Scientific Research Publishing

Journal of Geoscience and Environment Protection, 2024, 12, 164-179
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Anthropogenic Threats to Degraded Forest Land in the Savannahs' Region of Togo from 1984 to 2020, West Africa

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How to cite this paper: Ehlui, K. S., Atakpama, W., von Wehrden, H., Bah, A., Kola, E., Anthony-Krueger, C., Egbelou, H., Kokou, K. B., & Boukpessi, T. (2024). Anthropogenic Threats to Degraded Forest Land in the Savannahs' Region of Togo from 1984 to 2020, West Africa. *Journal of Geoscience and Environment Protection, 12,* 164-179.
https://doi.org/10.4236/gep.2024.121011

Received: December 14, 2023
Accepted: January 26, 2024
Published: January 29, 2024

Abstract

This study focuses on the landscape dynamics of the savannahs' region in the far north of Togo. Based on a literature review and satellite images analysis using GIS and remote sensing, the study aims to ascertain the effects of anthropogenic threats on the forest coverage of the Savannahs' Region between 1984 to 2020. The objective is to clarify the dynamics of land use in the region from 1984 to 2000 and from 2000 to 2020. The findings indicate a significant decline in forest coverage within the region from 1984 to 2020, a trend attributed to land use patterns. Dry forests in the Savannah region are largely converted to farmlands, housing, dry savannahs or agroforestry parks, leading to a steady reduction in forest areas.

Keywords

Forest, Degradation, Land Use, Land Cover, Savannahs Region, Togo

1. Introduction

Forest resources worldwide, particularly in tropical regions, are experiencing unprecedented degradation due to a number of factors, including human activities and climate change (Dourma, Soou, & Atakpama, 2019). The primary drivers of forest degradation are human activities such as population growth, urban sprawl, and agricultural and agro-pastoral practices. Furthermore, the impacts of global climate change alongside the decline in rainfall and increasing temperatures in certain regions have resulted in the decrease or possible eradication of tropical forests (Barima, Kouakou, & Bamba, 2016). This situation is leading to a decline in biological diversity and an imbalance in local ecosystems. The unsustainable overuse of resources and lack of control over worsening climatic conditions are increasing the risk of the extinction of tropical forest resources. Forest ecosystems in West Africa are currently facing unparalleled pressures attributable to both climate and human activities (Atakpama et al., 2023).

In Togo, the forest cover of the country is estimated at 24.66% in 2021 (MERF /REDD+, 2020). Although the government has endeavored to conserve forest resources through creating national wildlife reserves since the 1980s, there has been a deterioration in forest cover to this day. Most of the policies have encountered resistance from local populations due to their at times forceful and non-inclusive implementation. This was the situation with the Oti Keran Mandouri Park, which primarily covers the Savannah Region and a portion of the Kara Region (Polo-Akpisso et al., 2018).

In this context, comprehension of landscape dynamics, specifically the various forms of land cover/land use and their changes over time, is crucial for implementing measures aimed at safeguarding, preserving or renewing the forest ecosystems of the region. The use of geographic information systems and remote sensing has proven to be successful tools for both monitoring and understanding landscape dynamics.

Limited research has been conducted on the overall landscape dynamics of the region. Previous studies have concentrated primarily on particular forest ecosystems like the Oti Keran Mandouri as well as specific protected areas.

The objective of this study is to offer lucid information on landscape dynamics in the region from 1984 to 2000 and from 2000 to 2020. Specifically, the study aims to identify the different types of land use and the different changes that have occurred in these types of land use over time.

2. Methods and Materials

2.1. Description of the Savannah Region

The Savannahs region (West Africa) is one of the five administrative and economic regions in Togo. It is located in the northern part of the country (**Figure 1**). The region experiences a Sudano-Sahelian climate characterized by a prolonged dry season that stretches from October to May, followed by a four-month-long wet season.

