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Challenges for the conservation and restoration of the forest ecosystems of the Oti-Kéran-Mandouri Biosphere Reserve in Togo

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ملخص

يُعد فهم تأثير حرائق الغطاء النباتي والتهديدات البشرية على التنوع البيولوجي أمرًا بالغ الأهمية للإدارة الفعالة للمناطق المحمية التي تتعرض لضغوط بشرية. تُعد محمية أوتي-كيران-ماندوري الحيوية (OKMBR)، الواقعة في شمال توغو، عرضة بشكل خاص للأنشطة البشرية، بما في ذلك التجمعات السكانية وحرائق الغطاء النباتي. تهدف هذه الدراسة إلى المساهمة في تحسين إدارة المناطق المحمية التي تتعرض للضغوط البشرية. وتقيّم بشكل خاص تأثير حرائق الغطاء النباتي والتهديدات البشرية على التنوع البيولوجي والبنية الديموغرافية للنباتات الخشبية في المحمية. استند التحليل إلى جرد غابي ونباتي شمل 158 قطعة مساحة كل منها 1000 متر مربع. تم تحديد ما مجموعه 263 نوعًا نباتيًا تنتمي إلى 169 جنسًا و56 عائلة. ويهيمن على الغطاء النباتي نباتات الحوليات (34.80٪) وعائلة النجيليات (41.76٪)، والتي لا تزال عرضة لحرائق الغطاء النباتي. تعكس البنية الديموغرافية غير المنتظمة، التي تتميز بغياب عدة فئات قطرية، التأثير الكبير للاستخراج المفرط على هذه الموارد. يجب استعادة هذه المنطقة المحمية، وينبغي تنفيذ نظام الزراعة الحراجية، كما يجب حماية بقايا الغطاء النباتي التي لا تزال في حالة جيدة نسبيًا. **الكلمات المفتاحية**: التهديدات البشرية، محمية المحيط الحيوي، توغو، حرائق الغطاء النباتي، الغطاء النباتي.

Abstract

Understanding the impact of vegetation fire and anthropogenic threats on biodiversity is crucial for the effective management of protected areas under human pressure. The Oti-Kéran-Mandouri Biosphere Reserve (OKMBR), located in the northern Togo, is particularly vulnerable to human activities, including human settlements and vegetation fire. The study aims to contribute to better management of protected areas under anthropogenic pressures. Specifically, the study assessed the impact of the vegetation fire and anthropogenic threats on the biodiversity and the demographic structure of the woody vegetation in the OKMBR in Togo. The analysis was based on forest and floristic inventories of 158 plots of 1,000 m^2. Overall, 263 species were identified, belonging to 169 genera and 56 families. The flora, which is dominated by therophytes (34.80%) and Poaceae (41.76%), is still vulnerable to vegetation fire. The irregular demographic structure, with the absence of several diameter classes, reflects the strong impact of extractivism on these resources. This protected area must be restored. Agroforestry must be implemented and the relics of relatively well-preserved plant formations must be protected. **Keywords**: Anthropogenic Threats, Biosphere Reserve, Togo, Vegetation Fire, Flora.

Résumé

Comprendre l'impact des feux de végétation et des menaces anthropiques sur la biodiversité est crucial pour une gestion efficace des aires protégées soumises à la pression humaine. La Réserve de Biosphère d'Oti-Kéran-Mandouri (RBOKM), située dans le nord du Togo, est particulièrement vulnérable aux activités humaines, notamment les établissements humains et les feux de végétation. Cette étude vise à contribuer à une meilleure gestion des aires protégées sous pression anthropique. Elle évalue spécifiquement l'impact des feux de végétation et des menaces anthropiques sur la biodiversité et la structure démographique de la végétation ligneuse dans la RBOKM au Togo. L'analyse repose sur des inventaires forestiers et floristiques réalisés sur 158 parcelles de 1 000 m^2. Au total, 263 espèces appartenant à 169 genres et 56 familles ont été recensées. La flore, dominée par les thérophytes (34,80 %) et les Poaceae (41,76 %), reste vulnérable aux feux de végétation. La structure démographique irrégulière, marquée par l'absence de plusieurs classes de diamètre, reflète l'impact important de l'extractivisme sur ces ressources. Cette aire protégée nécessite une restauration. L'agroforesterie doit être mise en œuvre, et les reliques de formations végétales relativement bien conservées doivent être protégées.
Mots clés : Menaces anthropiques, Réserve de biosphère, Togo, Feux de végétation, Flore.

