PATTERNS OF URBAN ECOLOGY AND SUSTAINABILITY CHALLENGES IN TOGO CITIES, WEST AFRICA

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Abstract. Within the past four decades, urbanization rates have greatly increased across Africa thus rapidly reshaping urban landscapes. Using high-resolution Landsat 8 imagery and SWOT Analysis, this study examines the spatio-temporal dynamics of urbanization and sustainable urban land use planning across three municipalities (Kozah 1, Kozah 3, and Ogou 1) in Republic of Togo. Results showed built-up areas and agricultural land use to have considerably expanded in Kozah 1 and Kozah 3 between 2013 and 2021. During the same period, savannahs and forests respectively decreased from 15299 ha and 7446.89 ha to 9655.61 ha and 5649.24 ha, corresponding to a decrease of 14.39% for savannahs and 4.58% for forests. Meanwhile, land under water bodies increased in the Ogou 1 from 1592.55 ha or 4.06% in 2013 to 2286.6 ha or 5.83% in 2021. The spatiotemporal analysis showed water bodies, built-up areas, and crops/fallows to have increased by 694 ha, 1178.77 ha, and 5568.22 ha respectively. In addition, agricultural land use was the major land use type in Kozah 1 and Kozah 3 whereas savannah and croplands dominated Ogou 1. With a fragmentation index of 1363 ha, croplands and fallows were the most fragmented land use types in Kozah 1 and Kozah 3. Meanwhile, with a fragmentation index of 735 ha, forests were the most fragmented land use type in Ogou 1. The degradation of green spaces was found to be a consequence of human settlements and infrastructure development, as demonstrated by focus group discussions that confirmed our findings in the satellite image analysis. In addition, research centers, non-governmental organizations, and politicians are encountering difficulties integrating urban ecology into urban planning, according to the surveys. African cities may become sustainable through the smart integration of urban ecology into local development strategies.

Keywords: *urbanization, ecological land use planning, urban development plans, sustainable cities, Togo*

Introduction

Urbanization is widely recognized as an indisputable process of human-induced transformation (André et al., 2014). It is a global phenomenon resulting from an increase in the demand for land due to population pressures (Oyalowo, 2022). According to the World Cities Report, by 2035, it is predicted that from a mere 8% in 2015, about 62% of the world's population will be living in urban areas (UN-Habitat, 2020). Also, between 2018 and 2050, it is anticipated that the urban populations of countries such as China (255 million), India (416 million), and Nigeria (189 million) will increase by approximately 35% of the global total (DESA, 2019). Here, it is thought that by 2035, more than half of the urban population of developing nations will reside in medium-sized cities (DESA, 2019).

The landscape and its environmental components are important indicators of the viable management planning of a city. This is because of their roles as facilitators of both individual and societal well-being (Saifane, 2017). According to Leger-Smith (2013) and Prieur et al. (2008), incorporating vegetation into urban areas improves social cohesion, leisure periods, and people's mental and emotional health (Prieur et al., 2008). Therefore, for a city to be termed green, it should be endowed with significant landscape environmental components and have an advanced realm of urban planning and sociology (Calame, 2015; Mallet and Montpetit, 2012). Hence, urban trees, green belts, and other peri-urban forests must be integrated into a city's landscape planning for it to attain sustainable development status (Sénecal, 1996; Vermeiren et al., 2012). Nonetheless, the development of genuinely sustainable cities necessitates local planning that incorporates ecological considerations while considering particular regional management needs (Yigitcanlar and Kamruzzaman, 2015; Maiga et al., 2023).

From this perspective, cities across Africa are faced with numerous urban problems including poor urban agricultural practices that disrupt ecological balance (Kanda et al., 2013; Leger-Smith, 2013; Parrot, 2010; Toublanc and Bonin, 2012). Similarly, researchers have likened biodiversity loss in urban environments to low levels of urban forestry (Abhervé-Quinquis et al., 2010; Gbinlo, 2010). Besides, issues of urban waste management, hygiene, and sanitation are recurrent (Gbinlo, 2010). Without proactive environmental planning, ecological communities and their related ecosystem services will continuously bear the brunt of urban land use systems expansion (Grimm et al., 2008).

Despite a shift and transition towards ecological land use planning for many African cities, the current decentralization situation in Togo is unfavorable. Data from the Togolese population and housing bureau show about 63.3% of the Togolese population to be urban dwellers (INSEED, 2011). Facilitated by global environmental changes, many rural and semi-urban populations have migrated to urban areas (Lüdeke et al., 2004; Matthew et al., 2022). This trend is quite discernible in cities like Kara and Atakpamé where uncontrolled and accelerated urbanization impedes the preservation of optimal surrounding ecological quality. Similarly, within the last decade, Ogou 1 has experienced a rapid growth in its population which has led to unchecked urbanization and unregulated infrastructural development.

Within the past two decades, several studies have examined the concept of urban landscapes, rapidly expanding cities, and sustainable development (Attali, 2008; LUCC and Change, 1999; Xie et al., 2008). For instance, studies by Pena-Salmon and Rojas-Caldelas (2009), Schmit (2006) and Yue and Xu (2013) observed that while the process of urbanization has slowed down across Western nations, it has accelerated across developing countries, especially in Africa. This trend is mainly due to rapid population

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growth, and rural outmigration and therefore cities in low-income countries south of the Sahara will witness significant population growth by 2050 (Fousséni, 2018; Kabanyegeye et al., 2021).

As part of its National Development Program (PND) and National Policy for Housing and Urban Development, the government of Togo has elaborated a road map aimed at making its cities more sustainable. This plan which runs from 2020-2025, is built on Objective 11 of the Sustainable Development Goals (SDGs) about sustainable cities and communities (Polorigni et al., 2015). This plan particularly Project 33, also aims at modernizing, reinforcing the country's infrastructure, and developing ten major cities across the country (Polorigni et al., 2015). Since 2009, the country has been implementing environmental safeguard initiatives including a national policy on land use planning. These environmental safeguards are fortified by Law No. 2008-005 enacted in 2008 which defines a national framework law on the environment. Furthermore, the government passed a framework law on land use planning and a National Plan for Sustainable Development (NPD) respectively in 2016 and 2018. Togo is among the countries in West African that have approved the Regional Spatial Development Plan (SDER) for 2021-2040. In 2018, Togo joined 27 other African countries engaged in the restoration by 2030 of 1.4 million ha of deforested and degraded landscapes, including urban green spaces.

Despite international initiatives to support the sustainable management of cities following objective 11 of the SDGs, there is a lack of concrete data on the spatiotemporal dynamics of Togolese cities such as Kara and Atakpamé. With the advancement of earth observation technologies, it has become easy to create a spatial database for the monitoring of Togo's eco-landscapes. Through an analysis of the spatio-temporal dynamics of urbanization and sustainable urban planning, this study contributes to and promotes the growth of applied research in Togo. It focuses on participatory and inclusive urban ecological planning while seeking to produce viable and sustainable urban ecological models for Kozah 1, Kozah 3, and Ogou 1.

Materials and methods

Study area

This study was conducted in the municipalities of Kozah 1, Kozah 3, and Ogou 1 located respectively in the Kara and plateau regions (*Fig. 1*). The municipalities were created by Law No. 2017-008 of June 29, 2017, which established municipalities in Togo. Although Kozah 1 and Kozah 3 cover an estimated surface area of about 488 km^2 and Ogou 1 an estimated surface area of about 398 km^2 (*Table 1*) belong respectively to ecological zones II and III (Ern, 1979).