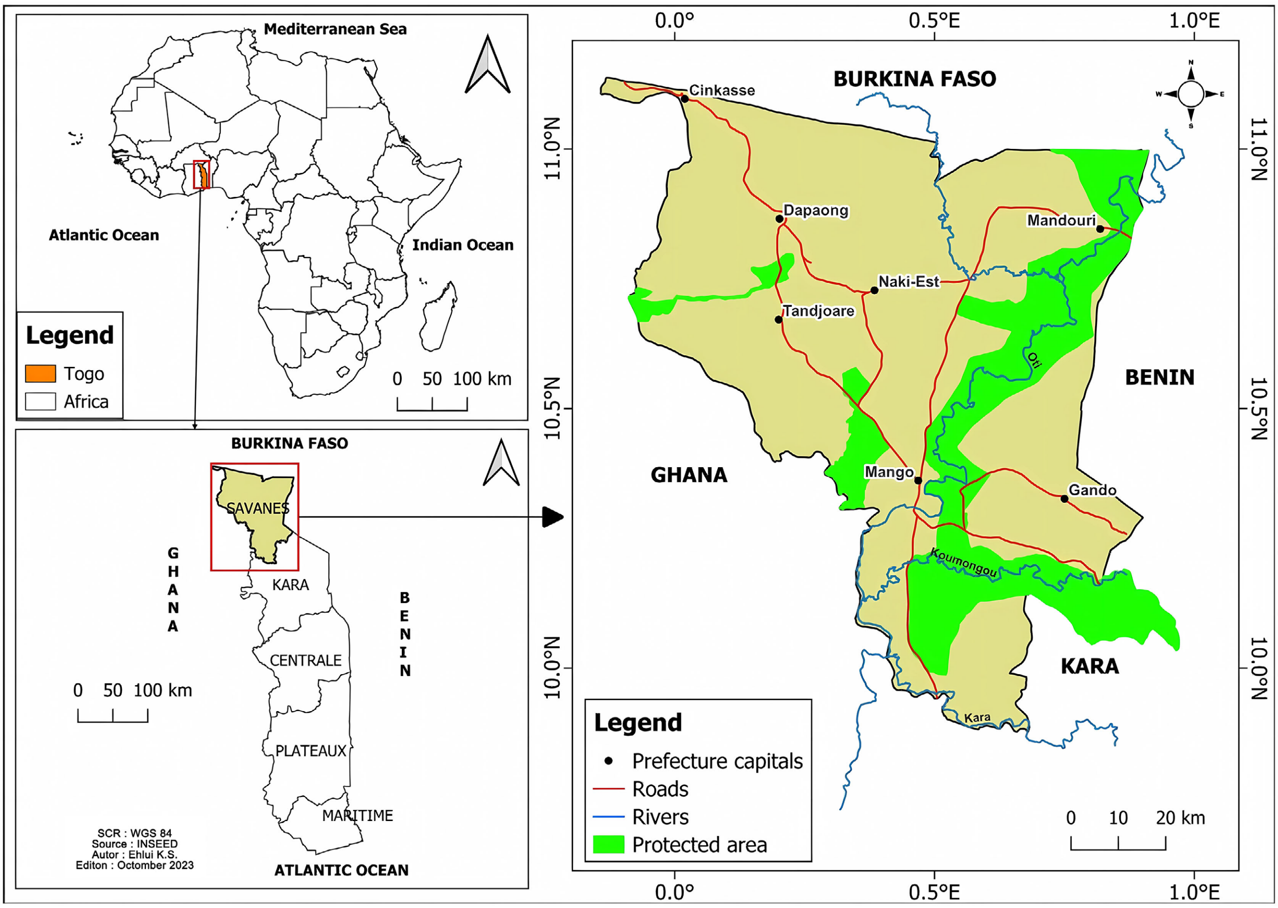

Figure 1. Location of the Savannahs' region of Togo and Togo in West Africa.

The region is characterised by savannahs, especially Soudanian savannahs (Brunel et al., 1984), due to the climate type. Dry dense forests are found along rivers and occasionally in protected zones (Diwediga et al., 2012; Folega et al., 2014; Folega et al., 2020). The most commonly occurring ecosystems, however, are anthropogenic, consisting of farmlands and agroforestry parklands (Folega, 2019). Several types of agroforestry parklands can be found. The following agroforestry trees are commonly found: shea tree (*Vitellaria paradoxa*), African locustbean (*Parkia biglobosa*), tamarind tree (*Tamarindus indica*), roast palms (*Borassus* spp) and African baobab (*Adansonia digitata*) (Kebenzikato et al., 2014; Padakale et al., 2015; Folega et al., 2019; Atakpama et al., 2022; Samarou et al., 2022b). Non-timber forest products from these agroforestry trees are crucial for the socio-economic livelihoods of the local community (Padakale et al., 2018; Samarou et al., 2021; Samarou et al., 2022a; Kebenzikato et al., 2023). It is imperative to conserve and improve these resources to enhance local resilience to climate change.

The Savannah Region is home to four main Protected Areas (PAs): the Oti-Kéran-Mandouri Biosphere Reserve, the Galangashi Classified Forest, the Barkoissi Classified Forest, and the complex of the Lion's Den Reserve-Classified Forest of Doungh (MERF/REDD+, 2020). Since 1990, social and political instability has resulted in significant degradation of these protected areas (Folega et al., 2012). The region has been impacted by encroachment from human settlements, cultivated land, and timber and non-timber forest product extraction (Folega et al., 2012; Polo-Akpisso et al., 2018; Badjare et al., 2021; Atakpama et al., 2023). There are sacred groves in the region, which are a traditional means of preserving biodiversity (Atakpama et al., 2021; Atakpama et al., 2022). In addition, new community forest settlements have been established (Assima, 2023).

2.2. Data Collection and Analysis

The methodological approach adopted was based on the remote sensing and geographic information systems (Koumoi et al., 2013; Kombate et al., 2022). Three categories of satellite images with a resolution of 30 m have been used: Landsat TM for 1984, ETM for 2000 and OLI_TIRS for 2020. These images were downloaded from the website of the US space agency (https://earthexplorer.usgs.gov/). The projection adopted was WGS 1884/UTM zone 31N.

The Landsat images obtained were processed utilizing the ENVI 4.7 software. The digital image classification procedure encompassed the selection of colour compositions, defining the ROI (Regions of Interest), selecting training plot samples, describing and filling different classes, and the selection of the classification algorithm (Kombate et al., 2020). Land use types were identified and training areas were delineated by visually interpreting the images following colour composition. The GPS data collected in the field further reinforced the delineation of these training areas.

