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RESEARCH ARTICLE

VEGETATION COVER DYNAMICS OF THE ECOLOGICAL CORRIDORS OF MAYO-KEBBI WEST IN CHAD FROM 2009 TO 2019

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Abstract

This study highlights the application of remote sensing and Geographic Information Systems (GIS) in monitoring vegetation formations in the Mayo-Kebbi West province. The general objective of this study is to contribute to better management and conservation of vegetation formations in the Léré-Binder wildlife reserves, Sena-Oura National Park, and the Yamba Bertè forest formation. The spatio-temporal evolution of vegetation was analyzed using Sentinel imagery from 2009 and 2019. The results and matrix analyses showed that 42.86% of the land cover units (grassland, shrubland to woodland, and flood zone) experienced a regression of 7.6 ha per year, while 57.14% (water bodies, fields, gallery forest, and open forest) showed progression. It is noteworthy that the main factors driving vegetation degradation are agriculture, livestock farming, logging, charcoal production, and gold mining.

Introduction:-

The importance of forests is undeniable in countries worldwide, as they serve as a source of food and protection, habitat, provider of paper, construction and combustion materials, as well as medicinal plants (F.B. ENONZAN, 2007: p.8). They form a key link between atmospheric layers such as the atmosphere, geosphere, and hydrosphere (CCT, 2008: p.10). For a long time, we have witnessed a tragic event in the Sahelian countries: the desert is gaining thousands of hectares every year. Therefore, we observe a degradation of the natural environment in these regions, namely a regression of wooded areas and an expansion of uncultivated lands. According to the report published in 1992 by the United Nations Convention on Environment and Development (UNCED), desertification affects 25% of the Earth's emerged lands. However, three-quarters of the Sahelian population relies on the exploitation of natural resources for their livelihood (D.G. PODA, 2012: p.12).

Since the advent of the United Nations Conference on Environment and Development, several efforts have been made in developing countries to combat environmental degradation. This degradation, which evolves with bioclimatic conditions and human action, remains worrisome in certain underdeveloped countries (F.B. ENONZAN, 2007: p.18).

In Chad, natural resources, which are under increasing anthropogenic pressure, lead to dysfunction of terrestrial ecosystems and biodiversity loss. These changes, further amplified by inappropriate modes and systems of exploiting available resources in the Mayo-Kebbi West province, have direct repercussions on the forest blocks found there and on the landscape configuration that comprises them.

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During the period between 2009 and 2019, several factors influenced the dynamics of vegetation cover in the ecological corridor of Mayo-Kebbi West. On the one hand, human interventions have had a significant impact on the vegetation of this region. Intensive agriculture, rampant clearing for farmland, excessive logging, and overexploitation of natural resources have led to degradation and loss of vegetation cover. Growing urbanization and the expansion of infrastructure have also contributed to fragmenting natural habitats. On the other hand, climatic factors have also played a key role in the dynamics of vegetation cover in the ecological corridor of Mayo-Kebbi West. Seasonal variations, such as periods of drought and heavy rainfall, influence the growth and composition of vegetation. Extreme events such as prolonged droughts and floods can have a devastating impact on local ecosystems. For example, frequent droughts can lead to a decrease in plant biomass and gradual desertification of certain areas.

However, during this period, several efforts have been deployed to preserve and restore vegetation cover in the ecological corridor of Mayo-Kebbi West. Initiatives have been put in place to raise awareness among local populations about the need to protect ecosystems and promote sustainable agricultural practices. Reforestation and natural regeneration of degraded areas have been encouraged to restore lost vegetation cover.

Beyond human interventions, the dynamics of vegetation cover also depend on the natural regeneration of species. The resilience and restoration capacity of ecosystems depend on the diversity and composition of the native flora present in the region. Studies have been conducted to assess the floristic composition and vegetation dynamics in the ecological corridor of Mayo-Kebbi West. These studies provide a better understanding of regeneration mechanisms and guide conservation and restoration efforts.

Methods and Data Collected:-

The images were downloaded from the following sites:

Sentinel:[https://scihub.copernicus.eu/dhus/#/home](https://scihub.copernicus.eu/dhus/#/home

Landsat :https://glovis.usgs.gov/app?fullscreen=0

In total, six Sentinel scenes were acquired on 11/05/2019, two Landsat 8 OLI scenes were acquired on 11/18/2014, and two Landsat 7 ETM+ scenes were acquired on 11/30/2009.

Table 1:- Characteristics of the Images Used in the Study.

Satellite	Scene Reference	Acquisition Date	Average Resolution	Number of Bands	Bands Used
Sentinel 2	S2A_MSIL1C_20191105T092151_N0208_R093_T33PUL_20191105T104050	05/11/2019	10 m	13	2,3,4,8 and 11
	S2A_MSIL1C_20191105T092151_N0208_R093_T33PVK_20191105T104050	05/11/2019	10 m	13	2,3,4,8 and 11
	S2A_MSIL1C_20191105T092151_N0208_R093_T33PVL_20191105T104050	05/11/2019	10 m	13	2,3,4,8 and 11
	S2A_MSIL1C_20191105T092151_N0208_R093_T33PVM_20191105T104050	05/11/2019	10 m	13	2,3,4,8 and 11
	S2A_MSIL1C_20191105T092151_N0208_R093_T33PWK_20191105T104050	05/11/2019	10 m	13	2,3,4,8 and 11
	S2A_MSIL1C_20191105T092151_N0208_R093_T33PWL_20191105T104050	05/11/2019	10 m	13	2,3,4,8 and 11
Landsat 8 OLI	LC08_L1TP_184053_20141118_20170417_01_T1	18/11/2014	30 m	10	1.2,3,4,5,7 and 8
	LC08_L1TP_184054_20141118_20170417_01_T1	18/11/2014	30 m	10	1.2,3,4,5,7 and 8
Landsat 7 ETM+	LE07_L1TP_184053_20091130_20161216_01_T1	30/11/2009	30 m	12	1.2,3,4,5,6 and 8
	LE07_L1TP_184054_20091130_20161216_01_T1	30/11/2009	30 m	12	1.2,3,4,5,6 and 8