Proof

Introduction

Vegetation fire is an essential ecological component in tropical ecosystems, playing an important role in regulating plant dynamics. Whether natural or anthropogenic, it affects the structure and composition of plant communities (Boisramé et al., 2017; Burkle et al., 2019). Inappropriate fire management can lead to biodiversity loss, forest and soil ecosystem degradation, and disruption of natural ecological processes (Burkle et al., 2015). Understanding how vegetation fires affect biodiversity is crucial for developing management strategies that support conservation and sustainability. Empirical evidence suggests that using vegetation fires is a common ancestral practice in agriculture and land management (Delagarde et al., 2014; Afelu et al., 2016; N'dri et al., 2018). Vegetation fires enable low-cost crop production, stimulate plant regrowth (Hallema et al., 2019), and improve the availability and quality of forage for wildlife. Such fires occur in most regions of Africa, where they play an important role in maintaining or altering canopy morphology and specific composition (Doamba et al., 2020). Vegetation fires are often necessary for ecological processes such as plant regeneration, but if poorly managed, they can devastate biodiversity. Regular burning promotes xerophytic and invasive species (Akodéwou et al., 2019). Fire regimes limit the regeneration of several woody plants, destroying seeds and saplings, and also restrict tree height growth. These effects significantly impact vegetation dynamics and its progression towards climax (Houinato et al., 2001).

Togo has experienced an increase in vegetation fires in its northern and southwestern regions (MERF, 2014). These fires typically start in late October and intensify in November and December. Sectoral regulations prohibit uncontrolled fires and encourage early fire prevention practices. Despite information and awareness campaigns and the mobilization of stakeholders, uncontrolled fires cause environmental and human damage each year (Afelu et al., 2016). Over 50% of the country (30,000 km2) is burned annually, leading to deforestation and direct negative health and economic impacts (MERF, 2014). In total, 707 vegetation fires were recorded during the 2017-2018 fire season (MERF/PRAPT, 2018). Among other anthropogenic activities, vegetation fires contribute significantly to the degradation of protected areas (Afelu et al., 2016; Atakpama et al., 2023b; Kombate et al., 2024).

Biosphere reserves like the Oti-Kéran-Mandouri Reserve (OKMBR) in Togo play a crucial role in tropical biodiversity conservation (Polo-Akpisso et al., 2015). They serve as refuges for many species and provide frameworks for studying interactions between human activities and natural systems. Therefore, effective management of these reserves, including fire control and other human activities, is essential to maintain their ecological integrity. Unfortunately, human activities detrimental to OKMBR biodiversity, highlighted in previous studies (Dimobe et al., 2011; Dimobe et al., 2012; Dimobe et al., 2014; Polo-Akpisso et al., 2015; Polo-Akpisso et al., 2018; Polo-Akpisso et al., 2020), remain relevant. How do vegetation fires and human activities affect the floristic diversity and demographic structure of forest formations in OKMRB?

This study aims to enhance understanding of degradation factors affecting plant formations in OKMBR, specifically assessing the impact of anthropogenic threats on woody vegetation biodiversity and structure.

2. Material and Methods

2.1. Description of the study area

The Oti-Kéran-Mandouri Biosphere Reserve (OKMBR) is located in northern Togo, spanning the Oti plain and covering the prefectures of Oti and Kpendjal (Savanes region) and the prefecture of Kéran (Kara region), between latitudes 9°55' and 10°20' N and longitudes 0°25' and 1°00' E (Figure 1). The Reserve comprises two protected areas: the Oti-Kéran National Park and the Oti-Mandouri Wildlife Reserve. Originally established on 28 September 1950 as the classified Kéran Forest, the reserve covered an area of 6,700 hectares. Kéran National Park was created in 1971, initially covering 147,840 hectares, later extended to 179,550 hectares. Following the expansion of the Borgou classi-