Supervised classification was preferred as it provides consistent treatment to each pixel, regardless of its neighbourhood (Kombate et al., 2023). The maximum likelihood algorithm was chosen for image classification. It calculates the likelihood of a pixel belonging to one class compared to another. The pixel was then assigned to the class with the greatest likelihood.

Spectral matching was employed in the classification of images from 2000 and 1984, utilizing spectral identification and recognition of land cover classes based on the 2020 image. Once classification was accomplished, post-processing was conducted to polish the results. To assess the accuracy of the classifications, a confusion analysis (Foody, 2002) was implemented. Classification validation relied on overall accuracy (percentage of well-classified pixels) (Skupinski et al., 2009), ground truth points, and Google Earth images.

The nomenclature for the various categories aligns with the Togo classification system (Skupinski et al., 2009). The respective areas of the different land use classes were estimated using QGIS 3.30, which was also utilised for the cartographic visualisation.

3. Results

3.1. Land Use in the Savannahs' Region of Togo

Define the overall accuracy for the three classified images in 1984, 2000, and

2020 stood at 89.53%, 81.20%, and 92.57%, respectively. The study identified five different land use types, including building, croplands/agroforestry parklands, riparian/dry forests, water bodies, and savannahs (Figure 2). The Savannah region in 1984 was mainly occupied by riparian/dry forest (44.64%), followed by savannah (31.53%) and crops/fallow (23.58%). In 2000, the Savannah ecosystems dominated the region with a share of 60.28%. This was followed by Cropland/Agroforestry Parkland (26.58%) and Riparian/Dry Forest (12.55%). Buildings and water bodies were poorly represented, comprising 0.44% and 0.14%, respectively. As of 2020, Cropland/Agroforestry Parkland dominates the Savannahs region with 49.47% share, followed by Savannahs (36.76%) and Riparian/Dry Forests (9.93%). Water bodies account for only 0.08%, while Buildings represent 3.75% (see Figure 2).

3.2. Land Use and Land Cover Dynamics

Only riparian and dry forests experienced a decrease of −71.85% between 1984 and 2000, among all identified land uses. The area occupied by buildings saw a remarkable increase of 171.26%, from 1396.88 hectares in 1984 to 3789.12 hectares in 2000. Buildings continued to experience a spectacular increase of 746.56% between 2000 and 2020. Croplands and agroforestry parklands showed an increase of 86.10%. In contrast, the areas of riparian and dry woodland, water bodies, and savannahs decreased by −20.90%, −41.04%, and −39.01%, respectively (Table 1; Figure 3).

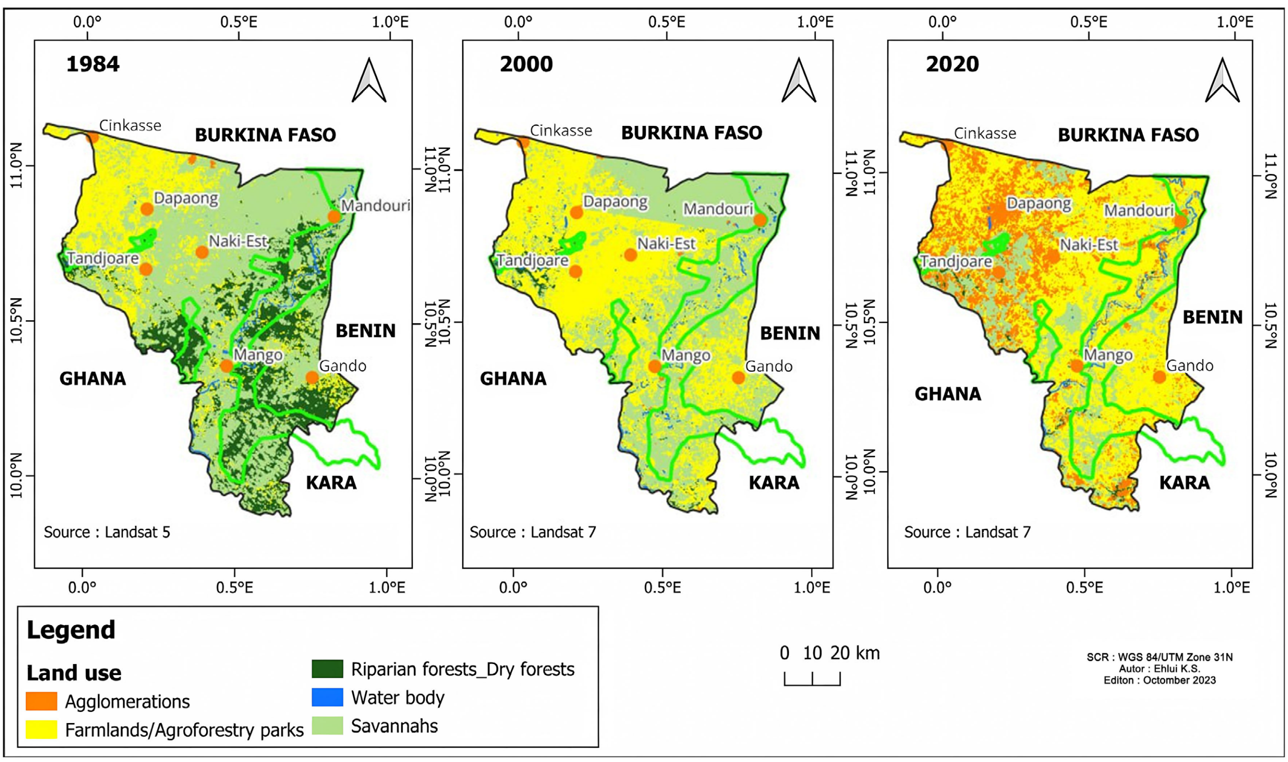

Figure 2. Types of land use in the savannah region of Togo in 1984, 2000 and 2020.

