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Spatio-Temporal Variation of Lake Chad Basin: The Implication of Conflict on Socio-Economic Activities

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ABSTRACT

The study assessed the spatio-temporal variation of Lake Chad including the implication of conflict on socio-economic activities. The specific objectives of the study included assessing the land cover change of the Basin from 2000 to 2020, assessing the hotspot conflict zones, examining factors causing conflict in the region, examining the effect of conflict on the socioeconomic and strategies to combat violence, and determining the conflict potential zones in the study area. Both primary and secondary data were used for this study and the primary data used included conduct key informant interviews (KII) for identified stakeholders. The secondary data used for this study included coordinates of the conflict sites, Landsat imageries (2000; 2010; 2020), Aster-DEM and conflict data. The Landsat imageries were subjected to unsupervised classification generating classified images and changes was calculated among the classified images using change detection algorithm. The conflict data was subjected to hotspot analysis in determining the hot and cool spot locations in the study area from 2012 to 2020. The KIIs were subjected to content analysis in addressing factors contributing to conflict, effect of conflict on socioeconomic and methods used in combating conflict in the study area. Multicriteria analysis was also used to generate conflict potential map. Results showed that 68% of the LGAs in the study area were found within the coverage of the hottest zone irrespective of any conflict type. However, 9442 and 5224 deaths were recorded as the total number of causalities during the arm conflict and violence on civilians respectively throughout the period of the study.

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KEYWORDS: *Spatio-temporal, Conflicts, Land cover, Socio-economic, Aster-DEM, KII*

INTRODUCTION

Conflict, generally is a reality of social relations. Human in a socio-physical environment lives in continuous process of dependence and interdependence which often produces contradictions and conflicts (Oji *et al*., 2014). The occurrence of different types of conflicts (political, religion, environmental, ethnic, resource, etc.) is not an alien phenomenon in Nigeria and the West Africa region at large (Okeke, 2014; Abbass, 2012; Blench, 2010).

Conflict occurs when the physical presence or behaviour of an individual or group interferes with goals, expectations or behaviour of another individual or group (Brown and Raymond, 2013). Conflict is also any type of disagreement among a number of parties or stakeholders who has the right to make the decision on the use of resources within a temporal and spatial boundary (Emad, 2014).

Increase in conflict has been a significant source of insecurity in Nigeria and in West Africa which has gradually shifted attention to insurgency of the terrorist group Boko Haram and the area of study is not exempted *(Ifabiyi, 2013)*. Although, Lake Chad Basin is experiencing series of conflicts due to high rates of population growth from the **North-south influx movement of pastoralists, herders and others, competing with each other on** the exploitation of natural resources **in this region. Nevertheless, the movement of terrorist groups and bandits around Lake Chad has increased the rate of conflict which has resulted in an intense**

violence *(Ifabiyi, 2013)*. **The** *security regiment departments from the existing normative framework for conflict intervention in Africa, with the responsibility of managing conflicts such as; African Union, European Union and Regional Economic Communities (RECs) have* determined the collective response necessary to reduce conflicts and defeat the terrorists in the Lake Chad Basin. The strategy conceived was to enhance regional cooperation with the reinvigoration of the Multinational Joint Task Force (MNJTF) comprising military personnel from Chad, Cameroon, Nigeria, Niger and Republic of Benin.

Moreover, the evolution of geospatial technology to handle conflict has been a function of the development of technology, and a function of the evolving perspectives of planning that represent the atmosphere in which the conflict is being handled (Emad, 2014). Geospatial technology can also help to clarify the spatial elements of a territorial dispute and its socio-economic and military implications. Due to increased level of conflict and violence in the study area, this study is highly imperative to assess and give a better understanding of why conflict is escalating around the Lake Chad.

The specific objectives of the study are to;

1. assess the land cover change of the Basin from 2000 to 2020;
2. assessing the hotspot conflict zones in the study area;