Table 1. *Summary of the most relevant information about the studied municipalities*

Municipalities	Region	Area (km^2)	Urban phytodiversity	Population	Economic sectors	Main ethnic groups
Kozah 1 and 3	Kara	488	*Albizia sp, Senna siamea, Khaya senegalensis, Acacia auriculoformis, Elaeis guineensis, Eucalyptus sp,* and *Acacia auriculoformis*	256 738	Agriculture Craftsmanship Commerce	Kabye, Nawda, Kotokoli, Bassar, and Fulani
Ogou 1	Plateau	398	*Terminalia sp, Acacia sp, Afzelia africana, Citrus sp, Mangifera indica, Tectona grandis, Elaeis guineensis,* and *Eucalyptus sp*	115 633	Agriculture Craftsmanship Commerce	Ifê, Akposso, Kabye, Nawda, and Ewé

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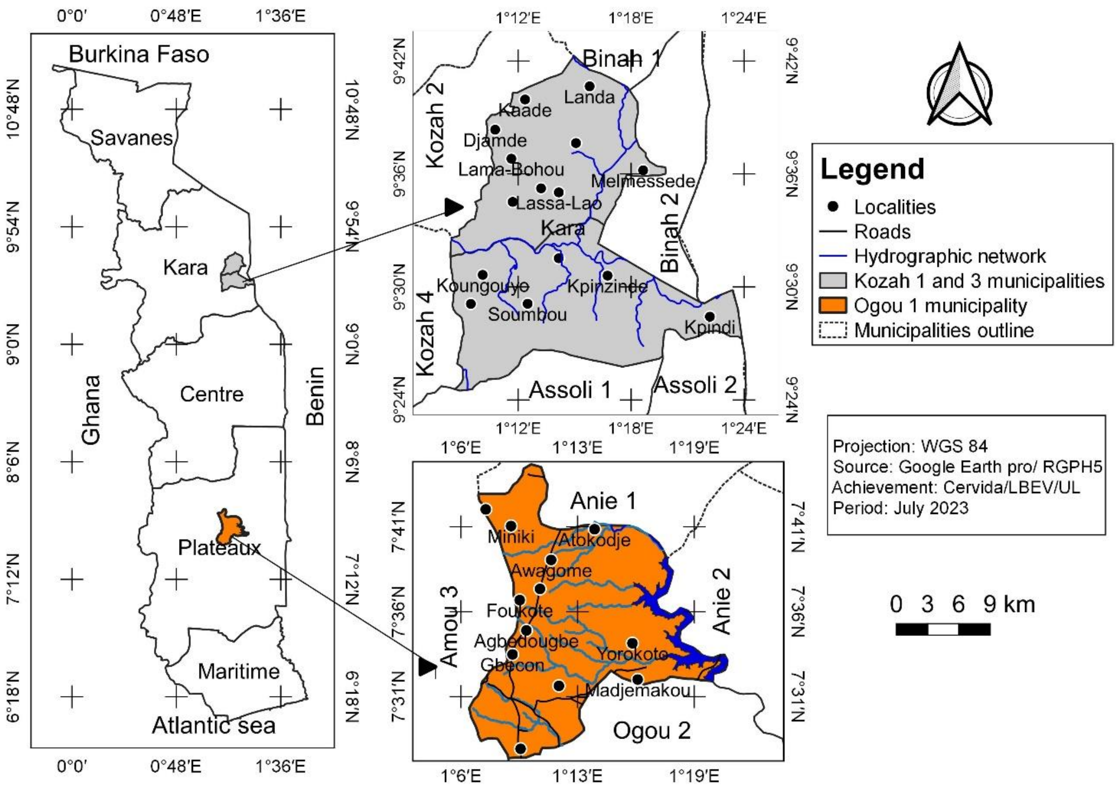

***Figure 1.** Shows the study areas of Kozah and Ogou municipalities*

The municipalities of Kozah 1 and Kozah 3 (1° 11 E, 9°30 N) are located in Kara, northern Togo. This region is 420 kilometers south of Lomé, the capital, and 212 kilometers north of the border with Burkina Faso. Kozah 1 municipality is geographically bordered by Kozah 2 municipality (to the northwest), Kozah 3 municipality (to the south-east), Kozah 4 municipality (to the south-west), and Binah prefecture (to the east). The Kabye, Nawda, Kotokoli, and Bassar, constitute the main ethnic groups and the major religions are African traditional beliefs, Christianity and Islam. Agriculture, animal rearing, and petit businesses constitute the main economic activities of the local population. Dominated by *Albizia sp, Senna siamea, Khaya senegalensis, Acacia auriculoformis, Elaeis guineensis, Eucalyptus sp,* and *Acacia auriculoformis*, the vegetation cover in Kozah 1 and Kozah 3 consists of plantations with small forest patches and urban groves.

Meanwhile, Ogou 1 municipality (7°28' to 7°45' N, 1°06' to 1°23' E) located in Atakpamé, southern Togo is 160 kilometers from Lomé. It consists of three counties including Djama, Woudou, and Gnagna. It is bordered to the northwest by the Doufio district, to the north by Anié 1 municipality, to the northeast and the east by the Anié River, the Mono River, and Anié 2 municipality, to the South by Ogou 2 and Ogou 3 municipalities and to the West by Amou 3 municipality.

The Ifê, Akposso, Kabye, Nawda, and Ewé constitute the main ethnic groups and the major religions are African traditional beliefs, Christianity, and Islam. Agriculture, animal rearing, and petit businesses constitute the main economic activities of the local population (Oladokoun, 2016). Dominated by *Terminalia sp, Acacia sp, Afzelia africana, Citrus sp, Mangifera indica, Tectona grandis, Elaeis guineensis, and*

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Eucalyptus sp the vegetation cover in Ogou 1 also consists of plantations with small forest patches and urban groves (Fousséni et al., 2019; Kokou et al., 2006). Meanwhile, various animal species including warthogs (*Phacocherous africanus*), monkeys (*Erythrocebus patas*), cane rats (*Thryonomys swinderianus*), and chameleons (*Chameleo senegalensis*) have been identified.

Data collection

Satellite images

Landsat 8 (OLI TIRS) satellite photos acquired in 2013 and 2021 were obtained from the USGS Earth Explorer website (https://urs.earthdata.nasa.gov) for land use and land change analysis purposes. These images were specifically selected for the Kozah 1, Kozah 3, and Ogou 1 and possess a high spatial resolution (30 m). Various land classification systems, including Corine Land Cover, Anderson, and IPCC, were used to identify urbanization as well as aspects. However, in the context of forest data terminology, the land use classes for Togo were established as outlined in (*Table 2*).

Table 2. *Classification of land use types for land cover mapping*

No	Level 1	Level 2
1	Forest land	Forests (semi-deciduous forests, riparian forests, dry forests, agroforests, mangroves, and plantations)
		Open forests/wooded savannahs
		Tree savannas/shrubs savannahs
2	Farmlands	Crops, agroforestry parks and fallow lands
3	Wetland	Swamp/marshy vegetation
		Water body
4	Human settlements	Housing, infrastructure, and quarries

Source: (MEDDPN, 2019)

A total of six landscape metrics, among the most widely used in landscape analysis, were selected and made it possible to understand the landscape structure at the prefecture scale (*Table 3*) (Abalo et al., 2021; Dimobe, 2017).

