change in Sambisa forest as a result of Boko Haram activities. Sambisa forest is one of the ungoverned spaces in Nigeria. Igboin (2021) opined that the concept of ungoverned spaces is sly and controversial. This is because many definitions proffered to encapsulate its contents have either failed woefully or succeeded only partially. Taylor (2016) noted that ungoverned space is a place where the state or central government is unable or unwilling to extend control, effectively govern, or influence the local population, and where a provincial, local, tribal or autonomous government does not fully or effectively govern, due to inadequate governance capacity, or restrictive norms of behaviour. Ungoverned area should be assumed to include under-governed, ill-governed, contested, and exploitable areas. Contested spaces are safe havens for non-state actors that have come to occupy them. Safe haven can be regarded as a space for operational activity, spaces where non-state actors can galvanize and mobilise forces for expansionist purposes. From there, they are able to establish themselves, consolidate, plan, organise, fundraise, recruit, train and operate. Boko Haram is contesting space with the government of Nigeria with the aim to institute its own kind of rule and form of Islam (a sharia governed space) as a forestate to what it probably plans to extend to other parts of the country. Its reference to a caliphate expressly underscores that it wants an exclusive rule based on sharia and Islamic Law. Since 2009, Boko Haram has not only continued to contest space with the Nigerian government but has also taken over some spaces where it has raised its flag and declared independence. Unfortunately, Sambisa forest happens to be one of those places occupied by Boko Haram due to its rugged terrain, room to hide or receive supplies, and low population density with Maiduguri close enough to allow necessary interaction with the outside world. It was based on this premise that this study tends to analyze the impact of Boko Haram activities on the LULC of Sambisa forest.

LITERATURE REVIEW

Norris and Grol-Prokopczyk (2018) argued that the definition of terrorism is a highly-contested and politicized process, and the term terrorism is applied in highly inconsistent ways. For example, left-wing activists contest their labelling as terrorists for minor crimes, while right-wing extremists who commit murder to advance

ideology are rarely labelled as terrorists (Norris, 2016, 2017). Terrorism is the illicit way of hostility carried out to accumulate ransom, bring down a government, get the release of hostages, ensure total breakdown of economic activities or penalize unbelievers of religion and lots more (Ball *et al.*, 2013). Terrorism is ultimately a form of psychological warfare that relies on fear to achieve its ends (Lutz & Lutz, 2017). This is evident in the situation faced by communities living within and around Sambisa forest of Nigeria. Terrorism restricts the environment for the people to enjoy their fundamental rights and freedoms. The environmental destruction that can be legitimately labeled terrorism is when the act or threat breaches national and or international laws governing the disruption of the environment during peace time or war time. It could also be when the act or threat exhibits the fundamental characteristics of terrorism (i.e. the act or threat of violence has specific objectives and the violence is aimed at a symbolic target).

There is a significant relationship between terrorism and forest areas. Umar and Naibbi (2015) stated that forests, grasslands, deserts and swamps provide different logistic and vulnerability potentials to states. For instance, while bare ground favours offensive, forests favour defence. This is the strategy that the Vietnamese understood and made the tactical use of their rainforest during the USA-Vietnam war in the 1960s – 70s. Vietnamese used the techniques of strike and run in to the bush till they frustrated the most powerful-heavily armed USA soldiers despite the defoliation of about 16,200km² of the Vietnam forest land by the USA armies. Studies on the impacts of defoliants estimated that ten percent of trees sprayed were not only defoliated but also killed by a single application of Agent Orange, with a particularly strong effect on sensitive and ecologically important mangrove forests along the Mekong Delta (Aju & Aju, 2018). On the same hand, the Indonesian military repeatedly bombed and napalmed forested areas in East Timor where independence guerrillas took shelter, with devastating impacts to the environment. In Darfur, Sudan, trees were deliberately destroyed by militia in an attempt to sever community ties and reduce possibilities for resettlement in the area. On the other hand, barren land of the Azawad region in Mali provided an easy terrain for the French and African Union forces to locate and destroy the military vehicles of the Tuareg rebels that cut-out Northern Mali in 2013.

Varga *et al.* (2015) noted that satellite images provide a wide range of possibilities of monitoring the environment in a fast way, especially on areas which are unavailable for a field survey due to the topography, dense vegetation or other local factors. Xue and Su (2017) stated that vegetation indices (Vis) obtained from remote sensing-based canopies are quite simple and effective algorithms for quantitative and qualitative evaluations of vegetation cover, vigour, and growth dynamics, among other applications. Vegetation indices (Vis) are now indispensable tools in land cover classification, climate

and land use change detection, drought monitoring and habitat loss, etc. Adelaja and George (2019) opined that an increase in the intensity of terrorist attacks results in an increase in the amount of land owned due to the abandonment of farms by neighbours and family members, increases the percentage of land left fallow, increases the average size of plots farmed, increases the average distance between plots farmed and the homestead, discourages mono cropping and encourages mixed. Farmers' expectations about the values of their lands also decrease with exposure to terrorism.

MATERIALS AND METHODS

The study area

The Sambisa Forest is one of the several forests that constitute the governed space in Nigeria geography (Ukah et al., 2025). Yet it remained a subject of no interest to both the leadership and the citizenry until the media shone a searchlight on the Boko Haram insurgency in the country. The Sambisa forest is located at the north-eastern tip of the west Sudanian Savanna and the southern boundary of the Sahel Acacia Savanna about 60 km south east of Maiduguri the capital of the state of Borno. It covers an area of 474km² (Figure 1). It is administered by the Local government areas of Nigeria of Askira/Uba in the south, by Damboa in the southwest, and by Konduga

and Jere in the west. The name of the forest comes from the village of Sambisa which is on the border with Gwoza in the East.

The Gwoza hills in the East have peaks of 1,300 meters above sea level and form part of the Mandara Mountains range along the Cameroon-Nigeria border. Seasonal streams drain the forest into the Yedseram and the Ngadda Rivers. Some of the Sambisa tributaries are linked to Balmo forest stretching from Bauchi State through to Jigawa State. The forest consists of a mixture of open woodland and sections of very dense vegetation of short trees about two metres high and thorny bushes, with a height of 0.5 - 1 metre which are difficult to penetrate. Major trees and bushes in the forest include acacia, date palm (dabiinuwa), terminalia, tallow, red bushwillow (baa ruwaanaa), rubber, tamarind (busai), wild black plum (dinyaa), jackalberry, monkey bread, birch, mesquite, baobab (bambu), shea tree (ciri), rubber vine (ciwoo), whitehorn (damaagiram) (Birdlife International, 2015). The climate is hot, dry and wet with minimum temperatures of about 21.5°C between December and February, a maximum of about 48°C in May with average temperatures of about 28 – 29°C. The dry season is from November to May and the wet season is between May and September/October with annual rainfall of about 190mm.