For better discrimination of land cover units, indices were calculated to create new bands. The new channels are as follows:

- NDVI (Normalized Difference Vegetation Index) = (NIR – Red) / (NIR + Red);
- NDWI (Normalized Difference Water Index) = (Green – Red) / (Green + Red);
- IB (Brightness Index) = $\sqrt{(NIR^2 - Red^2)}$;
- IH (Humidity Index) = (MIR – Green) / (MIR + Green).

The new channels were added to the initial bands to create a new multispectral image.

Numerical Interpretation of Satellite Images

Satellite images were processed using QGIS remote sensing software. Specifically, the mosaicking of scenes was performed using standard QGIS remote sensing tools, and false and true color compositions of bands 5,4,3 and 7,5,4 were created to produce red, green, and blue channels, respectively. These compositions were used to differentiate land use units and achieve accurate classification of the images.

For classification, supervised classification was employed. The map layout was prepared using mapping software (ARC-GIS 10.1). The evolution of vegetation formations between the two periods was then assessed using a transition matrix, conversion rates, and annual spatial expansion rates.

a) Mosaicking

Mosaicking involves merging two images from different scenes to create a single image of the study area. The area spans multiple scenes, including 6 Sentinel-2 scenes (2019), 2 Landsat 8 scenes (2014), and 2 Landsat 7 scenes (2009). For each period, the images are merged to cover the study area.

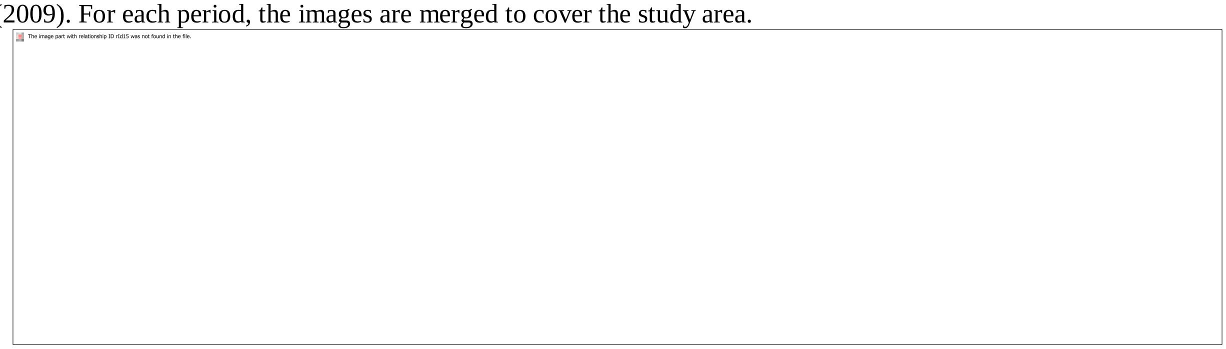

Figure 2:- Mosaicking of Images (Sentinel 2).

Figure 1 shows the mosaicked landscape in the QGIS Remote Sensing software. This represents the first step in image preprocessing.

The evaluation of the classification was carried out using the confusion matrix, which provides the degree of accuracy of the classification. It was performed with the "Maximum Likelihood" algorithm, a probabilistic method. For each pixel, its probability of belonging to one class rather than another is determined. This classification algorithm is quite satisfactory from a mathematical standpoint, as pixels are classified based on probability; this is desirable in image processing, where a single object may contain pixels with very different radiometric values. It also has the advantage of easily providing a measure of the classification quality and allowing for iterative improvements in classification.

After the classification of the images, the field survey, based on randomly extracted coordinates, allowed for the verification of land use units. All detected entities were identified and verified.

Table 3:- Ground Truth Control Sites.

N°	Land Cover Classes	Longitude (X)	Latitude (Y)
1	Fields	14,922186	8,980314
2	Fields	14,93732	8,9822
3	Shrubland to Woodland Savanna	14,910695	8,981022
4	Shrubland to Woodland Savanna	14,923503	8,975999
5	Open Forest	14,926872	8,983036

N°	Land Cover Classes	Longitude (X)	Latitude (Y)
6	Open Forest	14,905473	8,974989
7	Flooded Area	14,9235	8,991077
8	Gallery Forest	14,901765	8,976999
9	Gallery Forest	14,918782	8,987055
10	Grassland Savannah	14,816497	9,35468
11	Grassland Savannah	14,807352	9,362241
12	Open Forest	14,808232	9,34603
13	Open Forest	14,80605	9,356836
14	Grassland Savanna	14,528766	9,542962
15	Open Forest	14,554172	9,572526
16	Gallery Forest	14,555482	9,575355
17	Gallery Forest	14,564598	9,563881
18	Open Forest	14,565489	9,560056
19	Open Forest	15,032549	9,308989
20	Gallery Forest	15,032836	9,30805
21	Shrubland to Woodland Savanna	15,119663	9,222376
22	Grassland Savanna	15,045359	9,300144