Table 3. *Landscape metrics used in morphological landscape analysis*

Metric	Short description	Acronym	Full Description
Dominance	Percentage of landscape	PLAND	It quantifies the total proportional abundance of classes in the landscape $0 < PLAND \leq 100\%$
Fragmentation	Largest Patch Index	LPI	This metric is the ratio of the area (m^2) of the largest plots of the corresponding plot type to the total landscape area (m^2), multiplied by 100 (to convert to a percentage)
Fragmentation	Number of Patches	NP	Number of patches identified for each class NP > 1
Connectivity	Patch Cohesion Index	COHESION	It provides information on the configuration of the landscape and characterizes the connectivity of patches belonging to a class. $0 < COHESION < 100$
Connectivity	Euclidean Nearest-Neighbor Distance	ENN	It is the smallest distance (Euclidean) of the same type of patches
Heterogeneity	Shannon diversity index	SHDI	SHDI expresses the proportional abundance of each type of patch; multiplied by this proportion. SHDI = 0 shows the absence of diversity. SHDI > 0 when the distribution of landscape area between class types is increasingly equitable (diversity)

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Social survey

Focus group discussions were conducted in Kozah 1, Kozah 3, and Ogou 1 to inquire about the level of implementation of urban ecology involving government officials, sustainable development workers, NGOs, and grassroots development committees. To achieve this task, two fields and social surveys were handled during August 2022 and August 2023.

Data analysis

An unsupervised classification (*Isocluster unsupervised classification)* under the QGIS software (version 3.22), from the normalized vegetation index (NDVI) Landsat images. The NDVI was calculated according to the formula (Rouse Jr et al., 1974):

$$NDVI = \frac{NIR-R}{NIR+R} \quad \text{(Eq.1)}$$

where NIR represent the near-infrared and R the red radiation.

The NDVI values for each image have been clustered into eight (08) classes with twenty (20) iterations and the classes obtained are subjected to post-classification treatments as filtering, recoding in QGIS software (version 3.22). Field visits (control terrain) were made during August 2022, and august 2023 to remove uncertainties and increase the reliability of the mapping (*Fig. 2*).

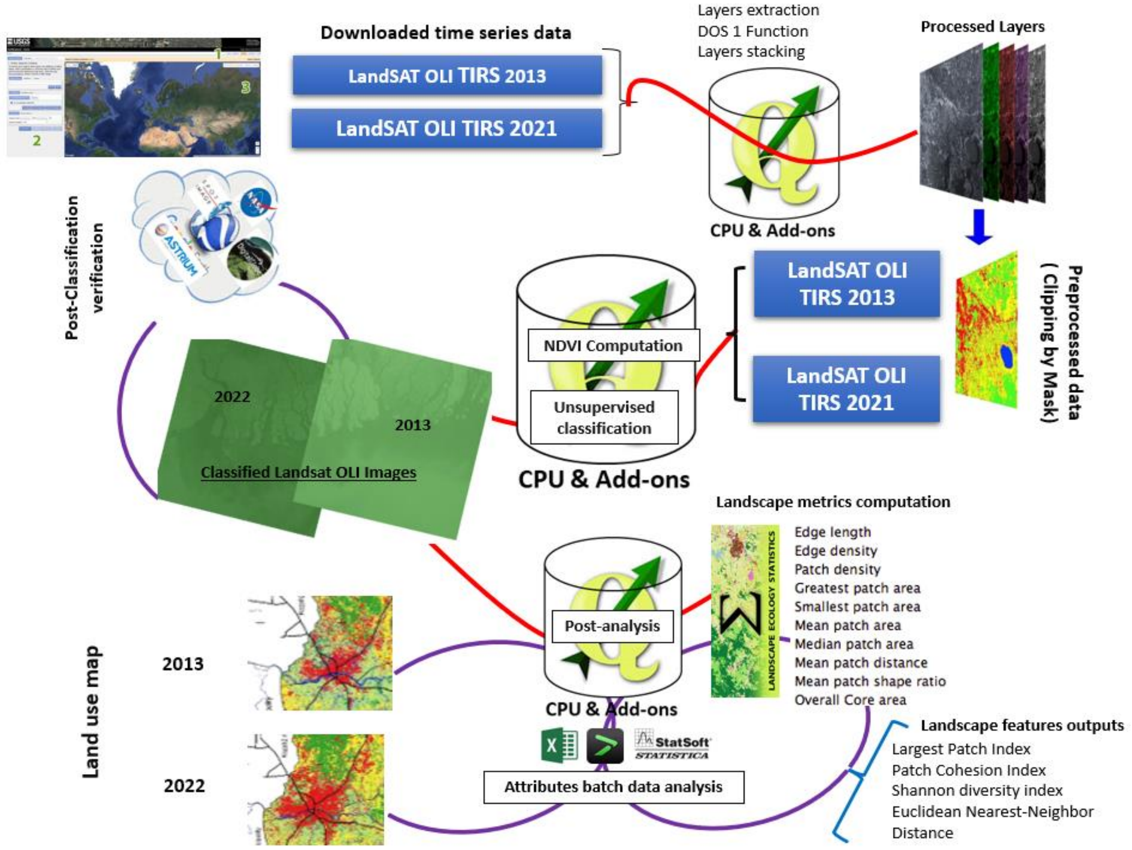

Figure 2. *Flowchart of the methodology for the structures of the landscape units*

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Quantification of landscape structures from remote sensing products is a crucial component of landscape ecological analysis. Therefore, the most appropriate landscape metrics to account for the spatial organization and degree of fragmentation of landscapes in the study areas were calculated using the LecoS Landscape Ecology Statistics add-on in QGIS (version 3.22). For processing related to the multi-criteria approach, the previously selected criteria, and the municipal master plan are vectorized and crossed with the QGIS fusion tool to create a single file comprising all the possible information for a future development proposal (*Fig. 2*).

The information's derived from local perception on how urban ecology is implemented by government agencies, sustainable development workers, NGOs, and grassroots development committees were analyzed follow strengths, weaknesses, opportunities, and threats (SWOT) technics.

By employing both landscape ecology and social perception data on urban ecology final spatial analysis were achieved to generate urban management map based on ecology.

Results

Spatial analysis of urban landscape

The mapping of Kozah 1, Kozah 3, and Ogou 1 displayed five land use units: forests, farms/fallows, water bodies, savannahs, and built-up areas. These land uses characterized the urban spatial expansion of the three surveyed municipalities using Google Earth imagery (*Figs. 3* and *4*).

Landscape metrics

Evaluation of land classification dominance

In 2013, the percentage of landscape (PLAND) was highest for crops/fallow (CF) (18.68%) and lowest for water bodies (WB) (1.26%) in Kozah 1 and Kozah 3. In Ogou 1, the proportion of land covered by savannahs (S) decreased from 18.66% in 2013 to 16.57% in 2016 and from 23.27% in 2016 to 11.67% in 2021. In summary, the predominant land use type in Kozah 1 and Kozah 3 in 2013 and 2021 was CF, whereas in Ogou 1, savannahs and cultivated areas were the dominant land uses in 2013 and 2021, respectively (*Fig. 5*).