Application of GIS Technology in Conflict Resolution

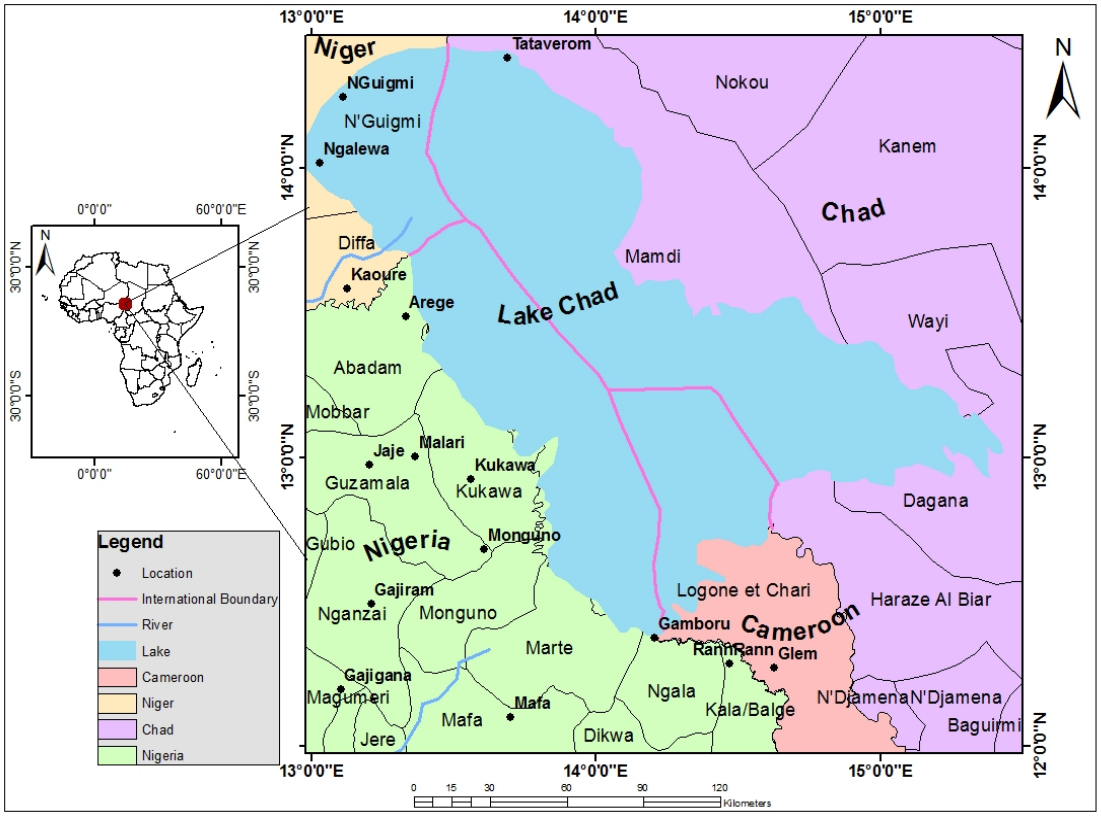
GIS technology has been used in resolving conflict such as land dispute, water boundary disputes and any other ethnicity conflicts. GIS is robust and it has played serious role in conflict analysis, using understanding multi-dimensionality and dynamism of conflict (Phattraporn and Ranjith, 2013). Application of GIS and RS tools were also used in resolving conflicts among stakeholders proposing different types of land use with multi-criteria decision analysis technique approach (Zhang *et al*., 2012). GIS and RS tools was used for conflict analysis and its resolution using prediction approach combining with time series data to detect changes in the environmental status of interest (Phattraporn and Ranjith, 2013).

Materials and Methods

Study Area

Lake Chad is located within latitudes 12º 00'N and 14º 30'N and Longitudes 13º 00'E and 15º 30'E. The Nigerian portion of the basin is about 200,000 km^2; it is the 4th largest lake in Africa, sustaining 37 million people, it forms the boundary of 4 littoral states. Three main drainage systems supply its water: the Chari-Logone River (in the Central African Republic), the Komadugu-Yobe River (in Nigeria) and the Yedsaram/Ngadda River (in Cameroon). Ecological zones surround the Lake including deserts, forests, wetlands, savannas and mountains (Ovie and Emma, 2011).

LOCATION OF THE STUDY AREA



Data Types and Sources

The data types used for this research consist of primary and secondary data. Primary data used is the qualitative data and is accomplished using phone to conduct Key informant interview for identified stakeholders (Lisa and Monica, 2001). The secondary data used for this study included; coordinates of the conflict site, Landsat imagery of three epochs of year 2000; 2010 and 2020. Landsat imagery used for this study was downloaded from the USGS archive, it has the spatial resolution of 15 meters for panchromatic, 30 meters for multispectral bands and 100 meter for thermal. Landsat is a multispectral images in which the same scene is recorded simultaneously in several bands of the electromagnetic spectrum and four different scene covered the study with the path and row of 185/50, 185/51,186/50 and 186/51. The Landsat image is used for the identification of land use and cover of the study area. However, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTERDEM) is also one of the secondary data acquired for this study with the aim of generating the elevation and the image was downloaded from the USGS website with resolution of 30m. Conflict data was also used in this study and acquired from DSS which was used to identify the conflict hotspot area.

Land Use/Land Cover Changes

To achieve this objective; the download paths and rows (185/50, 185/51,186/50 and 186/51) scenes were mosaicked and sub-mapped for further remote sensing analysis. Band composite known as false colour composite was done using bands 5, 4, 3 for Landsat 8 and bands 4,3,2 for Landsat ETM+ for global enhancement on Landsat imagery. For Landsat 8 band 5 represents the Near Infrared (0.845.-0.885 µm), band 4 represents red of wave length (0.630-0.680 µm) and band 3 represents green (0.525-0.600µm) and for Landsat ETM+ band 4 represents the Near Infrared (0.845.-0.885 µm), band 3 represents red of wave length (0.630-0.680 µm) and band 2 represents green (0.525-0.600µm). Unsupervised classification known as clustering algorithm was used for classification and USGS scheme was used for identified features in the area to achieve the land use/land cover. Five different features were identified during the classification process such as the built-up, swamp, water body, grass land and farm land. Change detection algorithm was also performed to check the changes in the study area over the period of twenty years.