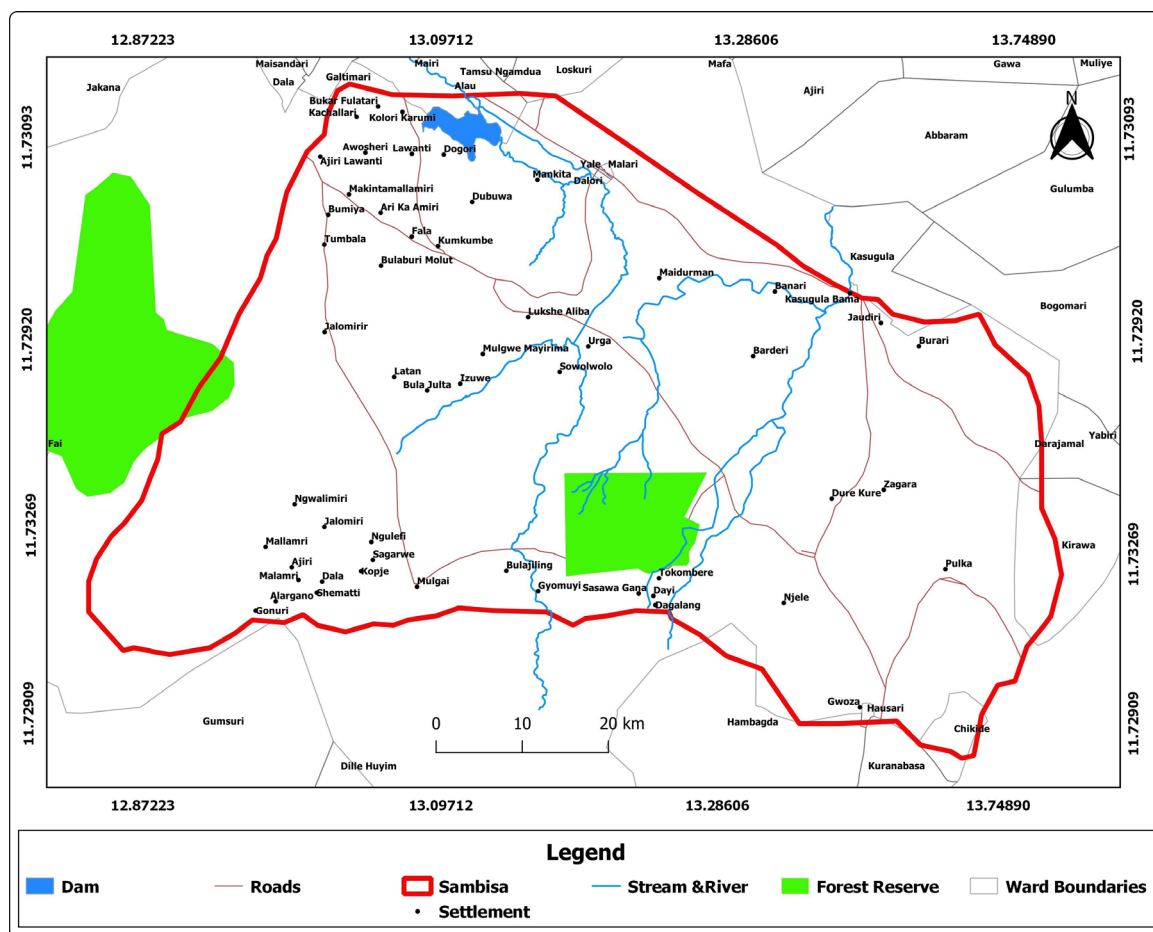


Figure 1: Map of Sambisa Forest
Source: Author, 2020

MATERIALS AND METHODS

This section comprised of the methods and techniques that were adopted to generate data for the study as well as the methods used to analyse the data. Remote sensing was employed in the course of this study. Secondary types and sources of data were used in this study and they include data on the vegetation cover of Sambisa forest before and during the emergence of Boko Haram and data on the land use/land cover. The data for the vegetation analysis of this study were obtained using satellite imageries of the study area from 1994, 1999, 2004, 2009, 2014 and 2019. They were used to assess the rate of change in Land Use Land Cover (LULC). GIS was used in the course of this analyses with Landsat 8 OLI imagery and Landsat 7 ETM. Multi-temporal Landsat satellite images of the study area were freely downloaded from the USGS' Earth Explorer portal. The imageries were downloaded in the months of June, July and August as they will give a better view or understanding of the vegetation (dense vegetation period). Except for the thermal infrared, all the visible and infrared spectral bands were included in the image classification. Pre-processing of the images such as atmospheric and geometric corrections, suitable band selection, sub-setting, layer stacking and image enhancements were applied before performing the

classification of the remote sensing data.

To obtain surface reflectance data, Landsat images were atmospherically corrected using SCP Plugin software tools. Spatial enhancement technique was also applied in order to improve the image quality. The Landsat images of each year was independently classified with supervised classification technique. Each analysis carried out was subjected to different formular for deducing each of the variables. For land use land cover, maximum likelihood classifier algorithm was applied to classify the LULC types in QGIS 3.8.2 software. More so, accuracy assessment was also carried out to evaluate the dependability of extracted information from the classification. The accuracy of the classification results was tested using the data for validation. Lastly, the post classification comparison was done using separately classified Landsat images and then a comparison was made for the LULC maps. The bands used were band 1, 2, 3, 4, 5 and 7 for Landsat 4 - 5TM, and Landsat 7ETM+. While for Landsat 8OLI, the bands used were band 2, 3, 4, 5, 6 and 7. Five major image classifications were employed which include; Water, Vegetation, Bare surface, Marshland and Built-up areas. Table 1 shows the data type and sources while the materials and methods for the analyses is shown on Table 2.

Table 1: Data used for the Analyses

Data Type	Source	Year of Acquisition	Month	Spatial Resolution
Landsat 4 and 5 TM	Earth Explorer	1994	August	30m
Landsat 4 and 5 TM	Earth Explorer	1999	August	30m
Landsat 7 ETM+	Earth Explorer	2004	July	30m
Landsat 7 ETM+	USGS Glovis	2009	June	30m
Landsat 8 OLI/TIR	USGS Glovis	2014	August	30m
Landsat 8 OLI/TIR	USGS Glovis	2019	August	30m
Shuttle Radar Topographic Mission (SRTM)	USGS Glovis	2019		30m

Table 2: Materials used for the Analyses

Material	Type	Uses
Hardware	Computer PC, GPS, etc.	Data processing, Classification and Analysis
Software	QGIS 3.8.0 LTR	Map Presentation, Land Cover Change Modeller LCCM to determine change detection between 1994, 1999, 2004, 2009, 2014 and 2019 and Classification Report to determine Area cover in Square Kilometres and Percentage.
	UTM Coordinate Converter	For coordinate conversion from Universe Transverse Mercator to Geographic coordinate for area AOI clipping.

Change Detection Analysis

Starting from previously described dataset of Landsat classified imageries, the process of digital change detection developed has allowed for the determination and description of changes in landcover between five fundamental intervals of 1994 – 1999, 1999 – 2004, 2004 – 2009, 2009 – 2014 and 2014 – 2019. There are many methods of change detection available and each has variations depending on the imagery

type, final purpose for the change image, and the type of change to be detected. In this case, the methodology followed has been the post-classification comparison. Such approach allows for the determination of the difference between independently classified images from each of the dates in question and it is the only method in which 'from' and 'to' classes can be calculated for each changed pixel. Hence, comparing each classified map with the successive,

it has been possible to determine the changes in land use land cover at different years from 1994 to 2019. QGIS 3.8 Post classification algorithm has been used to analyse and integrate LULC maps and extract the GIS layers describing changes and dynamics of land cover. Subsequently, in order to perform the accuracy assessment on the change detection, procedures and approach proposed by

Congnaltion and Macleod (2009) have been followed in which the error matrix normally used for the single date classification is purposively modified.

RESULTS AND DISCUSSION

The summary of the LULC from the year 1994 to 2019 is shown on Table 3.

Table 3: LULC distribution from the year 1994–2019

LULC category	1994 (km ²)	1999 (km ²)	2004 (km ²)	2009 (km ²)	2014 (km ²)	2019 (km ²)
Water	3.61	2.5	2.17	3.12	1.8	1.86
Vegetation	222.38	103.6	104.13	201.5	135.0	55.04
Bare surface	84.01	93.9	93.7	97.6	169.0	152.10
Marshland	63.4	181.0	178.3	90.7	93.62	155.0
Built-up	100.6	93.0	95.7	81.08	74.58	110.0
Total	474	474	474	474	474	474

Land use land cover of Sambisa forest for the year 1994 As at the year 1994, Water bodies including lakes, pond, streams and other smaller natural impoundment of water occupies an area of about 3.61km² representing 0.76% of the total landmass of Sambisa forest and vegetation covers

46.9% amounting to 222.38km². Bare surface covers an area of 84.01km² representing 17.72%, marshland covers an area of 63.4km² representing 13.38%. While Built-up area constitutes 21.22% representing 100.6km² as could be seen on Figure 2.