Source : Djangrang M., 2019

Mapping of Land Use Dynamics from 2009 to 2019

The mapping of vegetation dynamics and other land use units was carried out using vegetation maps from 2009 and 2019. The evolution of vegetation formations between these two years was assessed through a transition matrix, variation rates, overall evaluation rates, and average annual spatial expansion rates.

a) Identification of Vegetation State Changes

The identification of state changes involves implementing techniques aimed at detecting, highlighting, and quantifying the temporal evolution or state changes of an object or phenomenon from a series of observations taken at different dates. Several methods for detecting vegetation state changes exist, but the comparison method used by Ismaël et al. (2014) was adopted. This method involved interpreting a multi-date series of satellite images and then comparing the areas of land use classes. For this purpose, Sentinel-2 (2019), Landsat 8 OLI (2014), and Landsat (2009) images were interpreted.

The analysis of vegetation state changes was performed through the calculation of the overall rate of change and the annual rate of change.

b) Overall Rate of Change (Tg)

This rate evaluates the spatial variation of vegetation formations and other land use units over a given period (Arouna et al., 2009). It is calculated using the following formula:

$$\mathbf{Tg = \frac{DS}{S_1} \times 100}$$

Where:

- ΔS\Delta SΔS is the change in the area of the vegetation formation between t1 and t2,
- ΔS=S2−S1\Delta S = S2 - S1ΔS=S2−S1, with S1S1S1 being the area of a vegetation unit at time t1, and S2S2S2 being the area of the same vegetation unit at time t2.
- ln denotes the natural logarithm with base eee (where e=2.71828e = 2.71828e=2.71828).

c) Average Annual Rate of Spatial Expansion

The average annual rate of spatial expansion (Oloukoi et al., 2006) represents the proportion of each land use unit that changes annually. This annual rate \(T \), used to analyze land use dynamics in the Collines Department, is calculated using the following formula:

$$T = \frac{\ln S2 - \ln S1}{t \ln e} \times 100$$

Where:

- S1S1S1 is the area of the land use unit at the initial time (t1),
- S2S2S2 is the area of the same unit at the final time (t2),
- ttt is the number of years of evolution (t2 - t1),
- ln⁡\lnln denotes the natural logarithm with base eee (where e=2.71828e = 2.71828e=2.71828).

d) Transition Matrix

The transition matrix highlights the different forms of land use conversions that have occurred between two specific periods. It consists of \(X \) rows and \(Y \) columns. The number \(X \) of rows in the matrix represents the number of land use units at time \(t1 \); the number \(Y \) of columns represents the number of land use units converted by time \(t2 \). The diagonal contains the areas of land use units that have remained stable. Conversions are tracked from rows to columns. The areas of these different land use units were calculated by intersecting land use maps from 2009-2014 and 2014-2019 using the intersect tool in the ArcToolbox of ArcGIS 10.1.

Results:-

State of Vegetation Cover and Other Land Use Units in 2009 and 2019**

State of Vegetation Formations and Other Land Use Units in 2009

The analysis of the land use map from 2009 (Figure 2) shows that the most dominant natural vegetation formations are the wooded savannas, shrub savannas, and forests, which are found throughout the Mayo-Kebbi Ouest province.