Fragmentation measurement

The fragmentation index evidenced by the number of patches (NP) indicates that built-up areas (BA) are the most fragmented in Kozah 1 and Kozah 3 in 2013 (1480) and 2021 (1883), followed by Forests (F) in 2013 (1225) and 2021(1650). In Ogou 1, the fragmentation level was found to be highest in F H (735) in 2013, followed by Crops/Fallow (CF) (709). In 2021 in Ogou 1, the observed fragmentation was highest in BA (633), followed by Savannah (S) (591).

From 2013 to 2021, Kozah 1 and Kozah 3 experienced an increase in the HS for the number of patches by 395 and 231, respectively. Conversely, Ogou 1 witnessed a drop in the F (167) during the same period (*Fig. 6*).

Kozah 1, Kozah 3, and Ogou 1 achieved the highest values of the Largest Patch Index (LPI) in the S region in 2013. Specifically, Kozah 1 and Kozah 3 had an LPI of 19.61%, while Ogou 1 had an LPI of 22.53% for S. Furthermore, the LPI index exhibits

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a larger value in CF in the year 2021, mainly in Kozah 1 and Kozah 3 with a percentage increase of 9.54%, and in Ogou 1 with a substantial increase of 44.89%. Meanwhile, between 2013 and 2021, the LPI values of BA and F in Kozah 1 and Kozah 3 experienced a growth of 5.32% and 3.96%, respectively. In contrast, both CF and S saw a decline in their LPI values, with CF experiencing a decline of 5.45% and S a significant decline of 17.5%. During the same period, CF increased by 26.91% in Ogou 1, while S decreased by 11.5% (*Fig. 7*).

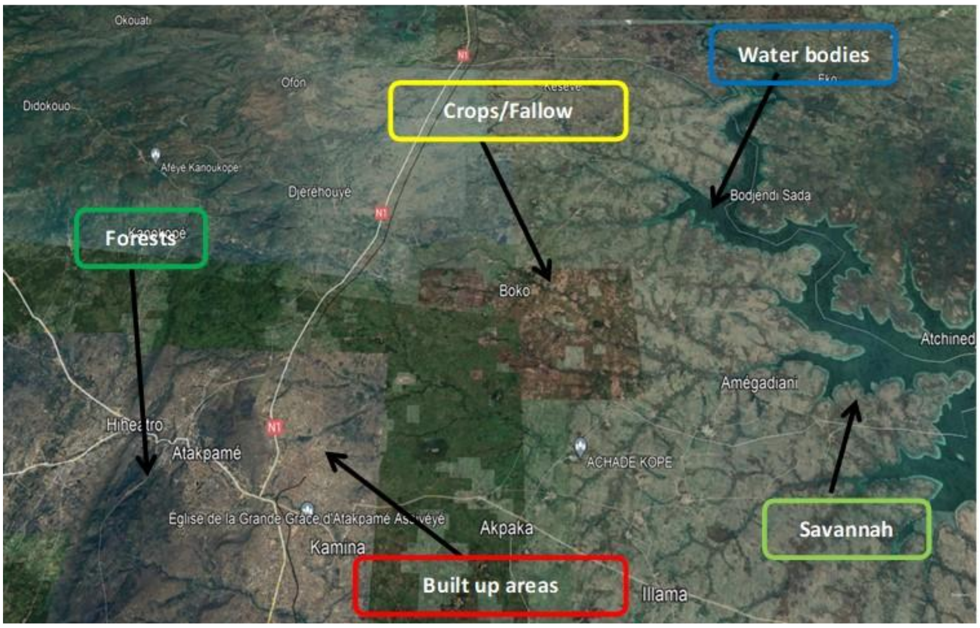

Figure 3. *Land occupation units of Ogou 1 from Google Earth Pro software*

Figure 4. *Land occupation units of Kozah 1, and Kozah 3 were observed and documented using Google Earth. The landscape can be categorized into five main classes: a-Forest (F); b-Savannah (S); c-Crops/Fallows (CF); d-Built up areas (BA); and e-Water bodies (WB)*

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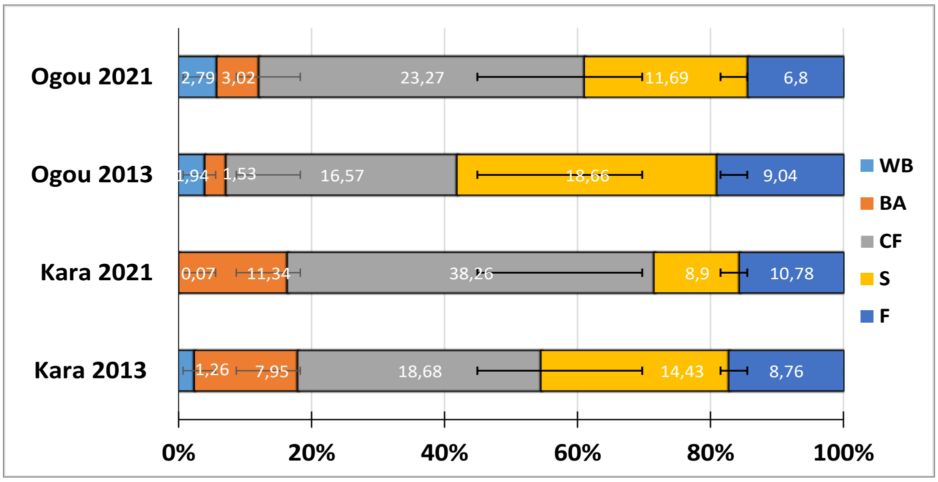

Figure 5. *Percentage of landscape coverage in Kozah 1, Kozah 3, and Ogou 1 between 2013 and 2021*

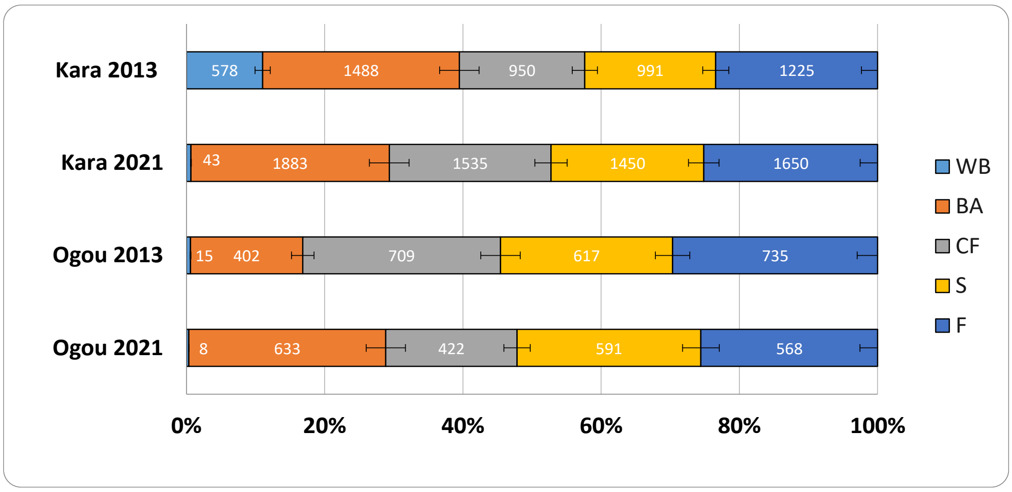

Figure 6. *Number of patches (NP) in each of the districts in Kozah 1, Kozah 3 (Kara) and Ogou 1*