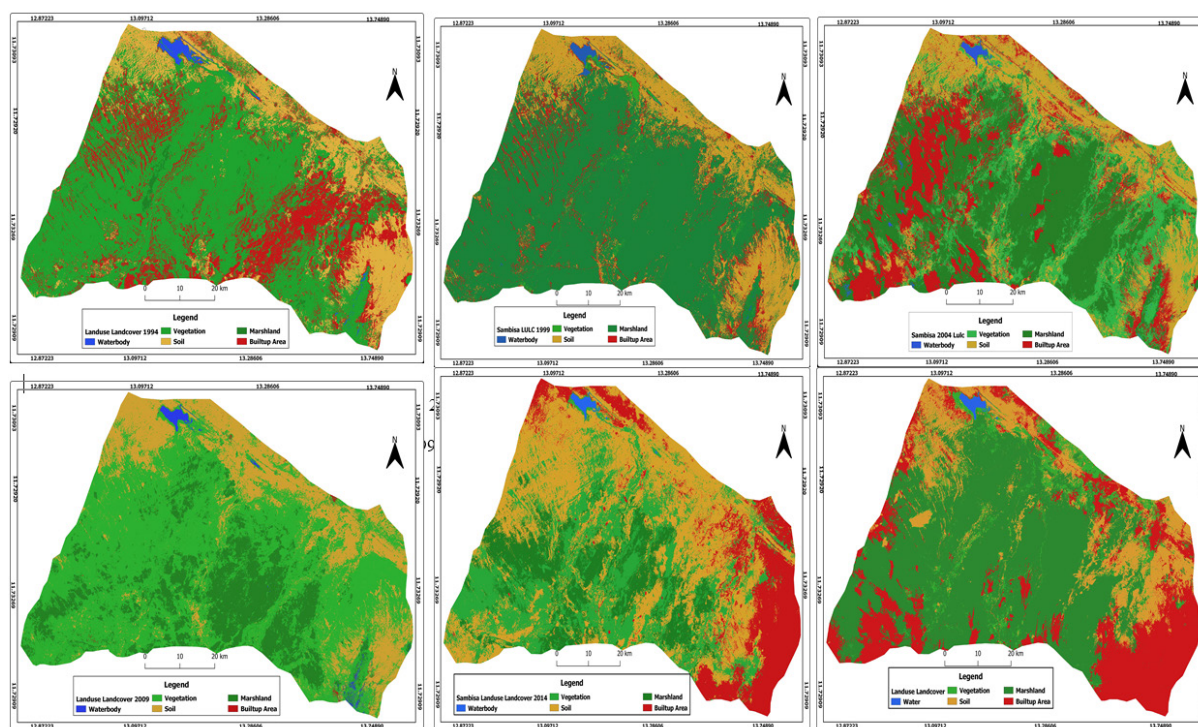


Figure 2: Land use land cover of the study area from the 1994 – 2019.

Land use land cover of Sambisa forest for the year 1999

The Landsat classification of Sambisa forest for the year 1999 is shown in Figure 2. The result from the analysis of the imagery for the year 1999 reveals that water constituted 0.53% amounting to 2.5km², vegetation had an area coverage of 103.6km² representing 21.9% of the satellite imagery, bare surface occupied an area of 93.9km²

representing 19.8%, marshland had an area coverage of 181km representing 38.2% while built-up constituted 19.6% amounting to 93.0km².

Land use and land cover of Sambisa forest for the year 2004

Figure 2 revealed the result from satellite imagery analysis for the land use and land cover of Sambisa forest for

the year 2004. From the analysis, water accounted for 0.46% covering 2.17km², vegetation covered an area of 104.13km² representing 21.97%, bare surface covered an area of 93.7km² representing 19.77%, marshland accounted for 37.6% covering an area of 178.3km² while built-up area accounted for 20.2% covering an area of 95.7km.

Land use land cover of Sambisa forest for the year 2009

The result from satellite imagery analysis of the land use land cover of Sambisa forest for the year 2009 is shown in Figure 2. From the analysis, Water constituted 0.66% representing 3.12km², Vegetation constituted 42.5% representing 201.5km², Bare surface recorded 20.6% amounting to 97.6km², Marshland constituted 19.1% representing 90.7km² while Built-up constituted 17.1% representing 81.08km² on the ground.

Land use and land cover of Sambisa forest for the year 2014

Figure 2 show that satellite imagery analysis for land use land cover of Sambisa forest for the year 2014. From the analysis, Water occupied an area of 1.8km² constituting 0.38% of the total area, Vegetation accounted for 28.5% representing 135km², Bare surface accounted for 35.7% representing 169km², Marshland constituted 19.8% amounting 93.62km² while Built-up recorded an area coverage of 74.58km representing 15.7% of the total area of Sambisa forest.

Land use and land cover of Sambisa forest for the year 2019

Figure 2 present the satellite imagery analysis for land use land cover of Sambisa forest for the year 2019. From Table 5.14, Water constituted 0.39% amounting to 1.86km² of the study area, Vegetation occupied an area of 55.04km² accounting for 11.6%, Bare surface accounted for 32.1% and area coverage of 152.10km² of the total study area. Marshland accounted for 32.7% representing 155km² while Built-up constituted 23.2% representing 110.3km².

Discussion of findings from LULC of Sambisa forest

The environmental implications of Boko Haram activities on land use land cover were discussed in this section. The removal of vegetation coupled with soil excavation either by anthropogenic activities or by natural ways increases the potential for soil erosion, and reduces water.

Land use land cover of 1994

The result from satellite imagery analysis for land use land cover of Sambisa forest for the year 1994 revealed that marshland constitutes 13.4% amounting to 63.4km² on the satellite image. Marshlands are areas with soil mixed with water and vegetation, often represented as slight dark on the satellite image. Vegetation measurement on the satellite image covers an area of 222.38km² representing

46.9%. It is noteworthy that the vegetation within this zone is a mixture of Sudan and Sahel savannah which are characterized by short shrub and trees. One of the major factors measured in the course of this study was the soil of the study area which could serve the potential of agricultural purpose especially as it relates to crop growth and other anthropogenic support. Bare surface covers an area of 84.01km² representing 17.7% of the imagery. This shows that agricultural activities especially farming takes place in the area. The reason for this may not be farfetched owing to the presence of water bodies around the forest and the presence of marshland which supports certain rare agricultural products that are grown in the Sahelian region. On this note, agricultural activities should thrive in this area for a good reason. It also accounts for why certain agrarian settlements might be found in and around the forest area and this brings about built-up areas as one of the major classifications. Built-up in this area could be villages and small farm settlements located in and out of the forest. Built-up accounts for 21.2% covering an area of 100.6km², such settlements include; Masba, Dalwa, Dalori, Bama, Konduga, Tateri, Kuka Kowa, among others. Water (lakes, ponds, streams, etc.) amounted to 0.76% covering an area of 3.61km². One of the major reasons for the stream availability in the area was the presence of vegetal cover which prevented the loss of water bodies via evapotranspiration in the forest. On the northern axis of the map is the state capital Maiduguri from where some of these streams take their rise from and flow onward into the forested region. During this period, Boko Haram insurgency has not emerged.

Land use land cover of 1999

The 1999 imagery analysis revealed another slight deviation with a strong follow-up from the previous years. Most of the deviations came from systemic reduction in the water bodies compared to imagery analysis of the year 1994. Compared to 1994 imagery analysis, water bodies ranging from lake, stream and natural ponds fell from 0.76% to 0.53% resulting to the reduction in area coverage from 3.61km² to 2.5km². This significant reduction in water bodies can be attributed to first, the increase in the rate of desertification or the encroachment of the Sahara Desert into the state via the north east corridor. This assertion can be deduced from the alarming increase in the bare surface analysis which can be seen as at 1994, it was 17.7% covering an area of 84.01km² but as at 1999, it had increased to 19.8% covering an area of 93.9km². Although, this increase can also be tied to the fact that there was significant increase in anthropogenic activities ranging from farming, hunting and significant decrease in waterbodies in the area. Mzuza *et al.* (2019) in their work found out that rapid population growth and increase in gross domestic product (GDP) are identified as the major drivers of deforestation and forest degradation due to clearing of vast fields for agriculture, land expansion for urban settlement, and cutting down

of trees for fuelwood. Hurt *et al.*, (2006) also noted that human activities have altered 42% - 68% of the global land surface by transforming natural vegetation into crops, pastures and woods for harvesting from the years 1700 to 2000. Added to this, the agricultural practices which were supported five years ago (1994) could be seriously impeded. It is worthy to note that at this time, Boko Haram insurgency was not in existence neither was it active during this period but there were issues bothering on the encroachment of the Sahara Desert in which one of the United Nation Convention to Combat Desertification initiative was the planting of the gum Arabic trees to slow and stop the encroachment of desert. From the analysis also, marshland increased from 13.4% to 38.2% leading to an increase from 13.4km² to 181km². One of the implications of this result is the increment in the agro-viability of these lands as marshland can serve as a great potential agricultural land for cultivation of crops such as rice and this also means an increase in the level of aquatic fauna existing in the area.