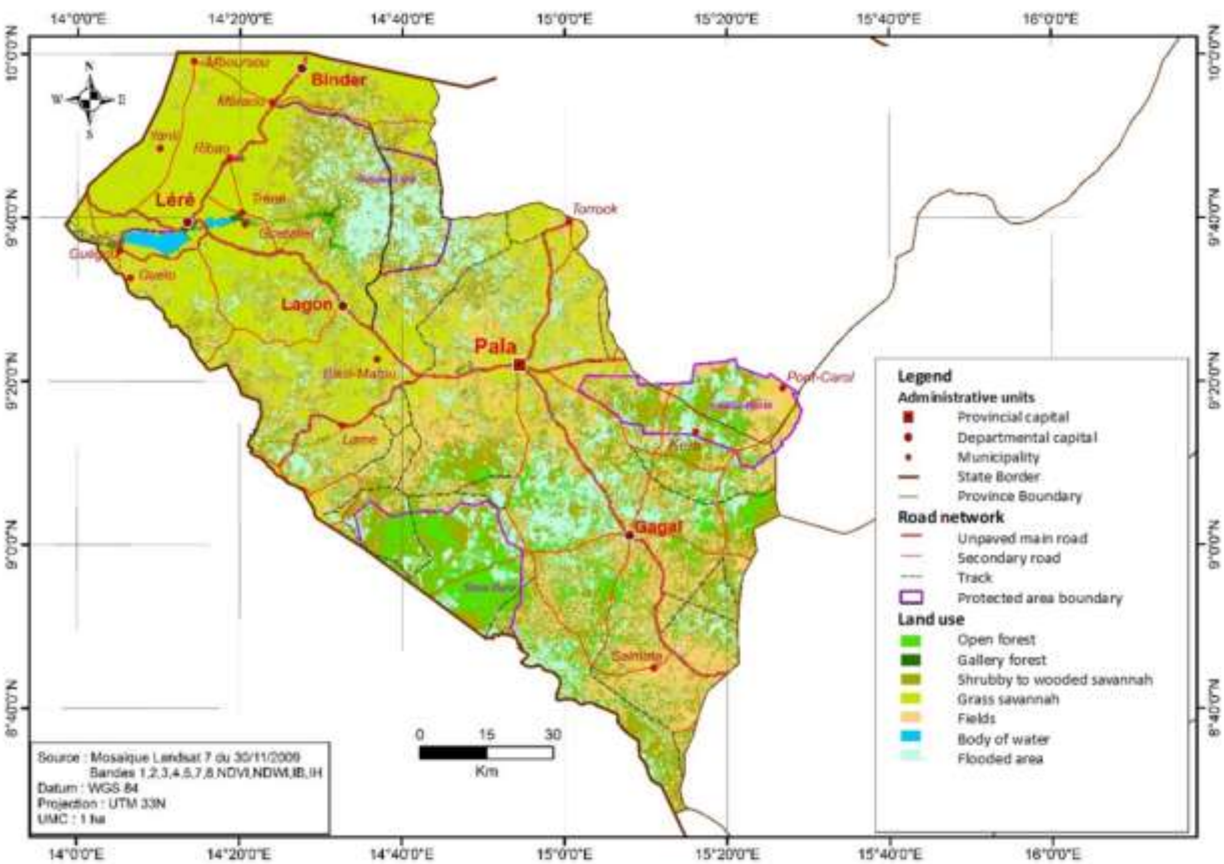

Figure 2:- Land Use in 2009.

The analysis reveals some fragments of dense forest, primarily consisting of the Yamba Berté and Léré-Binder classified forests, and the Sena Oura National Park (PNSO). Mosaic patterns of fields and fallow lands are observed in village areas and within the classified forests. Urban areas are sparsely represented.

Status of Vegetation and Land Use Units in 2019

The interpretation of the 2019 land use map (Figure 3) reveals that mosaics and fallow lands are widespread throughout the Mayo-Kebbi Ouest province, dominating other land use units. Urban areas have expanded compared to 2009. However, the Yamba Bertès and Sena Oura National Park (PNSO) forest blocks have shown significant improvement, whereas the Léré-Binder forest block has experienced a substantial decline.

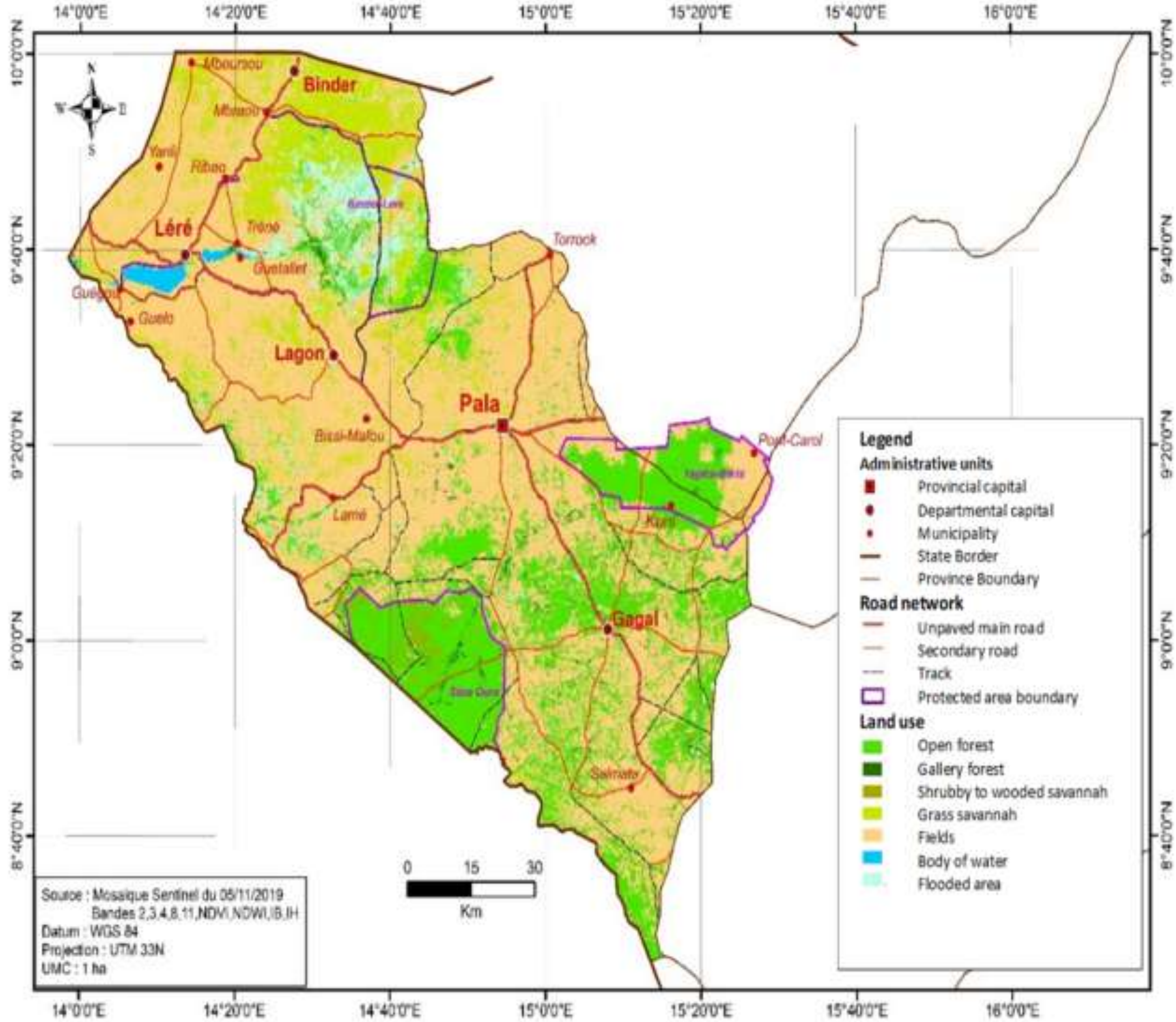

Figure 3:- Land Use Status in 2019.