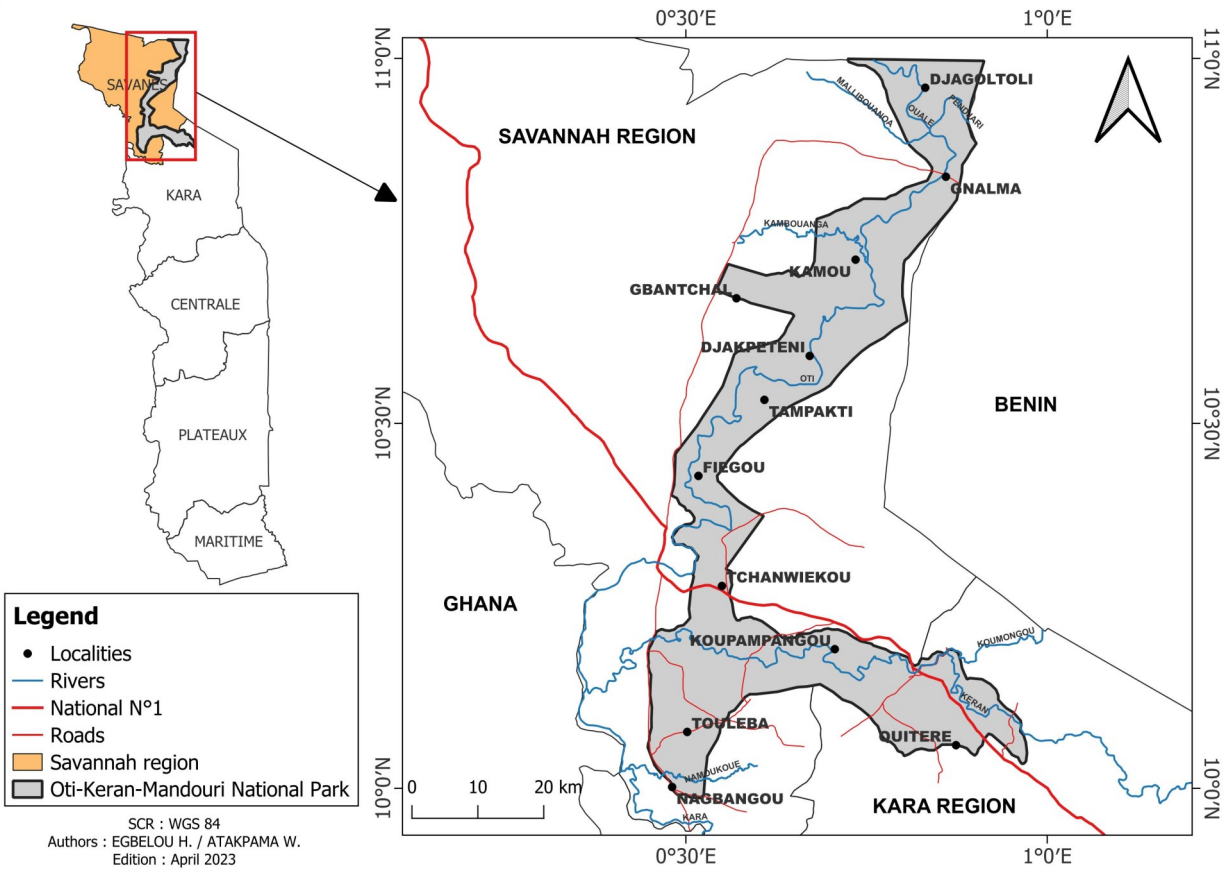


Figure 1. Location of Oti-Kéran-Mandouri Biosphere Reserve (OKMBR) in northern Togo.

fied forest, the Oti-Mandouri Wildlife Reserve was established in 1977.

Socio-economic unrest in Togo during the 1990s led to encroachment by local populations, causing major destruction of wildlife habitats. In response, the Togolese government initiated a rehabilitation process for protected areas, resulting in the redefinition of boundaries in 2005. The areas of Oti-Kéran Park and Oti-Mandouri Wildlife Reserve were reduced to 69,000 ha and 110,000 ha respectively, making the total area of the complex 179,000 ha (Jinping et al., 2016). OKMBR was designated a Ramsar site in 2007 and recognized as a biosphere reserve by the UNESCO MAB Commission at its 23rd session, held in Dresden from 28 June to 1 July 2011.