In the same vein, anthropogenic activities at this period also translated to a decrease in the number of built-up areas from 21.2% representing 100.6km² to 19.2% representing 93km² on the ground with a decrease of 2%. This particular result has two implications. Firstly, from the standpoint of the “push and pull” factor which implies that due to the arid nature of this area, people tend to migrate from dry zones to more favourable zone where their daily economic activities can be supported such as farming. The result by default includes clearing of farmlands for farming and building of shelters. These anthropogenic activities could spark up an exacerbation of desert encroachment. Secondly, the soil in the area hence with water, irrigation farming could possibly be carried out in the dry season with limited number of crops to be grown such as carrot, pepper, onions, among others. Tsendbazar *et al.* (2018) stated that the problems of land use land cover changes are global and serious in many developing countries where increasing population has resulted into excessive pressure on natural resources. Significant population increase, migration and accelerated socioeconomic activities have intensified environmental changes over the centuries.

Land use land cover of 2004

The satellite imagery analysis of 2004 revealed another progression in the analysis of the classified variables for the land use land cover. The result shows that water constituted 0.46% covering an area of 2.17km², which is another reduction from the previous year analysed (1999) that yielded 0.5% at 2.5km². The rate of this reduction would be examined later in this analysis but it is noteworthy that climate change was a major contributor to this factor as one of its attendant effect is the drastic reduction of water bodies around the semi-arid areas and attendant flood in the coastal areas. Anthropogenic activities due to the demand for water happened to be another factor that contributed to the steady reduction of

the water bodies in the study area with the fact that most of the streams are seasonal in nature. The reduction in the water bodies brought about a shift in the built-up areas as most of the built-up areas are agrarian communities whose farming is dependent on irrigation farming due to inadequate rainfall. In comparison with the result from the year 1999, the built-up area shows 20.2% on an area of 95.7km² as previously compared to 19.6% covering an area of 93km² of the study area. Marshland reduction also could be a contributory factor in the drastic increase of the population in the study area as compared with the year 1999. Marshland accounted for 38.2% covering an area of 181km² in 1999 but reduced to 37.6% representing 178.3km² in 2004.

Vegetal cover within the area showed a variation of 21.97% covering an area of 104.13km² as against the previous 21.9% covering an area of 103.6km². One of the reasons for this increase is probably the aggressive campaign launched by the then Federal Government and the United Nations as part of effort geared towards reducing the Sahara Desert encroachment through aggressive tree planting campaign in Nigeria especially in the Sudano-Sahelian region. Soil has been a major factor that attract population as ready arable land can be cultivated for food production either subsistent or commercially in this regard. Bare surface of the imagery analysed stood at 19.8% covering an area of 93.7km². Also, Boko Haram insurgency has not emanated during this era.

Land use land cover of 2009

It is important to note at this point that the Boko Haram insurgency gained momentum by 2009 after the death of its leader and founder Mohammed Yusuf. Before this time, the areas around the Sambisa forest was not a trouble spot even though information gathered was that the Boko Haram sect had withdrawn to the interior parts of Borno State from where they had been steadily gaining religious advantage and proceeded to launch attack on various government parastatals in Nigeria as a whole. The year 2009 witnessed the beginning of the vicious cycle of violence starting from Borno State, around the Sambisa forest northern corridor of Konduga, Bama Dalori and ultimately Maiduguri. The impact of their activities was not felt from the humanitarian point of view alone but also from the environmental point of view which brought in a sporadic increase in the number of anthropogenic activities within these areas from both side of the government force and Boko Haram militias who sought to declare Islamic caliphate over that area in alliance with the internationally recognised terror organisation (Islamic State and Levante (ISIL). The drivers of LULC change in the region include anthropogenic (such as economic and demographic) and environmental factors (Tran *et al.*, 2015 as cited in Spruce *et al.*, 2020). Both negative and positive forest change drivers occur, which can collectively affect the amount of agricultural expansion and contraction as well as the amount of deforestation and afforestation

(Imai *et al.*, 2018). The decrease in the amount of forest covered area may have a negative influence on the whole earth's environment (Modzelewska *et al.*, 2017). From the analysis, the result experienced a fluctuating dip and rise with water bodies accounting for 0.66% of the total landcover with an area coverage of 3.12km² comparing this result with that of 2004 which was 0.5% (2.17km²), this simply means that there was a slight increase by 0.16% which accounted for the rise. This was buttressed further by the fact that built-up areas as stated on the land use land cover map showed a decrease as residents fled from their homes as a result of the emergence of Boko Haram activities. The few settlements during this era were mostly military camps who were carrying out counter insurgency operation to root out the militant residents in the area. Resulting violence account for built-up area or settlements around that area to be overrun by Boko Haram militant who later declared the area of Dalwa and Konduga as part of the Islamic caliphate. Bare surface cover in the area was 20.6% representing 97.6km² precisely areas around Konduga. Marshland in the area accounted for 19.1% representing 90.7km². There was an increase in the vegetation of the study from 104.13 the previous year to 201.5 in 2009. The sharp increase in vegetation could be as a result of the United Nations Convention to Combat Desertification the previous years.

Land use land cover of 2014

The result from the imagery analysis for the year 2014 witnessed a drastic shift environmentally and anthropogenically especially as it affects human habitations and land cover within the study area. It should be asserted that the Boko Haram crisis witnessed a massive upscale in 2014 which made several Nigerians affrighted for their safety. It would also be recalled that it was from 2014 the militant group declared fully their allegiance to the international renowned terrorist group, Islamic State of Iraq and the Levante. In May 2013, Nigerian government forces launched an offensive attack in the Borno region in an attempt to dislodge Boko Haram fighters after a state of emergency was declared on the 14th of May, 2013. All the activities of Boko Haram in the area had an attendant effect on the environmental structure of the Sambisa forest added to the fact that the upsurge in violence brought about the use of modern weaponry such as bombs, anti-craft gun and other sophisticated weapon which could pose catastrophic effect on the environment. Military operations in the area would definitely bring about the clearing and destruction of vegetation thereby reversing the gains made in the aggressive afforestation approach especially with weapons such as Armoured car, Tanks, among others. Specific reduction was experienced in the amount of water bodies in the area as percentage coverage for water reduced to 0.38% covering an area of 1.8km within the study area. There was a massive decrease in vegetation of the area as vegetation fell to 28.5%. Thus, virtually the gains made through the federal government afforestation program around the forest environs was

completely lost as a result of intense military operations in this area. This reduction in the amount of vegetal cover gave rise to an increase in the Built-up of the area as both the military and Boko Haram insurgents were trying to gain dominance of the area.

Ahmad (2012) made it clear that vegetation is profoundly impacted by anthropogenic activities, particularly trampling. The ultimate effect of trampling is a reduction in amount of vegetation, often resulting in complete loss of vegetation cover. Soil in the area was 40% covering 189km² of the total area of coverage. It should be noted that there is no way farming would have taken place in this area during military operation which involves clearing and recovering lost areas to Boko Haram militants. A careful examination of 2014 imagery would give an understanding that vegetation in the area started decreasing especially around the water bodies where ordinarily vegetation would thrive. It is pertinent to note that as water bodies and vegetation experience steady reduction, there would be a progressive desertification in the area over the space of 5 years. This could serve as an advantage for the military conducting military operations from both the air and land which involves dropping of bombs and artillery shelling of militant positions and hideouts in and around the forest. But this operation is quite a catastrophic disadvantage to the ecosystem as flora and fauna composition within the area are almost on extinct leaving just bare land and the desert to consume the area. Marshland had 19.8%, another reduction by 0.7% from the previous year 2009 imagery. This reduction also signalled the alarming rate at which vegetal cover are being depleted seriously and giving space for the Sahara Desert to encroach on the remaining arable land for agriculture.