Dynamics of Land Use Between 2009 and 2019

The dynamics of vegetation formations and other land use units between 2009 and 2019 are summarized by the transition matrix (Table III). The cells in the rows and columns represent vegetation formations and other land use units, respectively. The units along the diagonal correspond to the areas of units that remained stable between 2009 and 2019 (Figure 4). Units outside the diagonal represent changes in the state of vegetation and other land use units.

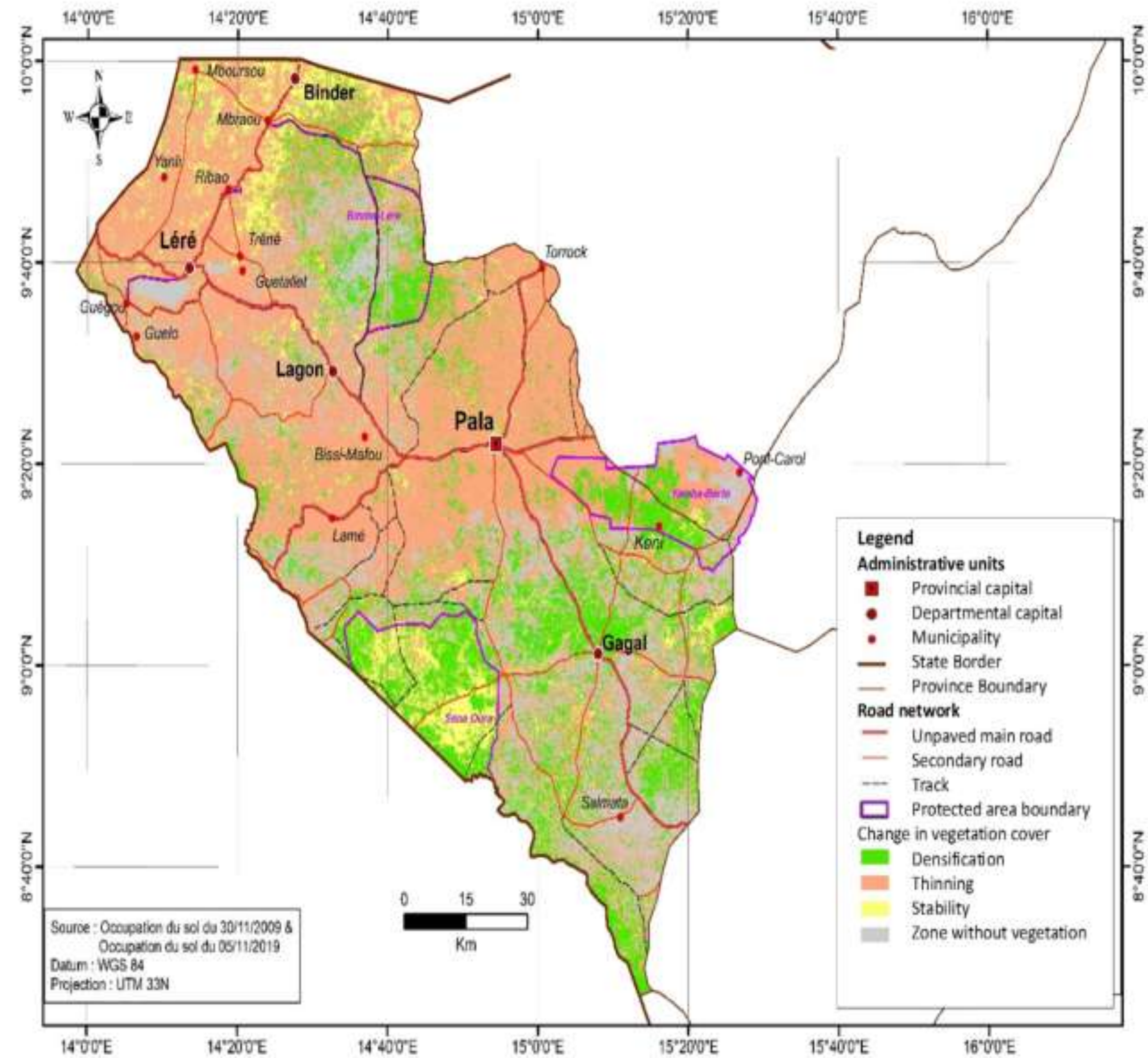

Figure 4:- Vegetation Change Map Between 2009 and 2019.

Figure 14 shows that six (06) land cover classes were observed in both 2009 and 2019. The analysis highlights the changes in these land cover units.

Gallery Forests :

These areas have experienced a gradual increase. From 8,688.6 ha in 2009, they grew to 14,676.3 ha in 2019, representing a proportional increase with an average annual growth rate of 0.7%.

Open Forests:

From 2009 to 2019, open forests saw a significant increase of 19.5%. In 2009, these formations covered an area of 93,717.5 ha, which expanded to an estimated 276,188.3 ha in 2019.