OKMBR has a tropical climate with two contrasting seasons: a rainy season from April to October with regular but uneven rainfall, and a harsh dry season for the remainder of the year (Pilabina et al., 2019). It lies on the low and flat Oti Plain (120–200 m), drained by the Oti River and its tributary, the Koumongou River. Open forests of Anogeissus leiocarpa (DC.) Guill. & Perr. occupy approximately 22% of the Oti-Kéran National Park (Adjonou et al., 2009). Riparian forests and anthropised ecosystems, such as fallows and cultivated fields, are also present.

2.2. Data collection

2.2.1. Sampling design

Using the 'search' tool in the vector tab of QGIS software, a 2 km × 2 km point grid was overlaid on the 2020 land cover map of OKMBR. Taking into account the representativeness of different land use units (Folega et al., 2023b; Kombate et al.,

2023), ten 2 km × 2 km quadrats were selected. Within each quadrat, 21 equidistant sampling points, spaced 200 m apart, were generated along two perpendicular transects (north–south and east –west) (Figure 2). The "Find" tool in QGIS 3.14 was used to create the quadrats and sampling points. A total of 158 sampling points were retained using this method.

Field inventories were conducted from 10 to 22 December 2020. At each point, a rectangular main plot (50 m × 20 m) and a square subplot (10 m × 10 m) were established (Polo-Akpisso et al., 2015; Dourma et al., 2019). Phytosociological and ecological inventories of woody species were conducted in the main plot, while regeneration and herbaceous inventories were carried out in the subplot.

2.2.2. Vegetation survey

Surveyed species were assigned abundance/ dominance coefficients using the Braun-Blanquet scale (1932). The following ecological variables were recorded: location relative to watercourses, fire frequency, canopy closure, stand density, and non-timber forest product collection. Dominant and pyrophytic species were also noted. Fire frequency was determined by indicators such as the presence of charred logs, ash, dead wood, burned herbaceous plants, and geophytes (Atsri et al., 2018).

Dendrometric data were collected for all stems with diameter at breast height (DBH) ≥10 cm (Folega et al., 2023a; Kombate et al., 2023), includ-