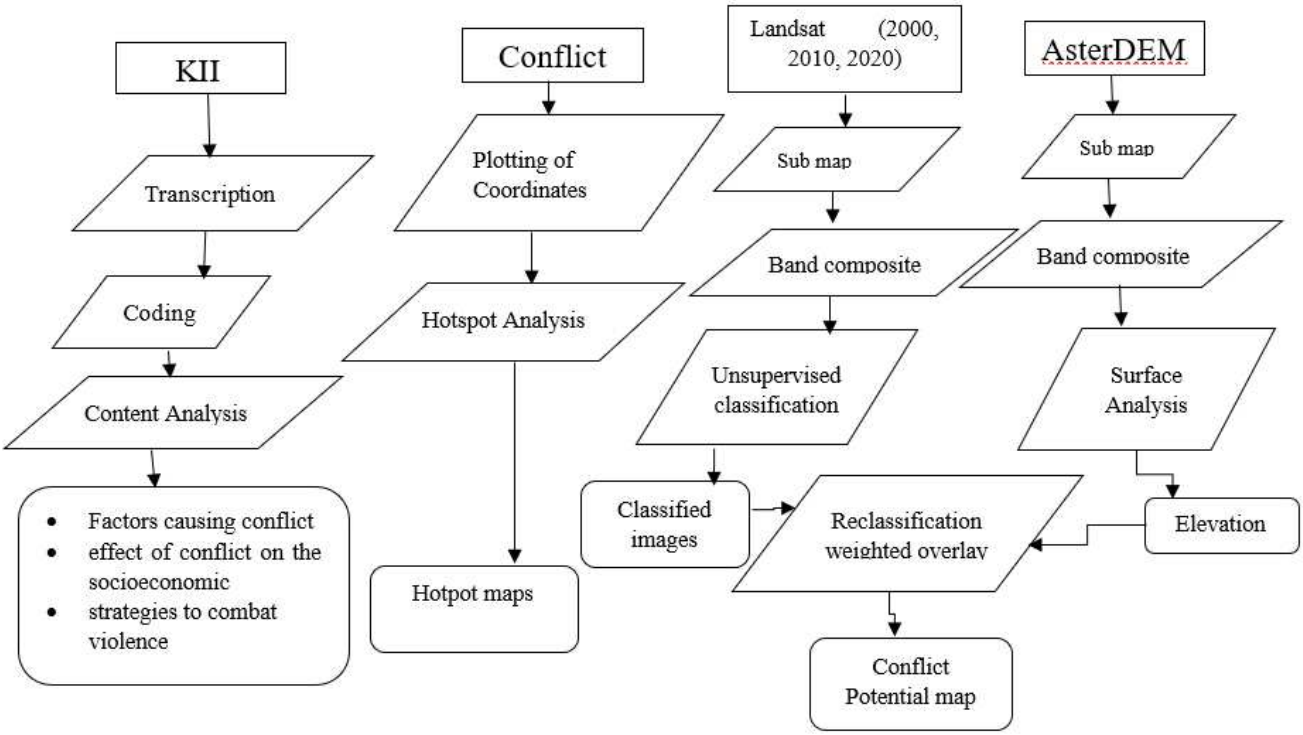


Fig. 2: Flow Chart of Methodology

Results and Discussion

This section shows the presentation and discussion of results according to the research objectives which are; assessing the land cover change of the Basin from 2000 to 2020, identifying conflict hot spot zones in the study area, examining various factors causing conflict in region from 2000 to 2020, examining the effect of conflict on the socioeconomic and strategies to combat and also identifying conflict potential zones.

Assessing the Land Cover Change of the Basin from 2000 to 2020

This analyzes land use and land cover changes in the Lake Chad region over 20 years (2000–2020) using remote sensing data from Landsat imagery. The area spans four countries—Nigeria, Niger, Chad, and Cameroon—and has been historically known for its vibrant agricultural market, particularly around Lake Chad. However, climate change and conflict have significantly impacted the region's land use.

In 2000, grasslands (30.3%), water bodies (28.3%), and swamp forests (21.8%) were the dominant land cover types. By 2010, farming activities increased, and farmland (28.4%) gained prominence, while the water body decreased by 13.4%. The most notable change from 2010 to 2020 was a sharp increase in grasslands (44.4%) and swamp forests (31%), while farmland decreased by 10.4%. The decrease in farmland was largely due to ongoing conflicts, which made farming dangerous and led to the destruction of crops and livestock by insurgents. Consequently, these areas transformed into grasslands.

Water bodies also shrank significantly, dropping by 22.1% over the two decades, primarily due to droughts and reduced inflows, likely exacerbated by climate change. The decline in water levels affected agricultural practices, particularly irrigation, and led to the encroachment of vegetation in former water areas. Swamp forests expanded as a result, likely due to the shift in ecosystem dynamics.

Built-up areas remained minimal, increasing slightly between 2000 and 2010 but declining after 2010, as conflict drove people away from the region. This study highlights the significant impact of climate change and conflict on land use, contributing to food insecurity and environmental degradation in the region.