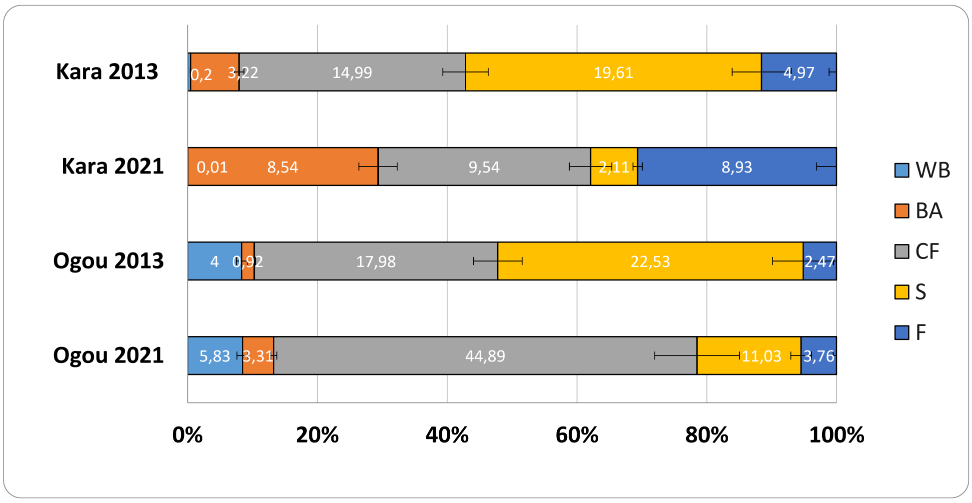

Figure 7. *Largest patch index (LPI) for Kozah 1, Kozah 3 (Kara) and Ogou 1*

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Connectivity between land uses

The Euclidean Nearest-Neighbor Distance (ENN) decreased in land uses for built-up area (BA) (from 133.39 ha) to 114.27 ha) and Forests (F) (from 128.09 ha to 123.27 ha) while showing an increase in Fallows/Crops (CF) (from 115.98 ha to 133.27 ha) and Savannahs (S) (from 125.46 ha to 128.59 ha) between the years 2013 to 2021 in the municipalities of Kozah 1 and Kozah 3. During the same period, the cohesion index increased in value for BA (9.39 to 9.7); CF (9.79 to 9.83), and F (9.55 to 9.73). In Ogou 1, the ENN and Cohesion indices exhibit a significant increase in value, namely in the S area, with values of 113.28 and 9.82, respectively, seen in 2013. Similarly, in 2021, the BA area demonstrated a comparable trend with values of 109.89 and 9.92 for the ENN and Cohesion indices, respectively (*Figs. 8* and *9*).

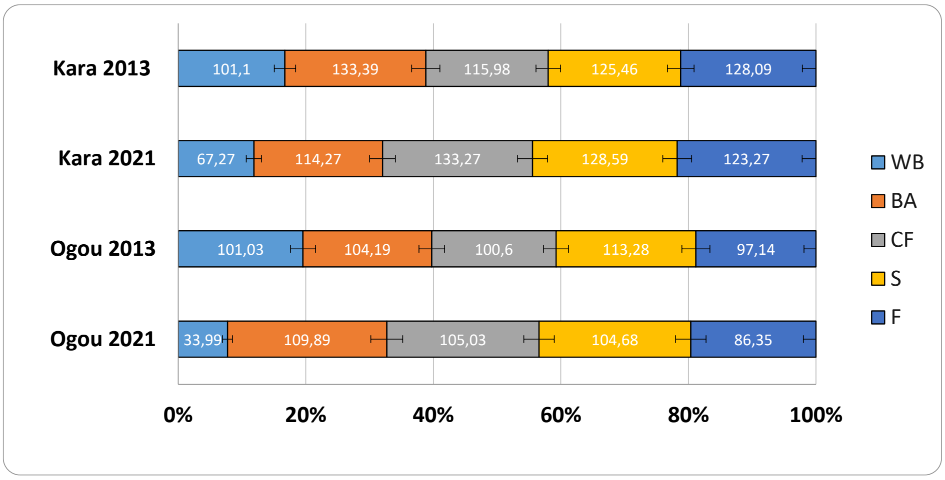

Figure 8. *Mean Euclidean nearest neighbor distance (ENN_MN) at the Municipalities landscape level*

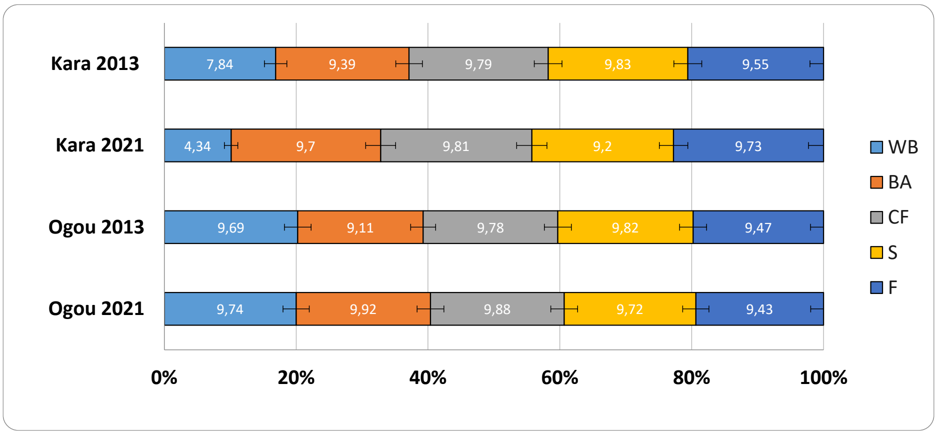

Figure 9. *The municipalities landscape patch aggregation cohesion index*

Heterogeneity of land uses/landscape

Between 2013 and 2021, the diversity index (SHDI) decreased in Kozah 1 and Kozah 3 (1.408 bits to 1.343 bits). During the same period, this index increased from

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1.289 bits to 1.314 bits in Ogou 1. In 2013, the highest value was obtained from the Kozah 1 and Kozah 3 landscapes, while the lowest value was obtained from the Ogou 1 landscape.

Structure and dynamics of the landscape

The land use/land cover maps of Ogou 1, Kozah 1, and Kozah 3 provide an analysis of the variations in their respective landscapes from 2013 to 2021 (*Fig. 10*).

In 2013, Kozah 1 and Kozah 3 comprised 7479.7 ha of BA accounting for 15.62% of the total area. This area experienced an increase of 3067.19 ha equivalent to a 6.41% increase in 2021. The area of CF increased from 17581.65 ha to 18863.62 ha and the area of F increased from 8079.9 ha to 10011.36 ha (*Fig. 8*).

In 2013, in Ogou 1, WB occupied 1592.55 ha or 4.06% of the total area and increased to 2286.6 ha or 5.83% of its original size in 2021. The comparison between 2013 and 2021 revealed an increase of 694 ha in WB. During the same period, BA and CF expanded by 1178.77 ha and 5568.22 ha, respectively. Between 2013 and 2021, S and F decreased from 15299 ha and 7446.89 ha to 9655.61 ha and 5649.24 ha, representing a decrease of 14.39% for S and 4.58% for F (*Fig. 10*).