Table 1. Land use change in Savannahs' Region of Togo from 1984 to 2020.

	Area (ha)			Rate of change (%)	
LUT	1984	2000	2020	1984-2000	2000-2020
BA	1396.88	3789.2	32078.12	171.26	746.56
C/AP	201587.64	227449.41	423284.32	12.82	86.10
RF/DF	381679.9	107408.94	84959.99	−71.85	−20.90
WB	815.61	1189.31	701.18	45.81	−41.04
Sa	269608.96	515733.14	314546.38	91.28	−39.01

LUT = Type of land use, BA = Bulding areas, C/AP = Croplands/Agroforestry parklands, RF/DF = Riparian Forets/Dense Forests, WB = Water bodies, Sa = Savannahs.

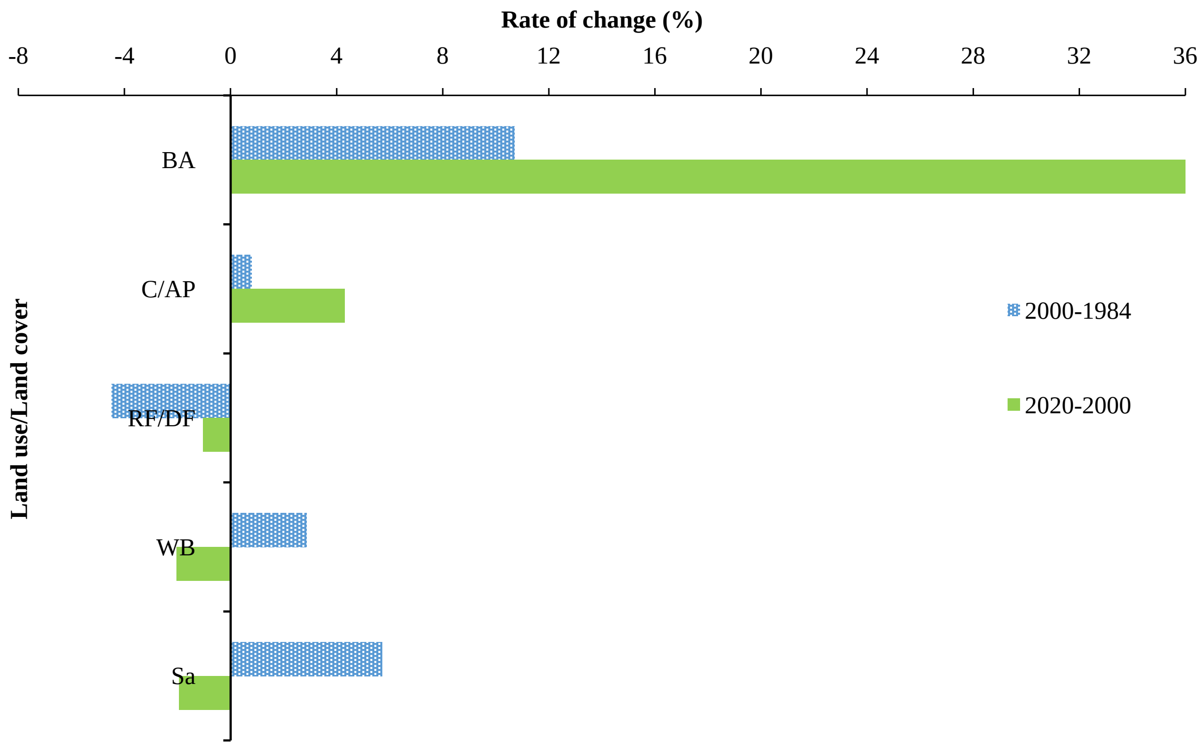

Figure 3. Land use and land cover change in Savananahs' Region from 1984 to 2020. BA = Bulding areas, C/AP = Croplands/Agroforestry parklands, RF/DF = Riparian Forets/Dense Forests, WB = Water bodies, Sa = Savannahs.