Shrub and Tree Savanna:
The area of this unit decreased from 329,924.6 ha in 2009 to 14,746.46 ha in 2019. The average annual expansion rate was 9.6%, with 315,178.1 ha transformed into crop and fallow mosaics and the remainder into settlements, totaling 329,924.6 ha.

Crop and Fallow Mosaics :
This class showed a progressive increase with a proportional rate of 20.3%. The area expanded from 249,336.95 ha in 2009 to 756,475.09 ha in 2019 (Figure 5).

Water Bodies :
The area of this land cover unit underwent a slight change within the study area, increasing from 5,545.19 ha in 2009 to 8,100.93 ha in 2019.

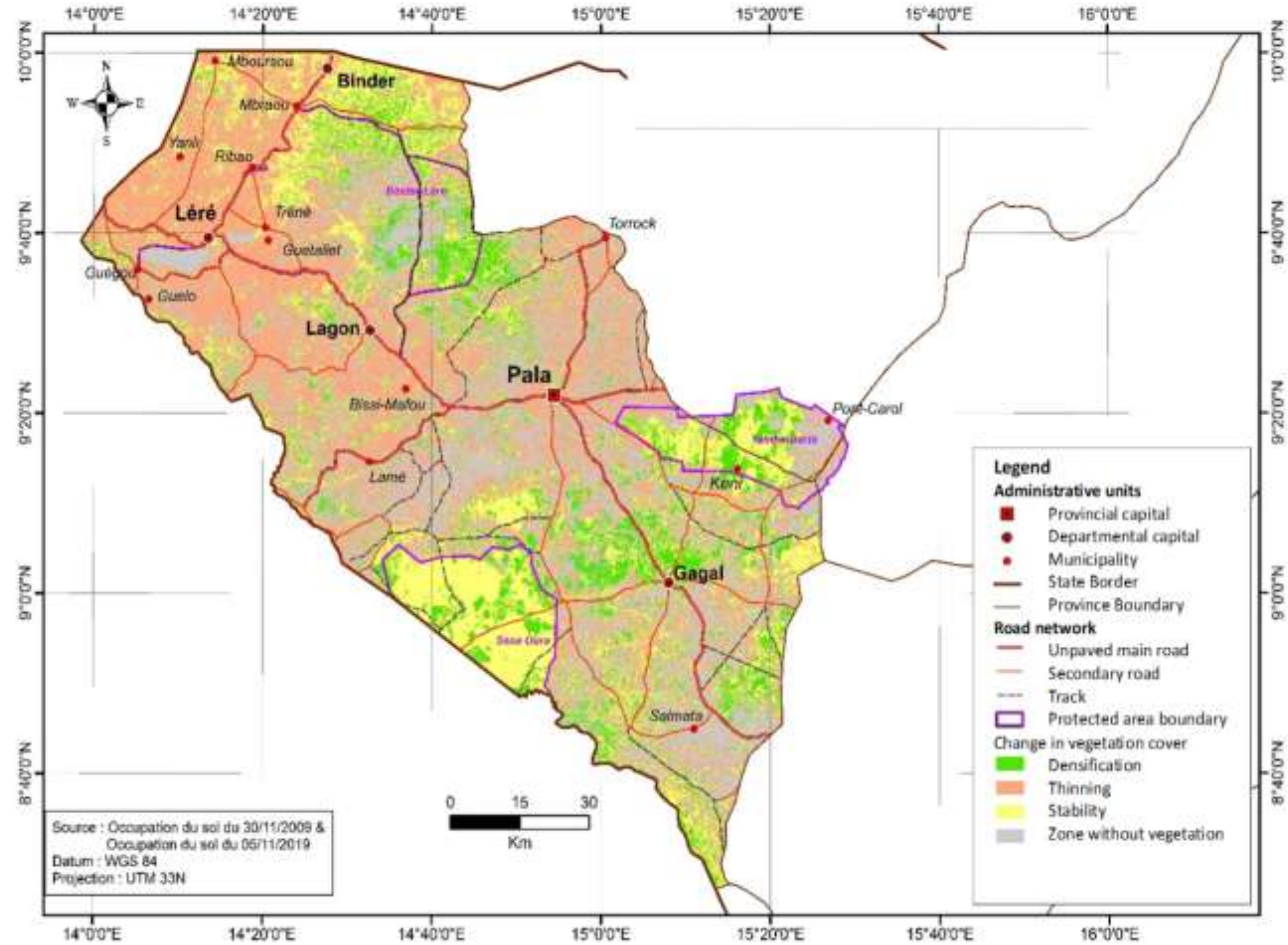

Figure 5:- Comparative Evolution of Land Cover Units Between 2009 and 2019.

From the analysis of Figure 5, it is observed that the state of vegetation has undergone a significant regression of all natural vegetation formations in favor of other land cover units between 2009 and 2019.

During this period, mosaic cultures and fallow lands, along with human settlements, experienced the largest expansions. The slight decrease in wooded and shrubby savannas observed in 2019 is attributed to the fact that the proportion of these formations converted to other land cover units was offset by the conversion of mosaic cultures, fallow lands, and settlements. However, it should be noted that not all classes remained the same between these two years. Gallery and clear forests increased in area. It is assumed that the implementation of Law 14/PR/2008 on forest, wildlife, and fishery resources has been effective in reducing the number of activities in protected areas. The phytomass calculations support this conclusion.