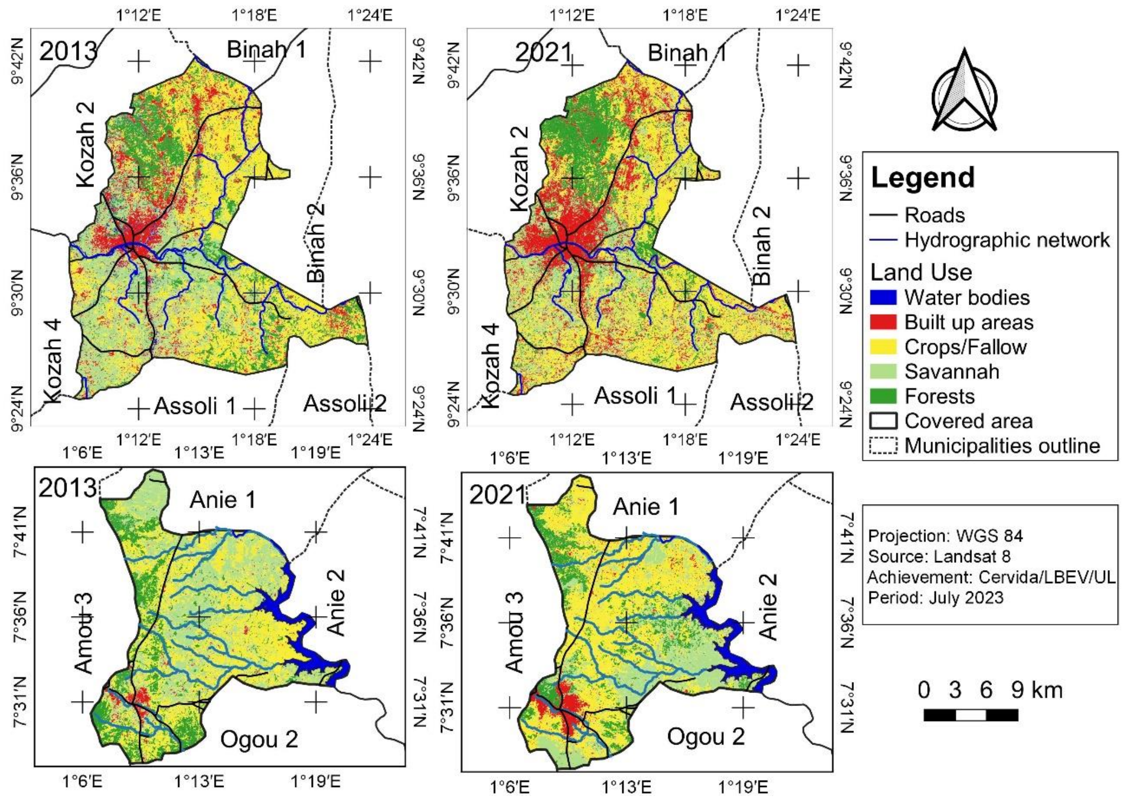

Figure 10. *Temporal changes in land use patterns within Kozah 1, Kozah 3 (upper panel), and Ogou 1 (lower panel) between 2013 and 2021*

SWOT analysis

It was conducted to reveal the areas of weakness, chances to boost strengths, and threats in Ogou 1, Kozah 1, and Kozah 3 (*Tables 4* and *5*).

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Table 4. *SWOT Matrix of the sustainable city features in Kozah 1 and Kozah 3 municipalities*

Strengths	Weaknesses
• Abundant natural potential • Relief conducive to the drainage of runoff water • Significant funding sources • Dynamism of sustainable development actors, in particular, NGOs (ANADEB, ANASAP), grassroots development committees (CVD, CDQ, etc.), and decentralized services (ODEF, DRERF) • Direct involvement of the local council in reforestation through the cultivation and free • Distribution of plants during reforestation campaigns and at the request of volunteers	• Clandestine housing estates • Insufficient quantitative and qualitative data • Lack of competent staff in urban planning, environment, and management of the urban landscape • Orientation scheme in urban ecology not specified • Confusing communal boundaries • Land challenges: Insufficiency of land and difficulty in applying the land code • Low level of perception of the urban ecology • Insufficient planning and development of green spaces • Lack of awareness of ecological planning
Opportunities	**Threats**
• Favorable geographical location: Economic crossroads city • Geography favorable to ecological urbanization • Presence of several sites for green spaces • Temporal availability of suitable spaces	• Clandestine housing estates • Failure to comply with land regulations, in particular the Land Code • Inter-municipality conflict • Loss of the municipality’s natural green spaces • Heatwaves and natural disasters • Climate variability and disappearing biodiversity

Table 5. *SWOT matrix of sustainable city features in Ogou 1*

Strengths	Weaknesses
• Abundant natural potential • Relief conducive to the drainage of runoff water • Significant funding sources • Dynamism of sustainable development actors, in particular, NGOs (ANADEB; ANASAP, ONG ODIAE, ONG JVE…) grassroots development committees and government decentralized services (DRERF, ODEF…). • Direct involvement of the Town Hall in reforestation through the cultivation and free distribution of plants during reforestation campaigns and at the request of volunteers	• Clandestine housing estates • Insufficient quantitative and qualitative data • Lack of competent staff in urban planning and environment and management of the urban landscape • Orientation scheme in urban ecology not specified • Confusing communal boundaries • Land challenges: Insufficiency of land and difficulty in applying the land code • Low level of perception of the urban ecology • Insufficient planning and development of green spaces • Lack of awareness of ecological planning
Opportunities	**Threats**
• Favorable geographical location: Economic crossroads city • Geography favorable to ecological urbanization • Presence of several sites for green space • Temporal availability of suitable spaces	• Clandestine housing estates • Failure to comply with land regulations, in particular the Land Code • Inter-municipality conflict • Loss of the municipality’s natural green spaces • Heatwaves and natural disasters • Climate variability and disappearing biodiversity

The majority of the green spaces contain square trees, roadside trees, and degraded forest remnants (*Table 6*). Lack of management plans incorporated into the municipalities master plans is the major hindrance to the expansion of green spaces in a sustainable way.

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***Table 6.** Typology of green spaces in Kozah 1, Kozah 3, and Ogou 1*

Municipalities	Green spaces
Kozah 1 and Kozah 3	Few roadside trees Recreational land Sacred forests
Ogou 1	Third-age green spaces Sacred forests Roadside trees

Ecological land use planning

A proposal for future sustainable development of Ogou 1 includes sugar cane farms belonging to the Anié sugar refinery, a 500 m buffer zone around the Mono River for market gardening (2342.1 ha), and a restoration policy for the Atakpamé Classified Forest (*Fig. 11*). Furthermore, while, 18071.71 ha were set aside for agroforestry purposes14211.44 ha, 4356.76 ha and 2578.97 ha were respectively reserved for private gardens, and community forests, forest conservation, and protected areas (PAs).