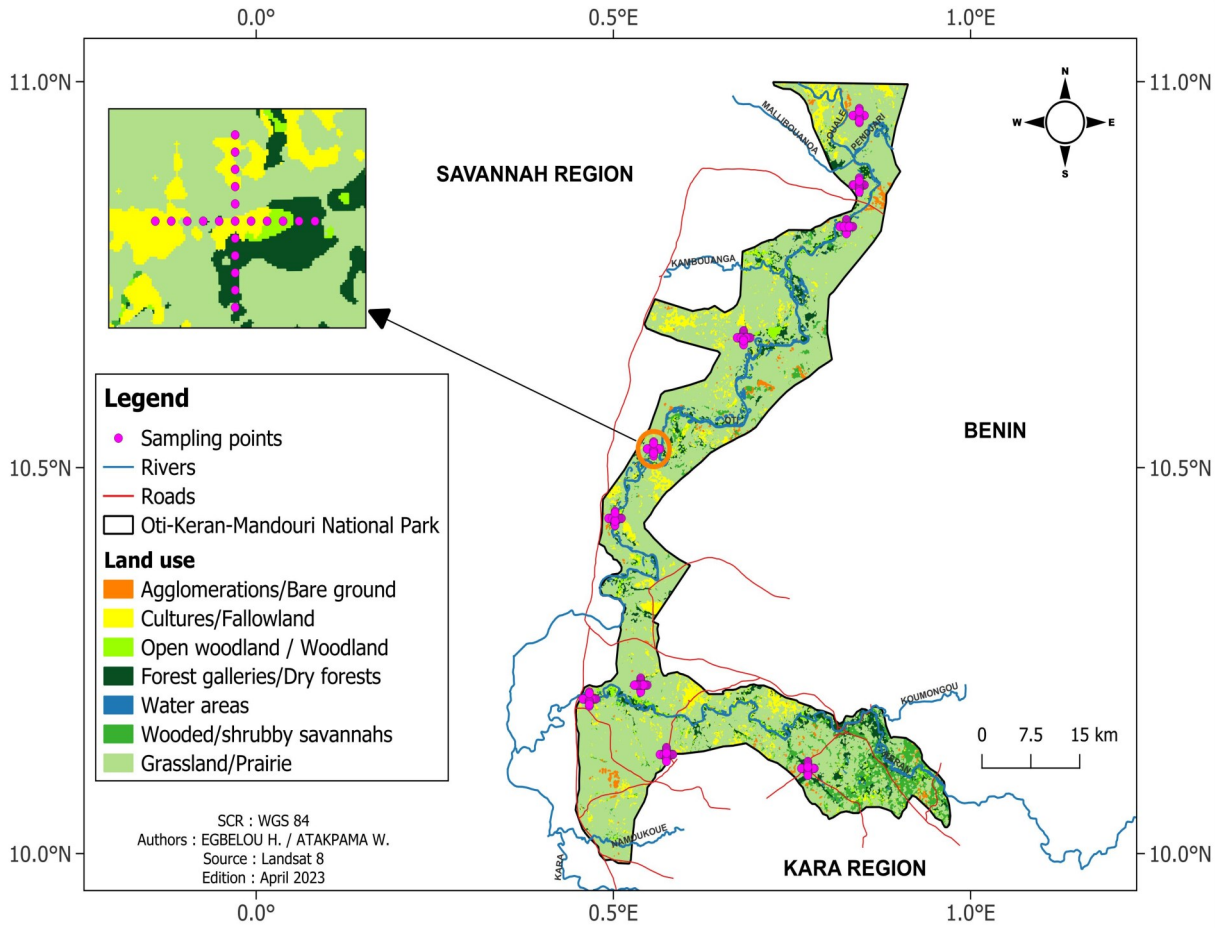


Figure 2. Distribution of sampling plots throughout the OHMBR.

ing total height, bole height, and diameter at 1.30 m above ground.

2.2.3. Data analysis

Species were classified using the Analytical Flora of Benin (Akoégninou et al., 2006) and grouped by family, biological type, and phytogeographical type. A matrix of plots versus ecological factors was constructed. The ecological variables included type of plant formation, degree of human disturbance, vegetation cover level, and fire impact. Canonical Correspondence Analysis (CCA) was conducted with CANOCO 5.0 software (Ter Braak & Šmilauer, 2012) to discriminate plots based on ecological parameters.

The structure of diameter and height was analyzed using Minitab 16 software. Diversity metrics used included species richness (Rs), Shannon index (H'), Pielou's evenness index (Eq), and the rarefaction index (Magurran, 2004; Atakpama et al., 2021).

H' was calculated based on the abundance of each species (ni) and the total number of individuals (n). H' increases with diversity and reaches zero when only one species is present; it reaches its maximum when species are evenly distributed, Hmax = log2(Rs).

Pielou's index (E) expresses evenness as the ratio of observed diversity to the maximum possible value, ranging from 0 (uneven) to 1 (even distribution).

The following dendrometric parameters were also calculated: stem density per hectare (D, stems/ha), mean Lorey height (Hm, m), mean diameter (Dm, cm), and basal area (G, m^2/ha) (Bonou et al., 2009; Assogbadjo et al., 2010). Table 1 summarizes the formulas used. The rarefaction