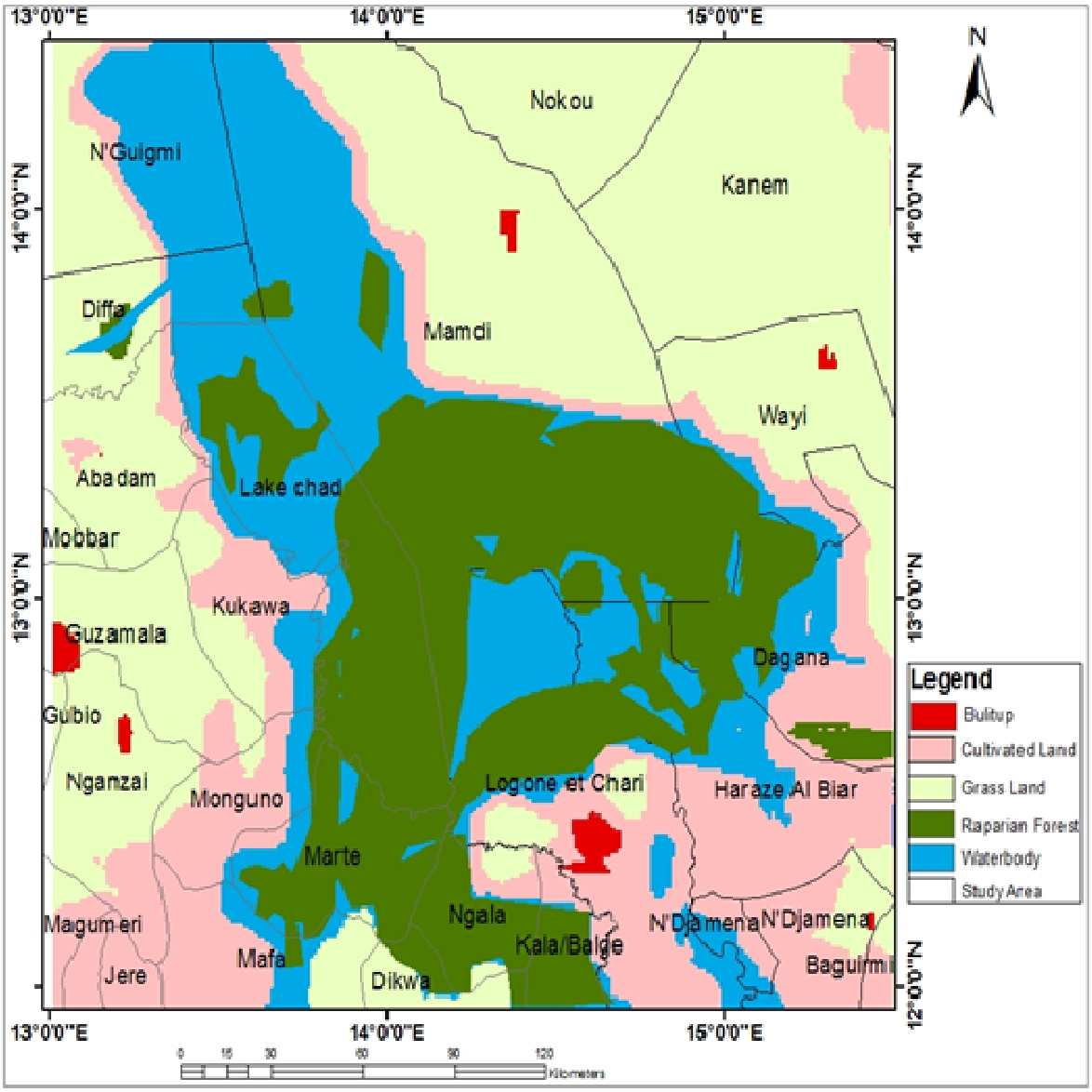


Fig. 3: Classified Land Use/Land Cover of the Study Area in 2000

Table 1: Classified Land Use/Land Cover Features in 2000

S/N	Features	Percentages (%)	Hectares (Ha)
1	Farmland	19.6	1498156.5
2	Water body	28.3	2231464
3	Grassland	30.3	2389165.3
4	Built-up	0.6	47310.2
5	Swamp	21.8	1718937

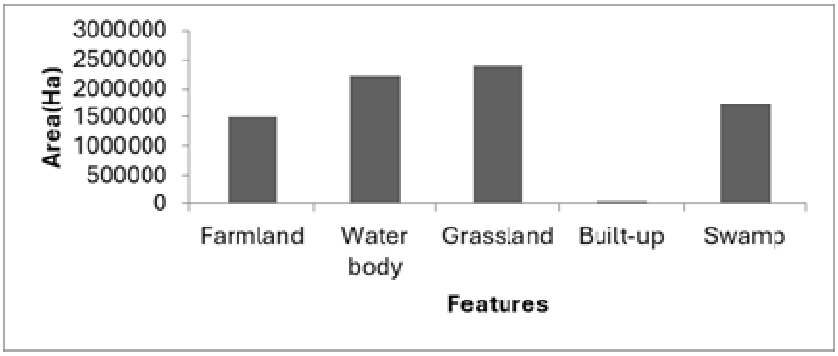


Fig. 4: Land Use/Land Cover Features of the Study Area in 2000

Table 2: Classified Land Use/Land Cover Features in 2010

S/N	Features	Percentages (%)	Hectares (Ha)
1	Farmland	28.4	2239349
2	Water body	15.0	1182755
3	Grassland	29.4	2286659.8
4	Built-up	1.24	97774
5	Swamp	26.0	2050109