The phytomass of shrubs in the wooded/shrubby savanna is 1.97 times greater than that of the clear forest, 2.12 times greater than that of the gallery forest, and 33.92 times greater than that of the field.

Local Population Perceptions of Vegetation Formation Dynamics in Mayo-Kebbi West Province
Farmers play a significant role, through both direct and indirect actions, in shaping vegetation dynamics. They often engage in intensive land clearing to increase agricultural production or exploit forests, sometimes resorting to the use of fire. We have observed that the demand for wood, agricultural techniques, logging, and hunting play a decisive role in altering the vegetation's appearance. In summary, the challenges of forest block degradation can be categorized into four main areas:
- Forest exploitation;
- Intensive land clearing (Agriculture);
- Transhumance;
- Vegetation fires;
- The weight of history.

a) Forest Exploitation
Forest exploitation is carried out haphazardly, often in disregard of the country's forestry regulations, with the exception of the PNSO (Sena Oura National Park). This exploitation primarily targets fuelwood and charcoal, which are mainly intended to supply the city of Pala and its surrounding areas.

b) Intensive Land Clearing (Agriculture)
To meet their food needs, the increasing number of farmers resort to intensive land clearing through inappropriate practices. The clearing of forests to expand agricultural lands contributes to a rise in the amount of carbon dioxide released into the atmosphere. The loss of thousands of animal and plant species in various forest formations is driven by poverty and demographic pressures. This loss is also largely due to the ever-growing demand for firewood and food, coupled with the clearing of new areas. The urgent need for foreign exchange (especially with the introduction of cash crops such as peanuts, sesame, maize, etc.) encourages people to exploit forests indiscriminately and convert forested areas into agricultural lands. In almost all villages, agriculture remains a primary economic activity.

c) Transhumance
This activity is practiced in and around forest blocks with varying intensity. Two modes of livestock farming coexist: sedentary and nomadic. The farmers' herds mainly consist of small ruminants (goats and sheep), pigs, and a few draft animals (cattle). They also keep poultry, which is allowed to roam freely. Of the entire domestic livestock, poultry represents 45%, followed by goats (26.6%) and cattle (Ponka, 2018).

During the dry season, animals are allowed to graze in fields to consume crop residues. In the rainy season, cattle are sent to pastures away from crop areas, while small ruminants are kept in place.

Nomadic herding is practiced by the Mbororo pastoralists, who have much larger herds, predominantly consisting of large ruminants. In the dry season, there is a trend towards the sedentarization of the Mbororo, who take advantage of the constant greenery and water for their cattle. This practice contributes to the destruction of woody vegetation.

d)**Vegetation Fires**
In the Mayo-Kebbi Ouest province, vegetation fires are a cultural phenomenon and an integral part of the farmers' lives. They are traditionally used for several reasons:
- field Cleaning,
- hunting:.
- easier Movement:
- post-Harvest Cleaning:
- protection of Crops

However, sometimes the control of these fires escapes the farmers, who are unable to manage them effectively. These devastating fires, sometimes set on vast areas, engulf entire forests. Often, the perpetrators are not held accountable. Among these fires, we can mention:

- Pastoral fires, primarily aimed at regenerating pastures sought by livestock during the dry season;

- Creeping fires, fueled by discontinuous grassy cover, which dry out the shrubs;
- Running fires or "harvest" fires, which are more violent and engulf most shrubs, limiting their proliferation;
- Bush or canopy fires that spread both horizontally and vertically through the foliage: these are the most destructive to woody plants.

However, whether early or late, vegetation fires are significant environmental destructors. The damage they cause is extensive. Notable effects include:
- loss of Biodiversity:
- soil Degradation
- air Pollution.
- climate Change
- displacement of Wildlife
- destruction of Resources

d) Historical Factors
History today is a crucial factor in the degradation of vegetation cover. The land acquisition system generates numerous conflicts within our country, including in the Mayo-Kebbi Ouest province. Conflicts arise in the participatory management of forests, where one party does not acknowledge the rights of the other. Vegetation fires continue to ravage the forest daily. Despite the establishment of forest protection laws designed to preserve vegetation cover, these laws have remained unenforced.

Discussion and Conclusion:-
Understanding the distribution pattern of plant species and the factors governing them is crucial for the conservation and management of ecosystems (Adomou et al. 2009). Numerous studies have shown that, in many areas, the processes occurring in the landscape result from interactions between socio-environmental systems and take place within characteristic scale ranges (Quattrochi et al. 1997).

From 2009 to 2019, the proportion of natural vegetation formations, specifically bush and tree savannas, decreased from 329,924.57 ha to 14,746.46 ha, representing a reduction of 315,178.11 ha. In contrast, field mosaics and fallow lands increased in area. This regressive dynamic in vegetation formations is attributed to anthropogenic pressure. Indeed, agriculture, livestock, and forestry exert pressure on vegetation formations, either for clearing new cultivable lands, grazing, or harvesting valuable tree species. Several studies have confirmed the degradation of the forest massif (Djangrang et al., 2019). Participatory management of these protected areas is one of the best means for conserving natural resources. Forest management should involve monitoring deforestation caused by human activities (clear-cutting, bushfires, agricultural expansion, livestock transhumance), as well as monitoring health and growth for conservation and commercial exploitation. Additionally, it should incorporate new geoinformation technologies (ENONZAN, 2012). The vegetation of the studied classified forests develops on a hierarchical and disturbed spatial structure, characterized by the dominance of gallery forests and the co-dominance of wooded savannas and tree savannas (Djangrang M., et al., 2019).