Land use land cover of 2019

Land use land cover analysis for 2019 yielded another interesting result leaving little to doubt from the previous years. From the analysis, Water occupied 0.39% representing 1.86km², vegetation within the area had 11.61% which is a drop from the 28.5% in the previous year. Marshland covered 32.7% translating to 155km², Bare surface accounted for 32.1% covering an area of 152.10km² while Built-up had a drastic increase of 23.2% representing 110.3km² of the total area. This is a clear indication of Boko Haram activities and Military counter insurgency on Sambisa forest. Aju and Aju (2018) noted that the war in the north-eastern parts of the country by the Boko Haram insurgents is not just a war on the socio-political, socioeconomic and socio-cultural life of the people but also an environmental war. They stressed that since the emergence of Boko Haram insurgency, the Sambisa has never been the same and will never be the same again even when the militants are wiped out totally from the forest. A study on woody cover change in Colombia between 2001 and 2010 showed that the impact of illegally armed groups has reduced forest cover, particularly in areas rich in gold and lands appropriate for

cattle grazing (Sanchez-Cuervo & Aide, 2013). It was also revealed that aerial application of Agent Orange and other herbicides during the Vietnam War, defoliated 14% of the country's forest cover and over 50% of its coastal mangroves. The illustration was shown in a study of the effects of high explosive munitions (bombs and shells), chemical anti-plant agents (herbicides), and heavy land clearing tractors (Rome plows) as employed by the USA in South Vietnam during the Second Indochina War of 1961 – 1975 for the purpose of extending large-scale area denial (Negasi *et al.*, 2017).

From the result of land use land cover for the year 2019, it was very obvious that if nothing is done to checkmate the activities of Boko Haram on Sambisa forest or to bring to an end the issue of insurgency, time shall come when there will be no Sambisa forest. This implies that there is need for environmental monitoring of the forest to avoid future environmental problems. The works of Bell *et al.* (2018) opined that land use and management

practices are important factors in determining the extent of soil erosion. Good vegetation cover promotes infiltration of water into the ground and soil retention, while deforestation results into increased runoff than infiltration occurring during periods of more precipitation (Alexakis *et al.*, 2014). Increased runoff consequently leads to stronger soil erosion usually in areas with poor vegetation cover (Bell *et al.*, 2018). Netzer *et al.* (2019) stated that extensive conversion of forests to permanent crops or other non-forests can change the runoff characteristics within a sub-basin. The land cover changes occur naturally in a progressive and gradual way, however, it may be rapid and abrupt due to anthropogenic activities.

Change detection analysis

Remotely sensed data processed and elaborated can be useful in change detection task to monitor the land cover changes over the years at different times.

Table 4: Change detection analysis

LULC Category	Area diff b/w 1994 – 1999 (km ²)	Area diff b/w 1999 – 2004 (km ²)	Area diff b/w 2004 – 2009 (km ²)	Area diff b/w 2009 – 2014 (km ²)	Area diff b/w 2014 – 2019 (km ²)	Area diff b/w 1994 – 2019 (km ²)
Water	1.11	0.33	0.95	1.32	0.06	1.75
Vegetation	118.78	0.53	97.37	66.5	79.96	167.34
Bare surface	9.89	0.2	3.9	71.4	16.9	68.09
Marshland	117.6	2.7	87.6	2.92	61.38	91.6
Built-up	7.6	-2.7	14.62	6.5	35.42	9.4
Total	474	474	474	474	474	474

Thus, starting from previously described dataset of Landsat classified imageries, the process of digital change detection developed has allowed for the determination and description of changes in land cover between five fundamental intervals of 1994 – 1999, 1999 – 2004, 2004 – 2009, 2009 – 2014 and 2014 – 2019, with the addition of 1994 – 2019.

Change detection analysis of Sambisa forest from the year 1994 – 1999

Figure 3 shows the change variable from 1994 – 1999 with the white patch on the change detection map representing the unchanged area over the years while others were coded using colour code of the same variables in the land use land cover maps to identify the changes that have taken place over the years. From the change detection map of 1994 – 1999, Vegetation changed to Water, Vegetation changed to Bare surface, Marshland changed to built-up while Built-up changed to bare surface.

Change detection analysis of Sambisa forest from the year 1999 – 2004

The changed variables from 1999 – 2004 with the white patches on the change detection map representing the unchanged areas over the years. From the change

detection map (Figure 3), Vegetation changed to bare surface, Bare surface changed to marshland, Marshland changed to built-up and from built-up to bare surface while Built-up changed to bare surface.

Change detection analysis of Sambisa forest from the year 2004 – 2009

Figure 3 shows the variable from 2004 – 2009 with the white patches on the change detection map representing the unchanged area over the years while others were coded using colour code of the same variables in the land use land cover map to identify the changes that have taken place over the years. From the map, Vegetation changed to marshland, Marshland changed to bare surface, Bare surface changed to built-up while Built-up changed to vegetation and water.

Change detection analysis of Sambisa forest from the year 2009 - 2014

The change variables from the year 2009 – 2014 with the white patches on the change detection map representing the unchanged area over the years while others were coded using colour code of the same variables in the land use land cover map to identify the changes that have taken place over the years. From the map (Figure 3), Bare surface changed to water, Vegetation changed to bare

surface, Built-up changed to marshland while Marshland changed to built-up.

Change detection analysis of Sambisa forest from the year 2014 – 2019

The changed variables from 2014 – 2019 with the white patches on the change detection map representing the

unchanged areas over the years while others were coded using colour code of same variables in the land use land cover map to identify the changes that have taken place over the years. From the map (Figure 3), Bare surface changed to vegetation, Marshland changed to vegetation, Vegetation changed to built-up while Built-up changed to bare surface.