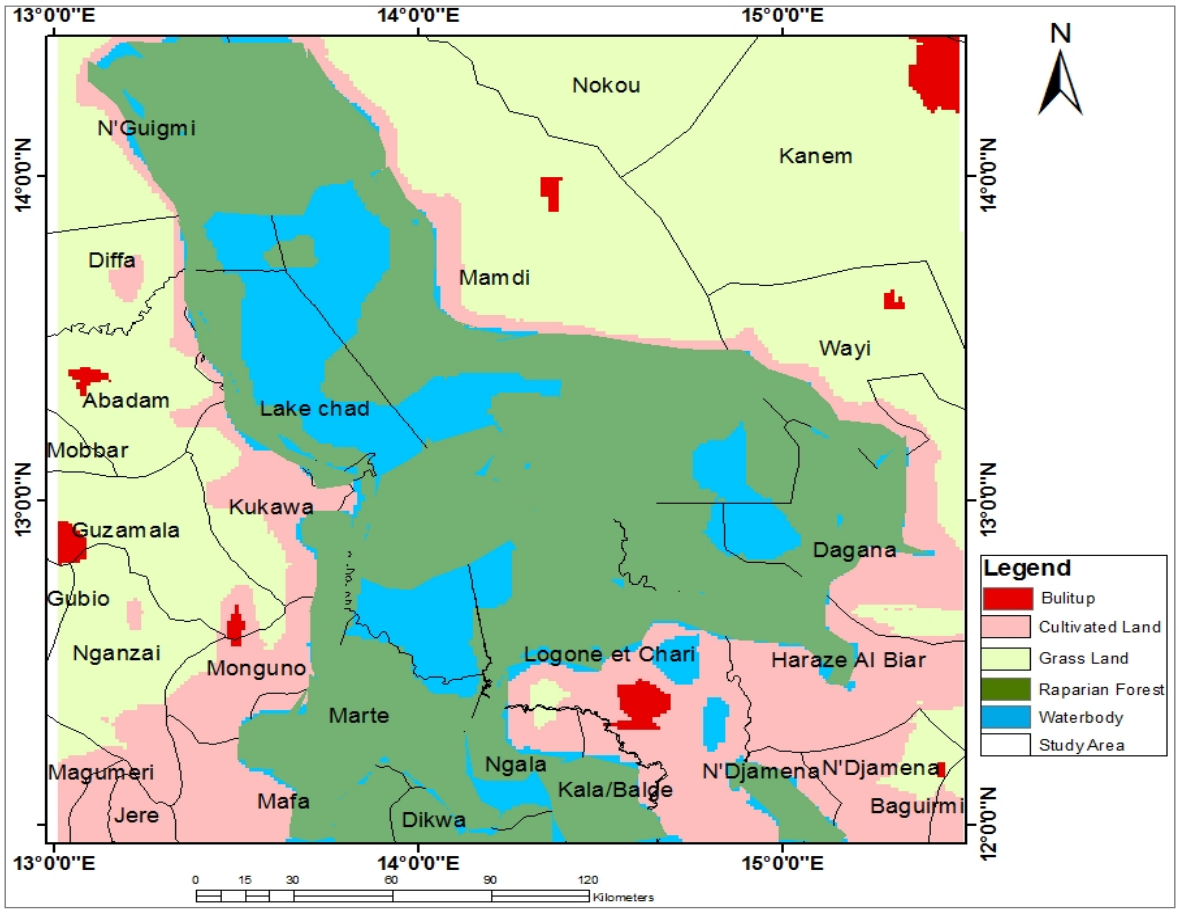


Fig. 5: Classified Land Use/Land Cover of the Study Area in 2010

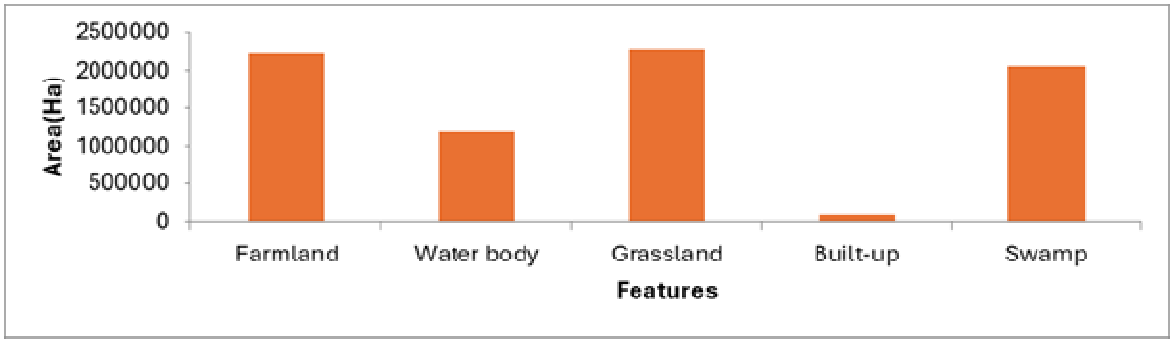


Fig. 6: Land Use/ Land Cover Features of the Study Area in 2010

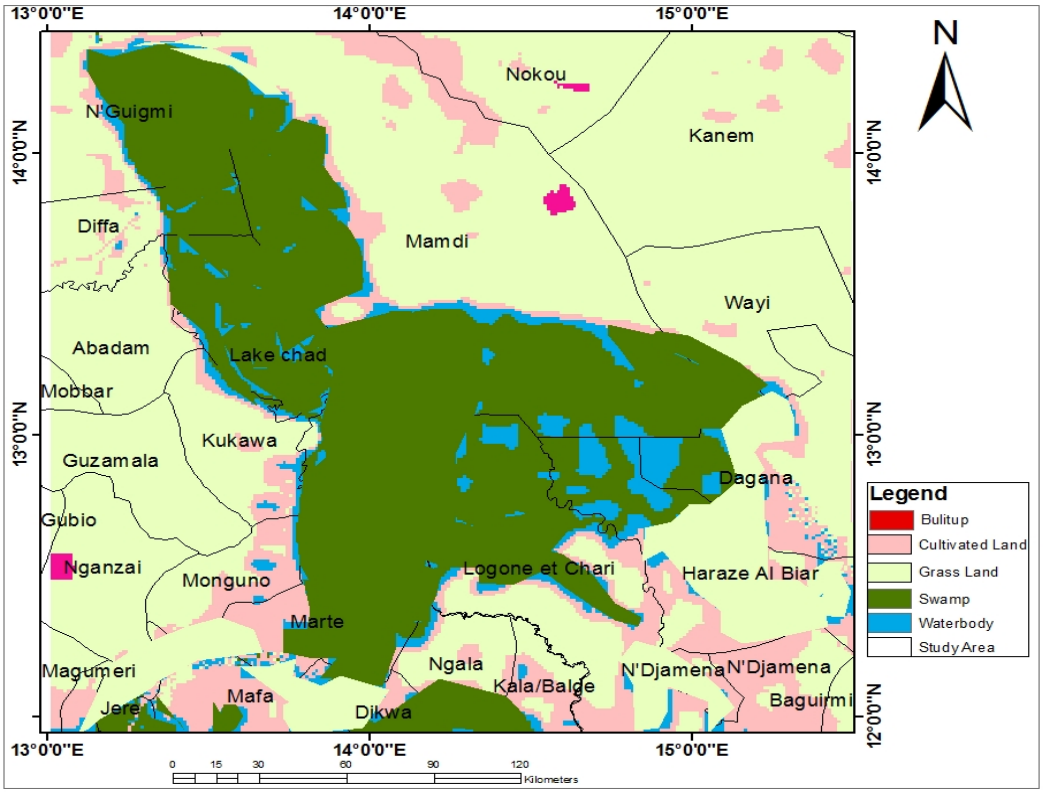


Fig. 7: Classified Land Use/Land Cover of the Study Area in 2020

Table 3: Classified Land Use/Land Cover Features in 2020

S/N	Features	Percentages (%)	Hectares (Ha)
1	Farmland	18.0	1419306
2	Water body	6.3	496757
3	Grassland	44.4	3500955