3.3. Land Use Transition Matrix

Between 1984 and 2020, the savannah region of Togo underwent significant changes classified as gains, losses, and stability (Figure 4). To identify the main conversions that occurred between 1984 and 2000, one can analyze the transition matrix shown in Figure 4. Losses occurred when forest land was converted to savannah, cropland/agroforestry parkland, or building land; whereas, the change was viewed as a gain. If the land use and cover remain constant, this is referred to as stability. The primary losses occurred in protected areas between 1984 and 2000, resulting in declining vegetation. Outside of these areas, losses between 2000 to 2020 were mainly observed. Arable and agroforestry parklands were especially

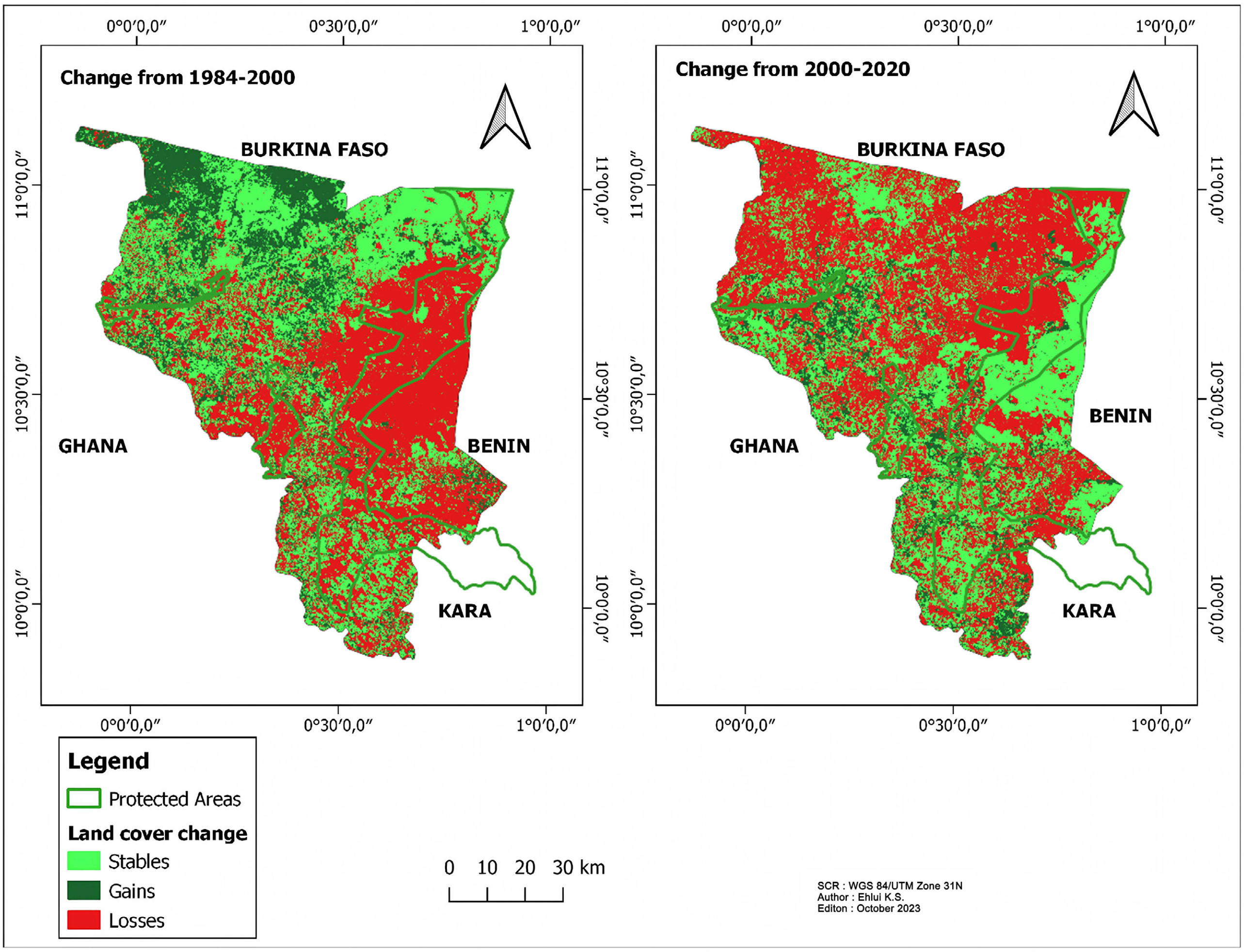

Figure 4. Global change of land use/land cover from 1984-2000 and 2000-2020 in Savannahs' Region of Togo.

affected and were converted into building areas. These losses are highlighted in red and are situated in the region's northern section, which have previously been stable or experienced gains.

Further information on the changes within each land type is outlined in Figure 5. The data indicates that 28.95% of riparian/dry forests have been converted to savannahs, while 7.17% and 7.07% were converted to croplands/agroforestry parklands respectively (refer to Table 2).

In the period spanning 2000 to 2020, it is projected that 26.67% of savannahs will be converted to croplands/agroforestry parklands, and 3.91% to riparian forests/woodlands. A proportion of 3.88% of riparian and dry forests has been transformed into croplands and agroforestry parklands, while 4.94% of croplands and agroforestry parklands have undergone conversion into savannahs.

4. Discussion

Geospatial analysis has long been employed by various authors to study land cover and land use dynamics. This is evident in the works of Pérez-Vega et al (2012), Aguejdad et al. (2016), Agbanou et al. (2018) and Osseni et al. (2023).