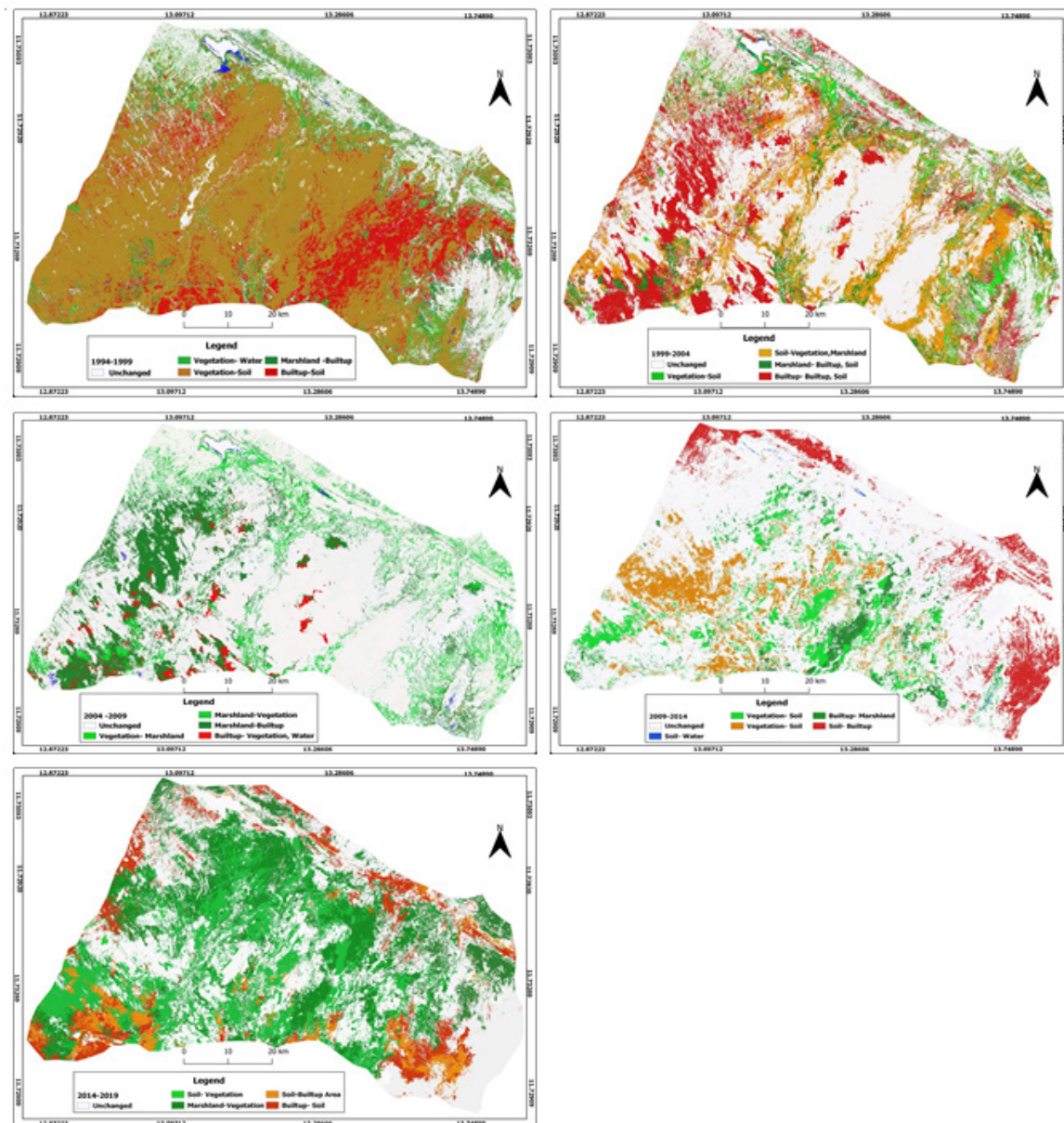


Figure 3: Change detection map from the year 1994 to 2019

Change detection graphical plot

Figure 4 shows the graphical plot of the rate of changes in the study area from the year 1994 – 2019. From the result, the rate of individual variables is not static as factors responsible for depletion are often changing. Anthropogenic activities would always be the game

changing factors responsible for the depletion. This implies that a reduction or increase in Anthropogenic activities would always result to either addition or subtraction in the quantities or values of environmental variables.

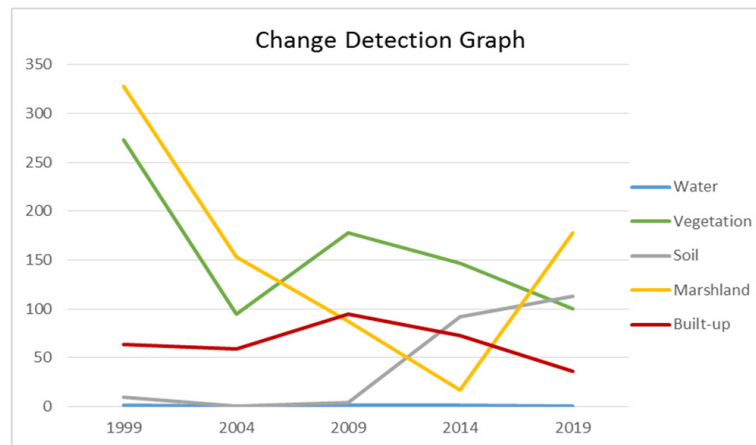


Figure 4: Graphical plot showing the rate of changes in environmental variables from 1994 – 2019
Source: Author's work (2020)

From the Figure, water was on a steady decline over the years with the highest as 9% from 1994 – 1999, while a sharp decline occurred from 1.11km² to 0.33km² which later increased to 0.93km², then to 1.28km² and later with a drastic fall to 0.04km² from 2014 - 2019. This gives a vivid representation of the nature of changes over the years with highest at 1.28km² and the lowest at 0.04km². When observed the factorial years in which there was a dip in water bodies size was the same period when the insurgency in the study area scaled up. Also, it might be an indication that not only the insurgency affects the environment of the study area but also the study area itself being in the Sudano-Sahelian region happens to have problems of desert encroachment.

Vegetation change rate from 1994 – 1999 was not reasonable. From 1999 – 2004, there was massive decrease which scaled to 94.4km² and with a sharp increase to 177.5km² from 2004 - 2009 which brought about plunging result to 146.5km² and ultimately to 100km².

Built-up areas are direct result of anthropogenic activities which brings about interference in the natural ecosystem. From the result displayed on the graphical plot, 1994 – 1999 had 63.6km² which slide down to 58.7km² between 1999 – 2004, with an upward increase of 94.6km² from 2004 – 2009, it later decreased to 72.9km² and 36.3km² between 2014 – 2019. It is noteworthy that 2014 - 2019 was the height of the insurgency with the government fierce attempt at recapturing the area from the terrorists. Soil had its lowest value from 1999 – 2004 at 0.2km², with 112.8km² as the highest from 2014 – 2019. The serious

increase experienced from 2014 – 2019 was as a result of consistent anthropogenic activities alongside the Sahara Desert encroachment.

Marshland had initial increase from 1994 – 1999 at 327.6km², and a drastic reduction to 152.7km². It later reduced to 87.6km² but fell drastically to 17.1km² with a massive increase of 177.4km² which suggested that the impact of the war waged on the insurgency in the area has had a tremendous effect on the marshland, bringing about some bit of stability for flora and fauna to flourish in the area.

Time series analysis

In the study of the land use land cover data gathered from imageries analysed and the values derived are subtracted from one point to another (example, 1994 – 1999) while all component of water, vegetation, soil, marshland and built-up areas are subtracted from previous years and applied to Microsoft excel to analyse using the time series method. A forward intercept of 0.5 representing a five year forward intercept was adopted for all the interval years done, the result yielded quite a number of results as can be seen on Figure 5. This shows that the year 2009 – 2014 witnessed the high fluctuation in behaviour as ecosystem disturbance and imbalance were witnessed, which was a direct result of the Boko Haram activities in the area. While 2014 – 2019 time series graph showed signs of high shift indicating that as long as the insurgency operation continues, it's only a matter of time before the entire environment will be completely disturbed.

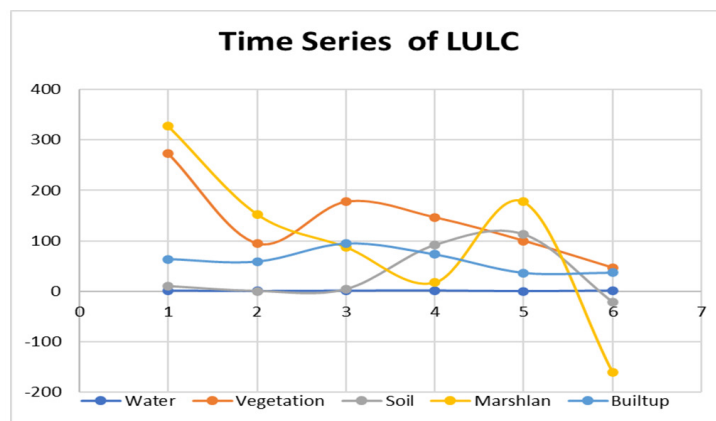


Figure 5: Time series graphical plot from the year 1994 – 2019

Time series analysis for the year 1994 – 1999

Time series projection between 1994 – 1999 shows the polynomial forward intercept graph revealing a gradual high value in marshland areas being the highest. Forward intercept of 0.5 was adopted thus projecting the possible scenario of what to expect between 1999 – 2004. From

the polynomial graph on Figure 6, if the change rate was held at 17.193, the expected rate of change in the area would be at 0.2147. This could be tagged as reasonable limit given that severe anthropogenic factors do not impair the rate of change within the environment.