4	Built-up	0.24	18924
5	Swamp	31.1	2452245

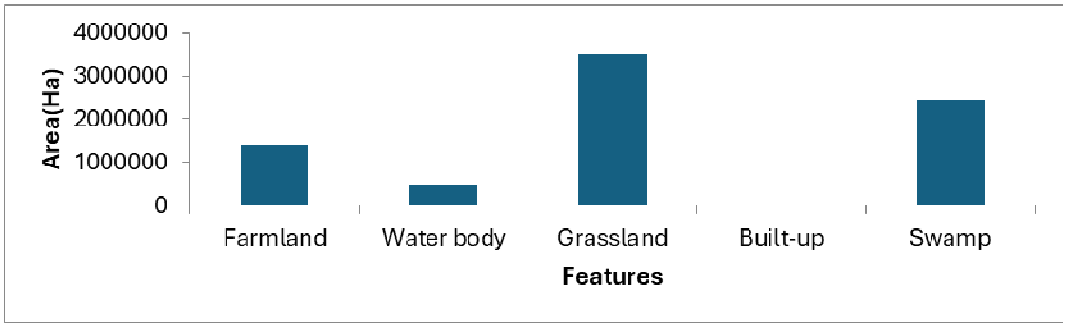


Fig. 8: Land Use/Land Cover Features of the Study Area in 2020

Table 4: Changes in Land Use/Land Cover Features from 2000-2020

Features	2000 (%)	2010 (%)	%Change 2000-2010	2010 (%)	2020 (%)	% Change 2010-2020
Farmland	19.6	28.4	+8.8	28.4	18	- 10.4
Water body	28.3	15.0	-13.4	15.0	6.3	-8.7
Grassland	30.3	29.4	-1.1	29.4	44.4	+ 15
Built-up	0.6	1.24	+ 0.64	1.24	0.24	- 1
Swamp	21.8	26.0	+ 4.8	26.0	31.1	+5.1