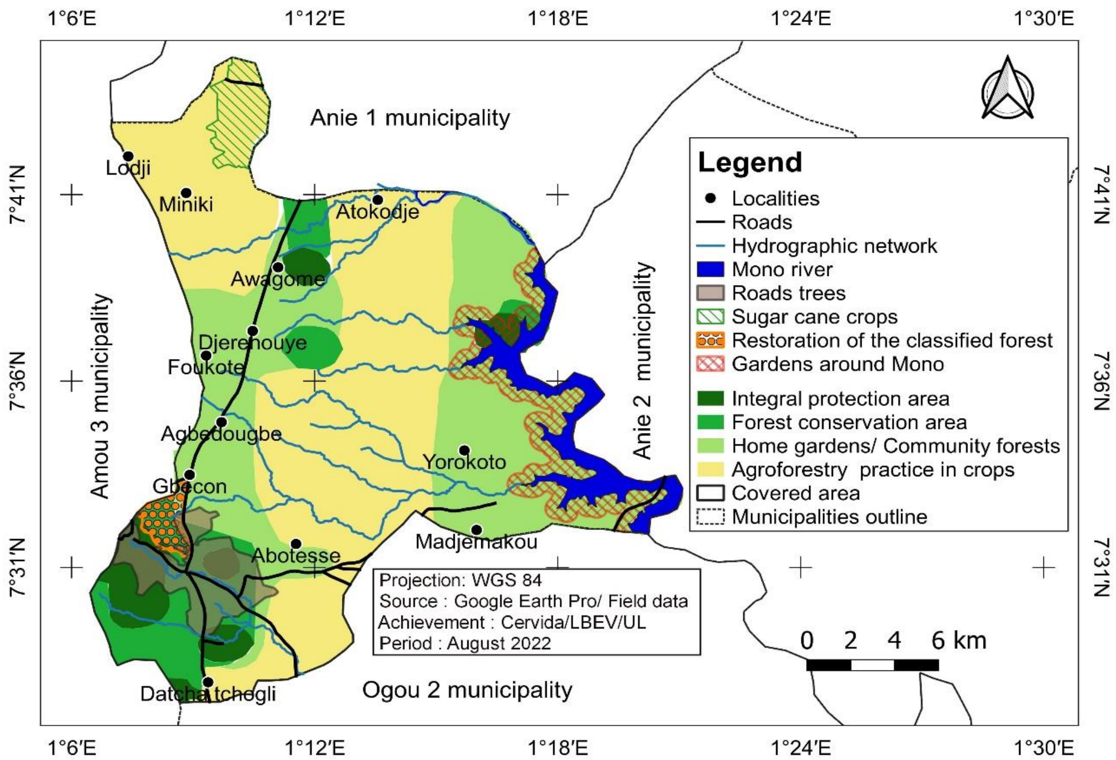

***Figure 11.** Presents the development plan aimed at achieving sustainable growth within Ogou 1*

In Kozah 1 and Kozah 3, a 20-m-wide buffer zone covering an estimated total area of 53.87 m^2 has been created around the Kara River specifically for reforestation purposes. Reforestation is planned for both sides of the Kara River with indigenous buttress tree species including *Ceiba pentandra*, *Anogeissus leiocarpa*, *Afzelia africana*, *Pterocarpus erinaceus*, *Khaya senegalensis*, and *Antiaris africana*. The adoptable area is 25 m^2 or 5 m × 5 m for all species following a staggered pattern and over 49,763 m^2 will be

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planted with vegetation. This gives significant weight to landscape and ecological diagnoses by proposing spatiotemporal designs of landscape spatial structures around water bodies (*Fig. 12*).

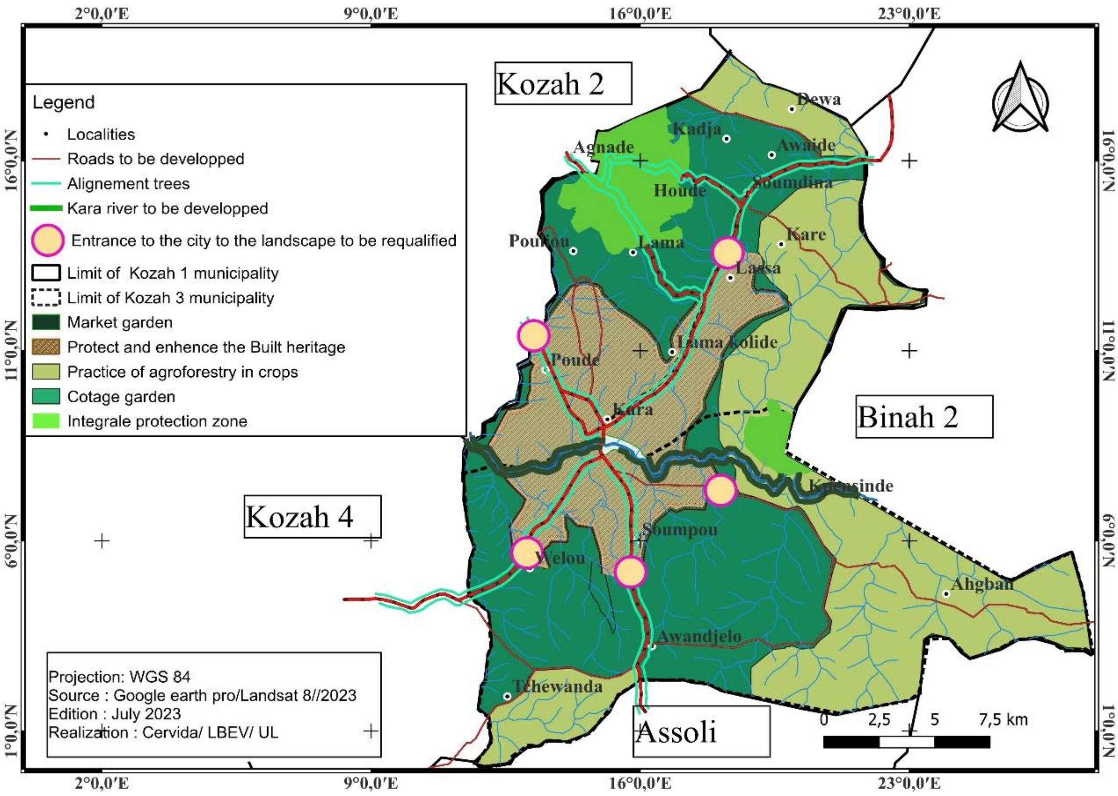

Figure 12. *Management plan of Kozah1 and 3 municipalities*

Discussion

Urban landscape structure feature

To assess the spatiotemporal dynamics of the Kozah 1, 3, and Ogou 1 municipalities, led by uncontrolled urban sprawl; earth observation techniques and mapping methods were used in the framework of urban landscape structure feature characterization (Mundia and Aniya, 2005; Nkeki, 2016; Agyemang et al., 2019). The study has successfully used the spatial resolution of 30-m remote sensing images to classify the land use map of the study areas. Similar research has noticed that 30 m spatial resolution satellite images are widely used for multi-temporal studies to assess land cover dynamics, especially in areas under a fast urbanization process (Idowu et al., 2020; Hu et al., 2018). By adopting a national land classification system, five land cover types such as WB, BA, CF, S, and F were clustered using Landsat OLI TIRS 8 images of 2013 and 2021. The same batch of Landsat 8 products have been successfully used in Benin, and Cameroon (Beckline et al., 2018; Tente et al., 2019) to address the same research topic. Also, previous studies have used the ASTER or Sentinel products respectively with 15 m and 10 m spatial resolution to maximize the accuracy of land patterns mapping (García-Llamas et al., 2016; Singh et al., 2012), although our study was faced with the unavailability of appropriate image that could be covered the target periods. Between 2013 and 2021 in Ogou 1, the savannahs and forest patterns decreased