The results of these studies indicate a general trend of vegetation cover degradation in the Mayo-Kebbi Ouest ecological corridor between 2009 and 2019. Anthropogenic pressure, intensive agricultural practices, and extreme climatic events have negatively impacted vegetation cover, leading to biodiversity loss and habitat fragmentation. However, significant progress has been made in ecological restoration through reforestation projects, local community awareness, and the adoption of sustainable agricultural practices.

It is important to note that the dynamics of vegetation cover in the Mayo-Kebbi Ouest ecological corridor are complex and will be influenced by many other factors in the coming years. Environmental policies, sustainable development choices, international cooperation, and local community engagement will play a crucial role in preserving and restoring the vegetation cover of this region. Coordinated efforts at all levels are necessary to promote environmental conservation and the sustainability of natural resources.

The dynamics of vegetation cover in the Mayo-Kebbi Ouest corridor in Chad between 2009 and 2019 have thus been marked by biodiversity loss, vegetation cover degradation, and habitat fragmentation due to the impact of human activities and extreme climatic events. However, significant efforts have been made to restore the region’s vegetation cover through reforestation projects, awareness programs, and the adoption of sustainable agricultural practices. The future of vegetation cover in this area will depend on political, economic, and social choices made to promote the conservation and sustainability of natural resources.

References:-

1. Abdelbaki Amina, 2012. "Utilization of GIS and remote sensing in the study of vegetation cover dynamics in the Oued Bouguedfine sub-basin." Master's Thesis, Rectas/ILE-IFE. 110 pp.
2. Abib F. C., 2005. "Quantification of carbon in some humid savannas of Ngaoundéré, Cameroon." Master's Thesis. 31 pp.
3. Adomou Aristide, Adi Mama, Missikpode Robert, and Sinsin Brice, 2009. "Mapping and floristic characterization of the Lokoli swamp forest (Benin)." Journal Home Vol 3 No 3, pp. 12.
4. Bogaert Jean & Mahamane Ali, 2005. "Landscape Ecology: Targeting Configuration and Spatial Scale." Annales des Sciences Agronomiques du Bénin (7) 1: 39-68.
5. Enonzan Bibiane Folohouncho, 2012. "Use of remote sensing and GIS in sustainable management of protected areas: Case of the Dogo-Kétou classified forests in Benin." Master's Thesis, Rectas/ILE-IFE. 83 pp.
6. Gockowski, J.J. & Dury, S., 1999. "The economics of cocoa-fruit agroforests in Southern Cameroon." In F. Jiménez & J. Beer (eds.), Multi-strata Agroforestry Systems with Perennial Crops, pp. 239-241. Turrialba, CATIE.
7. Greg G., Brown S., Massimimiliano L., and Singht K.D., 1998. "State and change in carbon pools in the forests in tropical Africa." Global Change Biology 4: 97-114.
8. Ibrahim A. & Habib F., 2008. "Estimation of carbon stock in arboreal and shrubby facies of the Sudan-Guinean savannas of Ngaoundéré, Cameroon." In Cameroon Journal of Experimental Biology, Vol. 04 No 01, pp. 1-11.
9. Jarkko K., Pekka N., Frank B., and Olavi L., 2000. "Tropical Forestry Reports 22: Implications of the Kyoto Protocol for tropical forest management and land use: Prospects and Pitfalls." Helsinki. 103 pp.
10. Lamotte M. & Brulière F., 1983. "Energy flow and nutrient cycling in tropical savannas." In: Ecosystems of the World 13: Tropical Savannas (ed. Boulière F.), pp. 583-603.
11. Peltier R., Njiti M., Ntoupka K., Moulay M., Henry V., & Moulou G., 2007. "Assessment of carbon stock and wood productivity in a Shea Park in Northern Cameroon." Revue Bois et Forêt des Tropiques, 294(4), pp. 39-50.
12. Rapport ENV-SRAE–94233, Paris, France, 6 pp.
13. Roche Philip, 1998. "Dynamics of biodiversity and human impact."
14. Saïdou A., Dossa A. F. E., Gnanglè P. C., Balogoun I., & Aho N., 2012. "Assessment of carbon stock in shea (Vitellaria paradoxa C.F. Gaertn.) and locust bean (Parkia biglobosa Jacq. G. Don) agroforestry systems in the Sudanian zone of Benin." Bulletin de la Recherche Agronomique du Bénin (BRAB). Special Issue Agriculture and Forest. pp. 1-9.
15. Saliou Abdou Rachidi Akingbé, 2011. "Application of remote sensing and geographic information systems for the sustainable management of ecotourism in the National Park of Tourism (Northern Benin)." Master's Thesis, Rectas/ILE-IFE. 72 pp.
16. Serpentier G. & Ouattara G., 2000. "Fallow land in tropical Africa: Roles, management, and alternatives." Edited by Ch. Floret & R. Pontanier. From natural fallow to improved fallow. Knowledge Update 1: 40-335.
17. Tchibozo Eric. Alain & Domingo Etienne, 2014. "Land use and analysis of the spatial structure of classified forests: Case of Dogo-Kétou in the Center-East of Benin." Revue de Géographie du Laboratoire Leïdi – ISSN 0851 – 2515 – No 12, December 2014. 16 pp.
18. Tchobsala, 2011. "Influence of timber harvesting on vegetation dynamics in the peri-urban area of Ngaoundéré (Adamaoua) Cameroon." PhD Thesis. 205 pp.