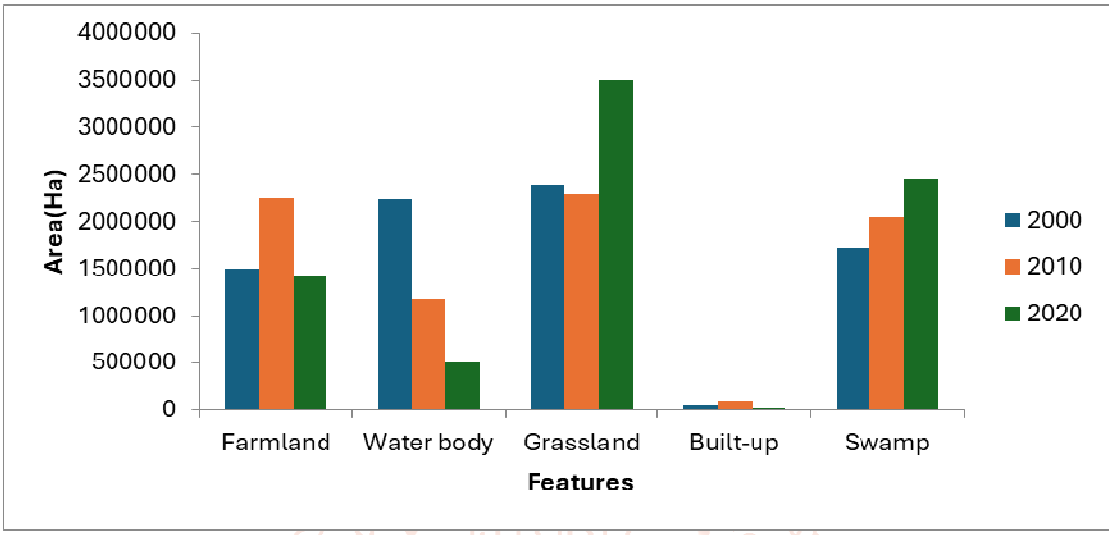


Fig. 9: Changes in Land Use/Land Cover Features of the Study Area in from 2000-2020

Conflict Hotspot Zones

This study categorised the conflict into two types according to the secondary data acquired from the DSS headquarter and these are; violence on civilians and arm or battle conflict. The violence on civilians' type described the attacks launched on the civilians by the terrorist, while the arm conflict described battle between security agents and the terrorist and these types of conflicts have been experienced in the study area. This section presents results of conflict hotspots in the study over a period of nine years (2012 - 2020). The secondary data was plotted in the GIS environment where geo-statistical analysis known has hotspot (Getis-Ord Gi*) was performed to get the final output.

Trend of Conflict in the Study Area (2020-2022)

Trend of Arm Conflict and Casualties in the Study Area (2012-2020)

Between 2012 and 2020, insurgent activities occurred with varying frequency across the Lake Chad region. Marte experienced insurgencies throughout the entire nine-year period, while other areas like Abadan, Dikwa, Guzamala, Mafa, Monguno, and Ngala saw insurgencies in eight years. The frequency decreased for areas such as Nganzai, Logone-et-Chari, and Kukawa, where insurgencies occurred in seven years. The lowest frequency was observed in Diffa, with insurgencies recorded in only two years.

A total of 9,442 deaths were reported over the study period. Monguno had the highest casualties with 1,325 deaths, followed by Logone-et-Chari (1,222 deaths) and Abadan (974 deaths). Diffa recorded the fewest deaths at just 57. Casualties peaked in 2015 with 2,097 deaths, followed by 2020 (1,392 deaths), 2018 (1,058 deaths), and 2016 (1,043 deaths). The lowest number of deaths occurred in 2012, with only 46, likely due to the insurgency being in its early stages. Local government areas such as Logone-et-Chari and Abadan saw significant casualties, with 485 deaths in Logone-et-Chari in 2015. In contrast, areas like Abadan, Dikwa, and Mamdi recorded very few deaths in specific years. The data reflects the ongoing and escalating violence in the region, with varying intensity across the years and locations.

Table 5: Trend of Causalities from 2012-2020 during the Arm Conflict in the Study Area

S/N	LGA	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
1	Abadan		13	1	223	174	99	326	85	53	**974**
2	Bosso				13	83	4	9	54	105	**268**
3	Diffa				55	2					**57**