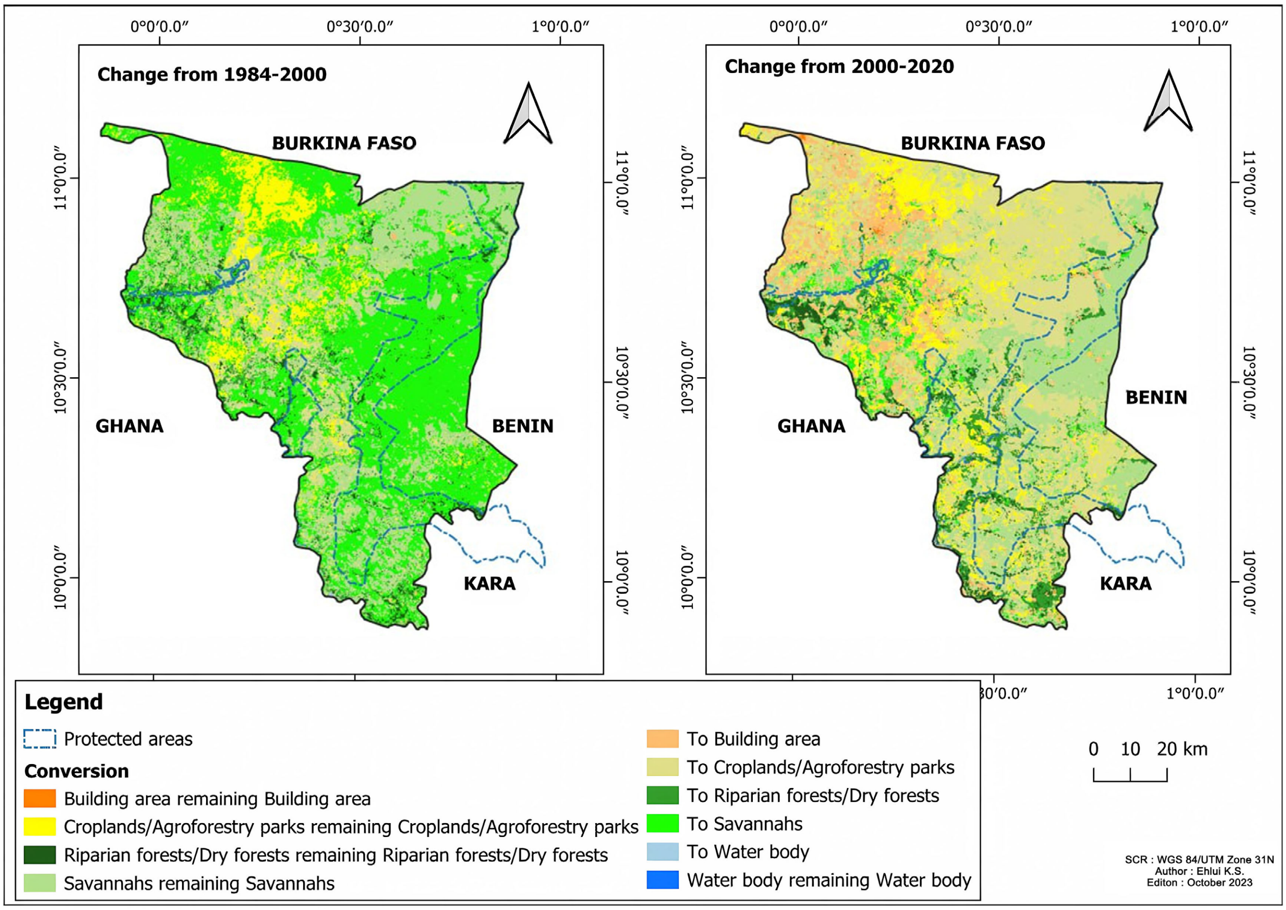

Figure 5. Changes in each type of land use from 1984-2000 and 2000-2020 in the Savannahs' Region of Togo.

Table 2. Land use transition matrix 1984-2000 and 2000-2020.

			1984-2000			
LUT (%)	**BA**	**C/AP**	**RF/DF**	**WB**	**Sa**	**Total 1984**
AG	0.04	0.03	0.00	0.00	0.09	0.16
C/AP	0.10	12.31	1.58	0.01	9.57	23.58
RF/DF	0.17	7.07	8.38	0.07	28.95	44.64
WB	0.00	0.00	0.04	0.03	0.03	0.10
Sa	0.14	7.17	2.54	0.03	21.65	31.53
Total 2000	0.44	26.58	12.55	0.14	60.29	100
			2000-2020			
LUT (%)	**BA**	**C/AP**	**RF/DF**	**WB**	**Sa**	**Total 2000**
BA	0.07	0.20	0.06	0.00	0.12	0.44
C/AP	1.52	18.71	1.41	0.00	4.94	26.58
RF/DF	0.82	3.88	4.51	0.03	3.32	12.55
WB	0.01	0.01	0.05	0.04	0.03	0.14
Sa	1.34	26.67	3.91	0.02	28.35	60.28
Total 2020	3.75	49.47	9.93	0.08	36.76	100

LUT = Type of land use, BA = Bulding areas, C/AP = Croplands/Agroforestry parklands, RF/DF = Riparian Forets/Dense Forests, WB = Water bodies, Sa = Savannahs.