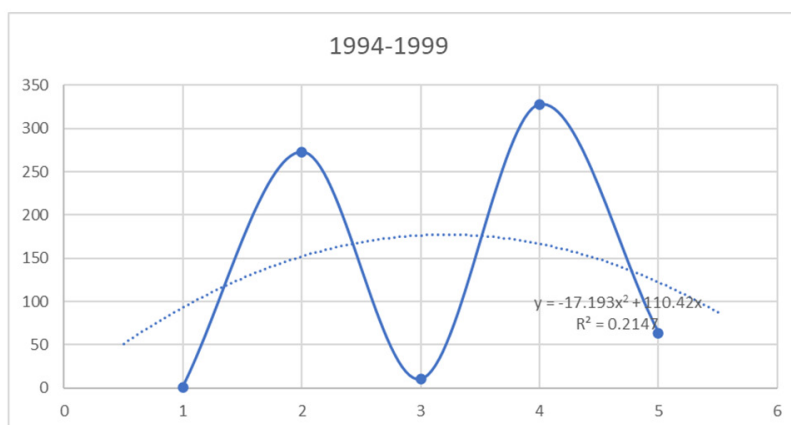


Figure 6: Time series graph analysis for 1994 – 1999

Time series analysis for the year 1999 – 2004

The year 1999 – 2004 revealed a number of time series changes which are quite interesting. There were reductions

in values of the parameters as can be seen on Fig. 7 when compared with that of 1994 - 1999.

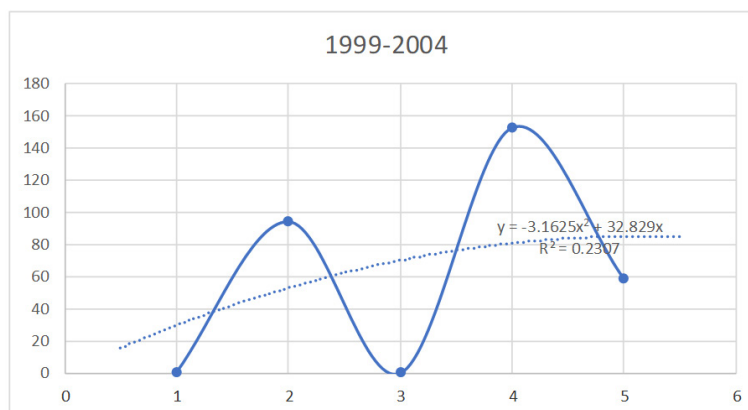


Figure 7: Time series graph analysis for 1999 – 2004

Time series analysis for the year 2004 – 2009

The year 2004 – 2009 shows there was a slight change as changes for vegetation shot up in the area. Although, the change rate was measured at 0.0662, it can be asserted that the changes that took place in the area based on all the five variables measured were expected

to grow at 0.0662. Thus, showing an indication that the Boko Haram activities in the area began to have minute effect on the environment even though its effect was not as pronounced as it was in the upcoming years. This illustration is shown on Fig. 8.

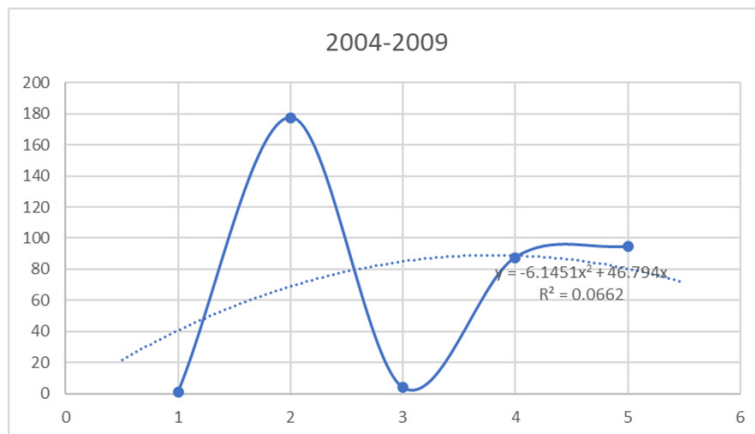


Figure 8: Time series graph analysis for 2004 – 2009

Time series analysis for 2009 – 2014

The year 2009 – 2014 shows a drastic change which occurred during this period and change rate revealing a steady decline in the various environmental variables that were available in the area. Time series graphical intercept was pitched at 0.1992 which was clear dive from previous 0.0662. This shows that vegetation loss was on

the increase powered by the insurgency activities as soil and marshland were a steady decline which was evident as at that time as the federal forces battled the militant to retake the area from them. It is projected that if this continues, then the rate of change in the environment would be at 0.1992 which translate to a 59.474 on the graphical scale. This is shown on Figure 9.

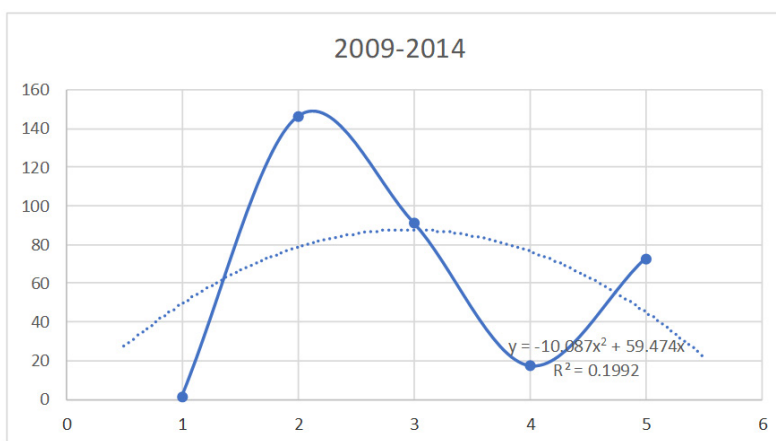


Figure 9: Time series graph analysis for 2009 – 2014

Time series analysis for the year 2014 – 2019

The year 2014 – 2019 brought about a major change in the area of the study as military operations in the Sambisa forest intensify due to the federal government renewed effort at capturing back the area. A lot of game changing weapons were deployed to the area as the Airforce bombarded the environment with the ground forces advancing columns and deploying heavy weapons such as tanks and artillery. After the recapturing of the forest areas

as put by the federal government, the graphical time series indicator showed an upward movement thus, revealing at the rate of 0.7938 which reveals gradual steady though minute recovery in the area. This shows that even though the area seems to be recovering from the destruction of the ecosystem, it might likely take some years before a full recovery is made as long as the ecosystem stability is maintained. This is shown graphically on Fig 10

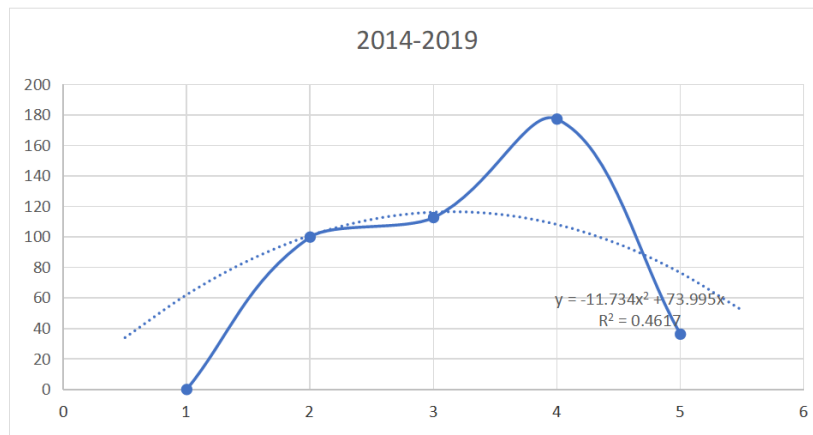


Figure 10: Time series graph analysis for 2014 – 2019

Time series analysis for the year 2019 – 2024

Fig. 11 shows the Time series analysis for the year 2019 – 2024. From the result when compared with 2014 – 2019, it reveals that there will be a drastic decrease in water, vegetation, soil and marshland but with a slight increase in built-up. This implies that with the serious

fight by the military to counter Boko Haram activities on Sambisa forest of Nigeria, there will be a total decline of vegetation of the forest. With the predicted decrease in vegetation, soil and marshland as they have regressed to the negative, desertification/desert encroachment might set in.