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while water bodies, crops/fallows, and built-up areas increased. However, in Kara municipalities, an increase in built-up and crop/fallow areas associated with a significant regression of savannahs is observed over the same period. Meanwhile a slight increase in forest patches can be noticed in Kara municipalities boundaries. The reduction in savannah and forest cover can be ascribed to the proliferation of agricultural practices and the expansion of built-up regions (i.e., settlements)
(Beckline et al., 2018) in order to supply sustenance for an urban populace that has doubled in size since the most recent national population census in 2010 (Lamboni, 2016). The increase in built-up areas and cultivated/fallow land can be linked to increased demographic growth for food, wood, and housing needs (Fuwape, 2003). This trend is also observed in West African cities such as Accra in Ghana (Ashiagbor et al., 2019), and Lagos in Nigeria (Oyalowo, 2022). As population density increases the number of households and migrant populations, and there is a significant increase in demand for agricultural land, forests, and forest products. It is well known that the urban population's rapid growth increases workforce availability for agriculture practices and impact negatively forestland degradation (Agidew and Singh, 2017; Yigezu Wendimu, 2021) in peripherical urban areas.
The analysis of the landscape index, based on the patterns of the classified image provides a synoptic dynamic of landscape attributes. Thus between 2013 and 2021, the municipalities Kozah 1 and 3 were dominated by CF while the Ogou1 commune was dominated by CF and S according to the values of the dominance index (PLAND). These findings are well in line with the land use change maps of the study area. The landscape fragmentation (NP, LPI) shows that both cities had important values and expressed the reasons for important dispersions of BAs in the landscape. The level of anthropization confirmed by these results is attributable to the socioeconomic activities of the locals (Magidi and Ahmed, 2019; Sobhani et al., 2021). Similarly, a recent study carried out in the Sancaktepe district, located in the metropolitan area of Istanbul, revealed a decrease in the number of patches due to their agglomerative nature, revealing a notable trend of extensive urban patches (Kowe et al., 2015). Connectivity as show by the index (ENN) decreased in BA and CF in Kozah 1, 3, and Ogou 1; at the same time, the cohesion index increased in these types of land uses. Recent urbanization trends in the communities of Kara and Atakpamé account for this phenomenon. The Shannon index shows an increase in Ogou 1 and a slight decrease in Kozah 1 and 3 and reflects an increase in patch diversity, as well as an increase of its regular distribution in the urban landscape among land use types as determined previously (Tente et al., 2019) in the commune of Zé in Benin.

Urban internal sustainability force versus weakness

SWOT Analysis was essential to have a comprehensive understanding of urban participative governance (Gebrihet and Pillay, 2021; Ewane, 2023). The national decentralization process that granted municipalities a number of territorial competencies sounds extremely promising. Promoting green urban initiatives that engage the majority of stakeholders is regarded as a significant opportunity and force (Ndam et al., 2023; Juta, 2023). Based on field findings, and the local perception of citizens; the chance and hope to develop a sustainable green city based on an ecological approach seem to be important willing's in both of the investigated municipalities. This need to live in better cities for a better life (Lytras et al., 2021; Musah et al., 2021) is almost determined by the active dynamism of local organizations (ANADEB; ANASAP, ONG ODIAE, ONG

JVE) in collaboration with municipalities technical department and government division in charge of environment and forest resources management.
More evidence that citizens want the promotion of optimum management of urban ecosystem services may be seen in the widespread adoption of trees in urban areas, efforts to protect biodiversity, and the activity in National Planting Tree Day (Chaudhuri and Kumar, 2022; Madureira and Monteiro, 2021). However, it is very regrettable to conclude that both investigated municipalities face a lack in terms of urban planning and ecological planning based on research results (Sy et al., 2022). Even though it revealed insufficiencies in city governance (Bibri, 2021; Hofer et al., 2021), it was well noticed that a significantly lower level of local perception about the urban ecology paradigm.

Ecological land use planning

Urban planning objectives gradually integrate a complexity of objectives linked to urban development that aims to be "sustainable" a set of urban development operations based on a balance between the three pillars of sustainability which are social, environmental, and economic (Clergeau, 2019; Emelianoff, 2007). Thus, with the aim to keep the Kozah 1, Kozah 3, and Ogou 1 municipalities sustainable as recorded in the SDGs, a development plan focused on the urban ecology concept is proposed. By considering Ogou 1 road trees (*Senna siamea, Ceiba pentadra, Terminalia spp, Khaya senegalensis, Blighia sapida, etc.)* increasing on both sides of the road network according to the extent of the city of Atakpame are very visible. for Kozah 1 and Kozah 3, beyond the practice of agroforestry in croplands, the protection of mountainous zones by buffering the landscape could sustain market gardening close to the Kara River (Souberou et al., 2018). Thus, restoration of the degraded classified forest with native plant species such as *Khaya senegqlensis*, *D. oliveri*, *V. paradoxa*, and *A. leiocarpus*, after long-term ecological disturbances mainly cause urban sprawl and high natural resource demands. To be able to cushion the deforestation and improve the impact of urban ecosystem services on any residents' professional activities, the ecological land use planning can be considered at the Oti River and Mono River watersheds scale respectively for Kozah and Ogou municipalities. Across any of the watersheds the market gardening areas could be well managed through agroforestry and restoration of swamp and riparian vegetation to cushion the effects of climate change (Chevallier et al., 2015; Ouattara et al., 2010).

Conclusion

The findings demonstrated the viability of using a series of high-resolution raster-formatted satellite images for investigating and monitoring urban expansion. These images have facilitated a more comprehensive characterization of land use patterns in the municipalities of Ogou 1 and Kozah 1, notwithstanding their restricted spatial resolution and insufficient capability to accommodate in-depth analysis. Between 2013 and 2021, savannah and forest areas decreased in both Kozah 1, Kozah 3, and Ogou 1 as built-up areas, gardens, and fallows grew substantially, most likely due to population growth and urbanization's rapid expansion. The focus group discussions confirmed the satellite image analysis and demonstrated that green spaces and urban trees are being degraded due to accelerated urbanization through human settlements and infrastructural development. The surveys also indicated that various stakeholders involved in the

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development of municipalities, such as non-governmental organizations, officials, and research centers, are encountering challenges in incorporating urban ecology into urban planning. However, their efforts are impeded by the limited availability of landscapes and environmental human resources, as well as insufficient financial resources. In light of climate change and rapid urbanization, the implementation of urban forestry initiatives in Kozah 1 and Kozah 3 (Kara), and Ogou 1 (Atakpamé) is anticipated to substantially improve the quality of life for urban residents and ameliorate environmental conditions. This can be accomplished through the restoration of urban forests, which should be governed by sustainable management plans and incorporated into the respective municipalities' development documents. To achieve this, measures must be taken to incorporate urban forestry into the master plans of these municipalities, particularly the Communal Development Plan (PDC), to implement sustainable city models in Togo and Africa.

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