Several remote sensing methods are available for land cover mapping. However, the maximum likelihood algorithm-based supervised classification method is the most common and effective approach used by researchers (Masoud & Koike, 2006). The creation of training zones in accordance with the user's knowledge of the study sector provides enhanced flexibility. In this study, our maps were deemed reliable and acceptable based on the image classification acceptance scale suggested by Pontius (2000) with an overall accuracy result of (>80%), as demonstrated by Li et al. (2013) and Mama et al. (2013). The maps produced by this study present several challenges. There were difficulties in separating the dense forest, savannah, and field/fallow categories, indicating complexity within the socio-ecosystems. Moreover, a lack of time series of high-quality satellite images hindered this study. Regardless, remote-sensing pre-processing methods were utilized to make corrections specific to each image's characteristics. Standardization of the visual rendering of the colour composite images was achieved through this processing. The study applied a cartographic approach to land cover using classifications from Landsat MSS, ETM+ and OLI TIRS satellite images in conjunction with ground truth data. Results showed a highly appreciable level of overall accuracy (Kombate et al., 2023), with accuracy rates of 89.53% for 1984, 81.20% for 2000 and 92.57% for 2020. According to the criteria outlined by Landis and Koch (1977) and Streiner, Norman, & Cairney (2014), achieving an overall accuracy rate higher than 74% is classified as "Very good" to "Excellent" (Barima et al., 2009). Nonetheless, authors recorded low classification accuracy levels of 61% and 51% respectively during their research (Khorram et al., 1999; Pham & Triantaphyllou, 2008). The variation can be attributed to the inability to gather field control points for the purpose of verifying and confirming the pre-classified maps. This demonstrates how crucial it is to know the terrain and gather supplementary data in order to enhance the quality of image processing. These findings are in line with those of Rachdi et al. (2011), who investigated the use of GIS and remote sensing in the evaluation of temporary ponds in the Moroccan province of Benslimane. When map units are difficult to recognize and smaller than a pixel, the classification accuracy decreases (Barima et al., 2009).

The classifications carried out allowed for the identification of five types of formations, namely dense/riparian forests, fields and fallow land, savannahs, buildings and bare soil and water. The various land-use maps indicate the extent of natural formations undergoing a regressive trend. Moreover, the transition matrix, which was drawn up between the land cover classes, illustrates a strong regression trend in wooded forest ecosystems, including dense forests and forests in savannahs. The regression observed can be attributed to the transformation of riparian and dense forests into open areas such as savannahs, fallows, built-up zones and bare grounds. The declining vegetation cover is primarily due to the extensive human activities that cause fragmentation and anthropisation.

This study reveals significant changes in land cover and land use in the Savannah region. Dense and riparian forests have experienced a 28.95% reduction in conversion to savannahs, with 7.17% and 7.07% respectively converted to cropland and agroforestry parks. Between 2000 and 2020, 26.67% of savannahs were converted to cropland and agroforestry, while 3.91% were converted to forest and riparian woodland. A total of 3.88% of riparian and dry forests were also converted to cropland and agroforestry parks, while 4.94% of cropland and agroforestry parks were converted to savannahs.

The high urbanisation rate in this region and various anthropogenic pressures causing landscape fragmentation could explain this dynamic. Moreover, Mama et al. (2013) highlighted in their study that in the Sudanian zone of Benin, forest and savannah formations are gradually yielding to anthropogenic formations such as fields and agglomerations. Overall, the findings align with other research on mangrove dynamics in the Beninese coastal area (Dansou, 2019; Zanvo et al., 2021). Zanvo et al. (2021) reveal more substantial mangrove decline in the Abomey-Calavi and Ouidah communes. Furthermore, Orekan et al.'s (2019) study indicates a 17.68% loss of mangroves on the coast of Benin from 2005 to 2015.

However, in 1983, forests were the primary land use within the Savannas Region, encompassing a total area of 381679.9 hectares, surpassing the area of savannas (269608.96 hectares) as well as cultivated land and agroforestry parks (201587.64 hectares). Human settlements and watercourses demonstrated the lowest percentages in land coverage during that period, as is illustrated in **Table 1**. Nevertheless, between 1983 and 2000, woodland area decreased by 71.5%, followed by a 20.9% decline between 2000 and 2020. The decline in woodland area from 1983 to 2000 can be attributed to the local forest inhabitants' resistance against the government's insufficiently inclusive policies in creating protected areas throughout the region. The policies faced opposition from the local communities in the 1990s, resulting in the encroachment of protected areas by local people for agricultural and housing purposes (Folega et al., 2012, op. cit.). This was notably evident in the Oti-Keran-Mandouri wildlife reserve, the most extensive protected area in the region. Local inhabitants exploited the socio-political instability of the 1990s to occupy protected areas, including the Oti Keran Mandouri Park, in order to reclaim their land for agricultural purposes and to exploit timber and non-timber forest products (Atakpama et al., 2012). Many authors have noted this period in their studies of the OKM park. The forests drew individuals looking to harvest wood resources for charcoal and firewood. The steady rise in demand for these resources in Togo and the region has been driven by significant population growth. Consequently, forest cover has sharply diminished, resulting in the expansion of cultivable land and agroforestry parks. Population growth, along with the expansion of residential areas and the expansion of agricultural land, including honey production, all contribute to the degradation of forest cover. The landscape comprises areas of wooded and shrubby savannahs and agroforestry parks, serving as a habitat to species of socioeconomic or cultural significance, including the dwarf (*Parkia biglobosa*), shea tree (*Vitellaria paradoxa*), tamarind (*Tamarindus indica*) and palmyra palm (*Boras-*

sus spp), which are conserved (Atakpama et al., 2022).