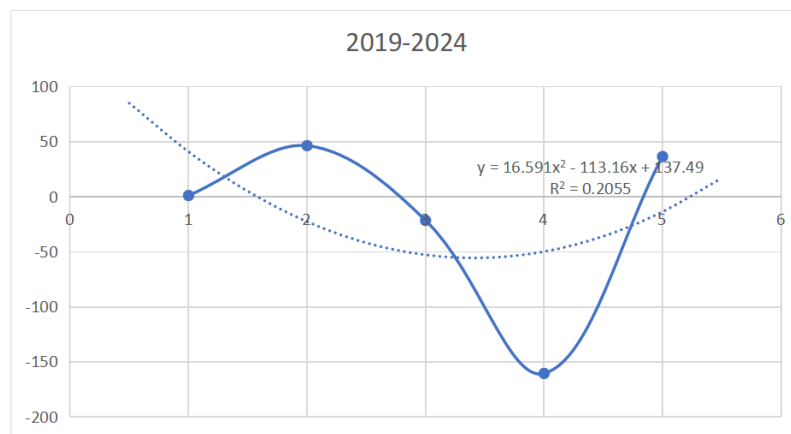


Figure 11: Time series graph analysis for 2019 – 2024

CONCLUSION

This study looked at the in-depth analysis of the terrorists activities on land use and land cover (LULC) change of Sambisa Forest of Nigeria. GIS and remote sensing were employed in the course of this study. Secondary types and sources of data were used in this study and they include data on the vegetation cover of Sambisa forest before and during the emergence of Boko Haram and data on the land use/land cover. The data for the vegetation analysis of this study were obtained using satellite imageries of the study area from 1994, 1999, 2004, 2009, 2014 and 2019. In line with the findings of the study, the following suggestions are made in order to put an end or to ameliorate the impacts of Boko Haram activities on the Sambisa forest of Nigeria:

I. The military should stop Boko Haram activities and force them out of the forest and the area will regenerate

and the soil remediated.

II. After recommendation I above is achieved, employ and empower forest guards to control activities and bring some form of governance in the forest and game reserve. By so doing, the vegetation indices as well as the soil of the forest will be conserved.

III. Northern youths as well as the children should be encouraged to go to school to avoid brainwashing and evil manipulation from the extremists as they will be educated enough to know the environmental implication of involving themselves with terrorism and thereby act as agents of conservation for the vegetation and soil of Sambisa forest.

IV. Awareness campaign should be organised in order to enlighten the communities within and around Sambisa forest on the need to conserve the forest to circumvent the dangers of desert encroachment or desertification.

REFERENCES

- Adelaja, A., & George, J. (2019). Terrorism and land use in agriculture: The case of Boko Haram in Nigeria. *Land Use Policy*, 88. <https://doi.org/10.1016/j.landusepol.2019.104116>
- Ahmad, F. (2012). A review of remote sensing data change detection: Comparison of Faisalabad and Multan Districts, Punjab Province, Pakistan. *Journal of Geography and Regional Planning*, 5(9), 236 - 251. <https://doi.org/10.5897/JGRP11.121>
- Aju, P. C., & Aju, J. A. (2018). Occupation of Sambisa Forest and Boko Haram in North eastern Nigeria as Security Threat and Challenges to Sustainable Forest Management. *Global Journal of Science Frontier Research: D Agriculture and Veterinary*, 18(5).
- Alexakis, D. D., Grillakis, M. G., Koutroulis, A. G., Agapiou, A., Themistocleous, K., & Tsanis, I. K. (2014). GIS and remote sensing techniques for the assessment of land use change impact on flood hydrogen: The case study of Yialias basin in Cyprus. *Natural Hazards and Earth System Sciences*, 14(2), 413–426. <https://doi.org/10.5194/nhessd-14833-2013>
- Bell, A. R., Ward, P. S., Mapemba, L., Nyirenda, Z., Msukwa, W., & Kenamu, E. (2018). Smart subsidies for catchment conservation in Malawi. *Scientific Data*, 5, 180113.
- Green, M. S., LeDuc, J., Cohen, D., & Franz, D. (2019). Confronting the threat of bioterrorism: realities, challenges and defensive strategies. *Elsevier Journal*, 19(2). [http://dx.doi.org/10.1016/S1473-3099\(18\)30298-6](http://dx.doi.org/10.1016/S1473-3099(18)30298-6)
- Hurt, G. C., & Coauthors (2006). The underpinnings of land-use history: Three centuries of global gridded land-use transitions, wood-harvest activity, and resulting secondary lands. *Global Change Biol.*, 12, 1208–1229. <https://doi.org/10.1111/j.1365-2486.2006.01150.x>
- Igboin, B. O. (2021). Ungoverned or Alternatively Governed Spaces in North-Eastern Nigeria: A Critical Exploration of Boko Haram's Ideological Motif. *Claremont Journal of Religion*, 3(4), 72 – 98. https://doi.org/10.1163/9789004435544_023
- Imai, N., Furukawa, T., Tsujino, R., Kitamura, S., & Yumoto, T. (2018). Factors affecting forest area change in Southeast Asia during 1980-2010. *PLoS One*, 13, e0197391.
- Modzelewska, A., Sterenczak, K., Mierczyk, M., Maciuk, S., Balazy, R., & Zawila Niedzwiecki, T. (2017). Sensitive of vegetation indices in relation to parameters of Norway spruce stands. *Folia Forestalia Polonica, series A – Forestry*, 59(2), 85- 98. <https://doi.org/10.1515/ffp-2017-0009>
- Mzuza, M. K., Zhang, W., Kapute, F., & Wei, X. (2019). *The impact of land use and land cover changes on the Nkula Dam in the Middle Shire River catchment, Malawi*. intechOpen.
- Netzer, M. S., Sidman, G., Pearson, T. R. H., Walker, S. M. W., & Srinivasan, R. (2019). Combining global remote sensing products with hydrological modeling to measure the impact of tropical forest loss on water-based ecosystem services. *Forests*, 10, 413. <https://doi.org/10.3390/f10050413>
- Sanchez-Cuervo, A., & Aide, T. M. (2013). Consequences of the Armed Conflict, Forced Human Displacement, and Land Abandonment on Forest Cover Change in Colombia: A Multi-scaled Analysis. *Ecosystems*, 16(6), 1052-1070. <https://doi.org/10.1007/s10021-013-9667-y>
- Solomon, N., Birhane, E., Gordon, C., Haile, M., Taheri, F., Azadi, H., & Scheffran, J. (2018). Environmental impacts and causes of conflict in the Horn of Africa: A review. *Earth-science reviews*, 177, 284-290. <https://doi.org/10.1016/j.earscirev.2017.11.016>
- Spruce, J., Bolten, J., Mohammed, I. N., Srinivasan, R., & Lakshmi, V. (2020). Mapping Land Use Land Cover Change in the Lower Mekong Basin from 1997 to 2010. *Frontiers in Environmental Science*, 8(21). <https://doi.org/10.3389/fenvs.2020.00021>
- Szabo, S., Gacsi, Z., & Balazs, B. (2016). Specific features of NDVI, NDWI and MNDWI as reflected in land cover categories. *Landscape and Environmental*, 10(3-4), 194 - 202. <https://doi.org/10.21120/LE/10/3-4/13>
- Taylor, A. J. (2016). Thoughts on the nature and consequences of ungoverned spaces. *S.A.I.S Review of International Affairs*, 36(1), 5–15. <https://doi.org/10.1353/sais.2016.0002>
- Tsendbazar, N., Herold, M., Lesiv, M., & Fritz, S. (2018). Copernicus Global Land Operations – Vegetation and Energy “CGLOPS-1”.
- Ukah, C., Ejaro, S. P., Makwe, E., & Iwara, A. I. (2021). The effect of Boko Haram activities on land use and land cover at Yankari Game Reserve, Bauchi State, Nigeria. *British Journal of Environmental Sciences*, 9(6), 1–18. <https://doi.org/10.37745/bjes.2013>
- Ukah, C., Ejaro, S. P., Makwe, E., & Magaji, J. Y. (2025). Analysis of the Impacts of Terrorists and Military Operations on the Soil Parameters of Sambisa Forest, Nigeria. Springer – *GeoJournal*, 90(219), 1 – 19. <https://doi.org/10.1007/s10708-025-11463-w>