4	Dikwa		1	5	100	106	121	20	37	36	**426**
5	Fouli				36			59	72	104	**271**
6	Guzamala		5	58	54	61	8	89	56	14	**345**
7	Jere			3		26	3	17	4	96	**149**
8	Kala Balge	5		39		76	58	10	11	10	**209**
9	Kaya	2			30			2	111	201	**346**
10	Kukawa		205		140	6	3	29	228	238	**849**
11	Logone-et-Chari			343	485	218	32	73	41	30	**1222**
12	Mafa	2		2	69	104	52	20	3	34	**286**
13	Magumeri	28	1	289	100				45	29	**492**
14	Mamdi				133	1	4	43	19	65	**265**
15	Marte	3	13	25	20	28	25	1	25	49	**189**
16	Monguno	2	58		110	27	43	174	26	120	**1325**
17	Ngala	4	26		208	23	33	34	41	46	**415**
18	Nganzai		50		66	65	10	23	24	109	**393**
19	N'Guigmi				255	43	40	129	69	53	**961**
	Total	**46**	**372**	**765**	**2097**	**1043**	**535**	**1058**	**951**	**1392**	**9442**

Source: Armed Conflict Location and Events Data, 2012-2020

Trend of Violence on Civilians and Casualties in the Study Area (2012-2020)

Between 2012 and 2020, insurgent attacks on civilians occurred with varying frequency across local government areas. Monguno, Dikwa, and Logone-et-Chari experienced the highest consistency, with eight years of repeated attacks, while Ngala saw insurgencies in seven years. Other areas, such as N'Guigmi, Nganzai, Mafa, Kala Balge, Guzamala, and Bosso, had attacks in six years, and Jere saw attacks in five years. Kaya, Kukawa, and Fouli also experienced insurgent attacks in five years, with Wayi having the lowest, with only one year of attacks.

A total of 5,224 deaths were recorded during the study period. Kukawa had the highest number of casualties, with 2,195 deaths, followed by Nganzai with 869 deaths. The year 2015 saw the highest number of casualties (2,553 deaths), while 2012 had the lowest, with just 29 deaths. Kukawa recorded the highest single-year death toll, with 2,116 deaths in 2015, while Ngala had 386 deaths in 2014.

Table 6: Trend of Causalities from 2012-2020 during Violence on Civilians in the Study Area

S/N	LGA	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
1	Abadan			58	6				9		**73**
2	Bosso				40	18	5	15	28	81	**187**
3	Dikwa	6	4	18	10	11		3	1	10	**63**
4	Fouli				7			18	2	18	**45**
5	Guzamala	5	18	3		4	47	19			**96**
6	Jere			18		18	8	8	3		**55**
7	Kala Balge				10	2	9	4	64	3	**92**
8	Kaya				3			1	3	12	**19**
9	Kukawa		73		2116	4				2	**2195**
10	Logone-et-Chari		2	3	106	71	19	28	67	29	**325**
11	Mafa		61	108	2		62	10	20		**263**
12	Magumeri	9		11	7						**27**
13	Mamdi				32				36		**68**
14	Marte			77						20	**97**
15	Monguno		5	9	91	22	6	20	14	11	**178**
16	Ngala	6	49	386	24	5	7	22			**493**
17	Nganzai		44		80	1	15		27	11	**869**
18	N'Guigmi				19	5	11	6	26	7	**74**
19	Wayi								5		**5**
	Total	**26**	**256**	**691**	**2553**	**188**	**189**	**154**	**305**	**204**	**5224**

Source: Armed Conflict Location and Events Data, 2012-2020

Conclusion

This study investigates various factors contributing to the ongoing conflict in the Lake Chad region, aiming to recommend sustainable peace and stability measures using geospatial techniques. The objectives of the study included assessing land cover change in the Basin from 2000 to 2020, and identifying conflict hotspotsl zones in the region.

The land use and cover analysis, using unsupervised classification (clustering algorithm), identified five key features: built-up areas, swamp, water bodies, grasslands, and farmland. In 2000, grasslands occupied 30.3% of the area, followed by water bodies at 28.3%, farmland at 19.6%, and swamp forests at 21.8%. By 2020, grasslands expanded to 44.4%, swamp forests increased to 31%, while farmland and water bodies decreased. The study highlighted a significant shift in land cover, with farmland increasing by 8.8% from 2000 to 2010 but decreasing by 10.4% from 2010 to 2020. Water bodies reduced by 13.4% and 8.7% between 2000–2010 and 2010–2020, respectively.

The socio-economic impacts of the conflict were also explored. A total of 9,442 deaths were recorded due to armed conflict, with Monguno suffering the highest casualties (1,325 deaths), while 5,224 deaths were attributed to violence against civilians, with Kukawa experiencing the highest civilian casualties (2,195 deaths). The conflict has led to widespread displacement, destruction of homes, and disrupted livelihoods, with agricultural and economic activities severely hampered, leading to food insecurity, inflation, and increased poverty.

To assess conflict potential, the study employed a multicriteria approach, using land cover, terrain, and conflict recurrence data. The analysis revealed that most of the study area (54.7%) falls under moderate conflict potential, with 32.5% classified as high potential and 12.8% as low potential. High potential zones were associated with resource-rich areas, such as lakes and water bodies, which are vital for the region's economy, particularly in fishing.

In conclusion, the study provides a comprehensive analysis of the factors driving conflict in the Lake Chad region, the socio-economic impacts, and the potential for future peace initiatives. By utilizing geospatial techniques, the study identifies key conflict zones, provides a better understanding of land use changes, and offers insights into strategic interventions to reduce violence and promote stability in the region.

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