From 2000 to 2020, there was a moderate decrease in forest coverage in the region, amounting to 20.90% in 20 years. This is in contrast to a considerable decline of 71.85% during 1983 to 2000. The slower reduction in decline is attributed to the concerted efforts of non-governmental organisations and the government to protect the remaining areas in the region. Notably, environmental policy underwent a transformation on a national level in the 2000s, with greater participation from local stakeholders and the establishment of community forests. The surface area of wetlands and watersheds has significantly reduced. Polo-Akpisso et al. (2018) attribute this decrease to the encroachment by local populations for farming, given the favourable water conditions for crops. Nevertheless, it should be noted that the decline in wetland and watershed space is attributed to climate change, notably through the increase in heat and lengthening of the dry spell (from 6 to 8 months). Over the same period, there has been swift expansion in cropland and housing. This phenomenon is linked by Folega et al. (2014) to the significant population growth experienced by the Savannahs region (over 3%) and the subsequent urban expansion, which heightens the anthropogenic pressure on these wooded resources.

The sharp increase in population density (i.e. the rise in number of villages) and the activities of vegetation burning, slash-and-burn farming, and indiscriminate logging plausibly account for these results. They indicate a growing demand for fertile land by the local community. The transition matrices analysis reveals a pronounced anthropisation of these ecosystems, alongside a surge in field and fallow land areas. The findings are similar to those documented in northern Benin's Sudanian area (Avakoudjo et al., 2014; Mama et al., 2013). These reports indicate a consistent decrease in wooded regions and grasslands and a rise in unused plots and urbanised zones. Human-made factors caused this occurrence, including shortened idling cycles, population expansion and the considerable expansion of profitable crops such as cotton (Kombate et al., 2022). All of these changes are having an impact on the climatic conditions that determine the ecological processes of vegetation succession. Studies have revealed that rural communities continue to rely heavily on the plant genetic resources available in their immediate surroundings (Atakpama et al., 2022). The reduction in vegetation cover within the study area could have an impact on climate regulation and disrupt the socio-economic conditions of the rural population, which is heavily reliant on it. The heightened level of human activity in the area dates back to the 1990s, when many of Togo's protected areas were encroached upon due to socio-political unrest. The intensification of human activities has resulted in the degradation and deforestation of forests, causing a significant loss of forest biomass (Mazo, Arouna, & Toko Imorou, 2021). These changes are attributable to alterations in the structure and composition of these ecosystems (Zakari, Adedoyin, & Bekun, 2021). Logging, urbanisation, and different types of pollution are identified as the primary causes of this harmful human activity

(Orekan et al., 2019). The sharp reduction in vegetation observed in this study is primarily attributed to the expansion of built-up areas, bare soil and fallow land. Osseni et al. (2023) conducted research on soil dynamics in the Basse Vallée de l'Ouémé Reserve (RB-BVO) and found that plant formations of dense forests/galleries, shrub/shrub savannahs and swamps have significantly declined by 24.4% over a period of 30 years. Settlements and fallow land have increased by 3.4% and 15.99% respectively during the same period (Osseni et al., 2023).

In previous research on land use in Abomey-Calavi commune, settlements by humans rose between 27 and 60% in 1991 to 2015, causing the destruction of vegetation, fields, and fallow land (Dovonou, Mama, & Chabi Adimi, 2017), providing evidence that corroborates our findings. Additionally, the impact of demographics and roads on urbanization implies a concentration of built-up or bare land in particular areas. This process results in a decline in the distribution of built-up areas or bare ground as distance from the roads increases. These findings may be elucidated by individuals' propensity to inhabit land parcels adjacent to major roads to benefit from the socio-economic advantages of cities. Alternatively, as Dansou (2019) posits, the gradual densification of transportation grid and the establishment of socio-community infrastructure can be ascribed to the progressive urbanization of towns.

5. Conclusion

The study has identified five land-use classes in the savannah region: Building areas (BA), Croplands/Agroforestry parklands (C/AP), Riparian Forests/Dense Forests (RF/DF), Water bodies (WB), and Savannahs (Sa). The reduction in forest coverage is mainly due to anthropogenic factors such as population growth, town and village expansion, agricultural land extension and increased demand for fuelwood and charcoal. Vegetation fires, hunting, shifting cultivation, and honey production are also major contributors to deforestation in this area.

Local communities in the region contribute significantly to the preservation of certain rare or endangered plant species by creating communal forests and protecting sacred groves. Supporting these local communities in managing their communal forests would help preserve scattered forests throughout the region. The communal management of these forests will enable the local populations to acquire extensive knowledge regarding the environment. Sustainable cultural practices, such as agroforestry, should also be enhanced through programmes and initiatives. This is exemplified by the agroforestry initiative of CAPAS NGO in the Kpendjal Ouest prefecture, which encourages local farmers to grow rows of trees through their plots to provide energy wood for both personal consumption and commercialization purposes. Promoting this practice in the region would divert local populations in protected areas from exploiting both timber and non-timber resources, thereby allowing for the restoration of degraded forests.

Acknowledgements

The authors would like to thank the German Federal Ministry of Education and

Research (BMBF) for funding this study under the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL) programme. We are grateful to all the stakeholders who invested their time and shared their experiences, and to the anonymous reviewers for their careful reading and comments on this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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