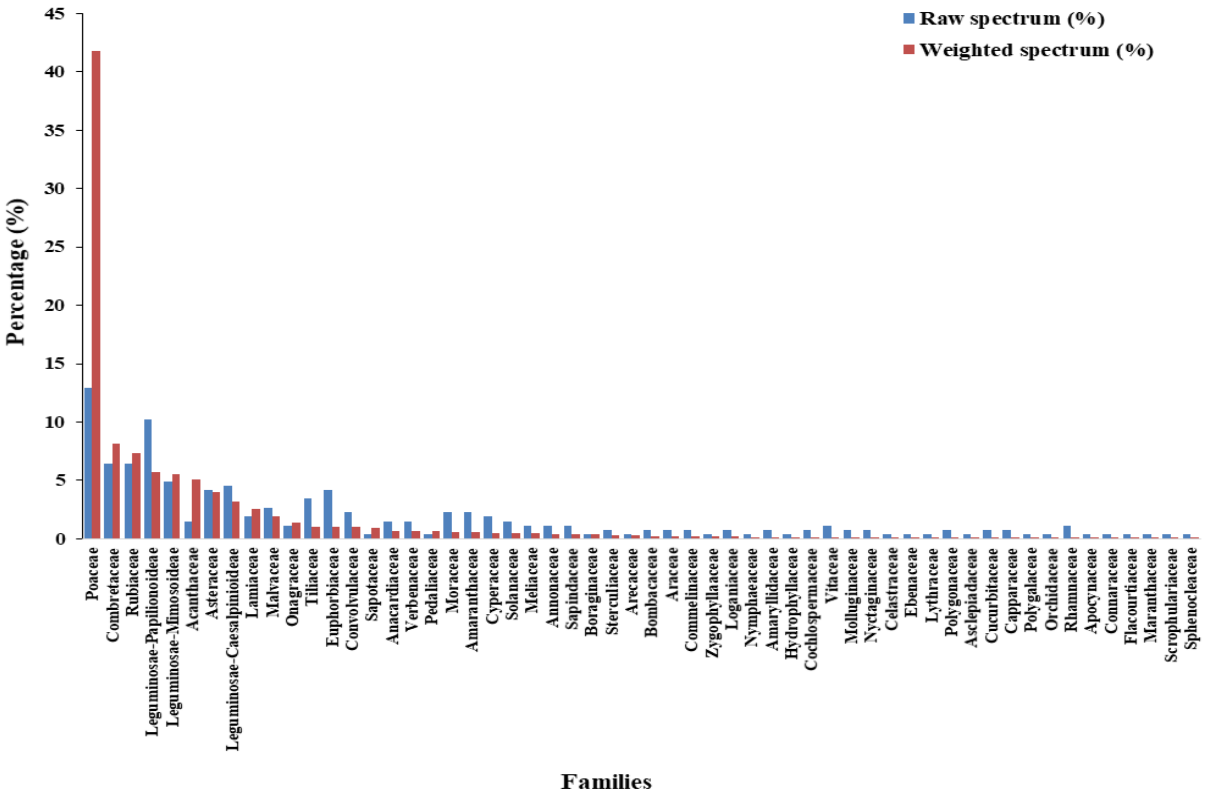


Figure 3. Spectre of the families of the OKMBR

index was calculated as: Ri = [1 − (ni/N)] × 100, where ni is the number of plots where species i occurs and N is the total number of plots. Species with Ri < 80% were considered preferred, and those with Ri > 80% were classified as rare (Kokou et al., 2006).

3. Results

3.1. Diversity of the Oti Kéran Mandouri Biosphere Reserve

A total of 263 plant species belonging to 169 genera and 56 families were inventoried. Of these, 105 species are woody plants belonging to 70 genera and 31 families. The most represented family was the Poaceae (34 species). These were followed by the Leguminosae-Papilionoideae (27 species), and the Combretaceae and Rubiaceae (17 species each). In terms of abundance, the Poaceae were prominent (41.76%), followed by the Combretaceae (8.16%) and the Rubiaceae (7.37%). The remaining families account for less than 6% of the total (Figure 3). Based on forest inventories, there were 95 woody species with DBH ≥ 10 cm.

The presence of cultivated plants indicates the impact of human activity. Altogether, 10 crops were identified. The five main crops were: rice, followed by maize, sorghum, peanuts, and soya (Figure 4). The remaining five crop species covered 5.63% of the cropped land. These were: Capsicum chinense, Capsicum frutescens, Corchorus olitorius, and Hibiscus sabdariffa.

In terms of both species diversity and spatial coverage, therophytes were the most dominant biological types, followed by nanophanerophytes (Figure 5). The least well represented were nanophanerophyte lianas, hydrophytes, chamaephytes, mesophanerophyte lianas, and geophytes.

(mP = mesophanerophyte, mp = microphanerophyte, np = nanophanerophyte, Lmp = mesophanerophyte liana, Lnp = nanophanerophyte liana, Th = therophytes, H = hemicryptophytes, Ch = chamaephytes, G = geophyte).

Guineo-Congo/Sudanese-Zambezia transitional species and Sudanese species were the most represented (Figure 6). Introduced species are less prevalent. They account for 6.08% of the total floristic inventory and occupy about 14.38% of the area.

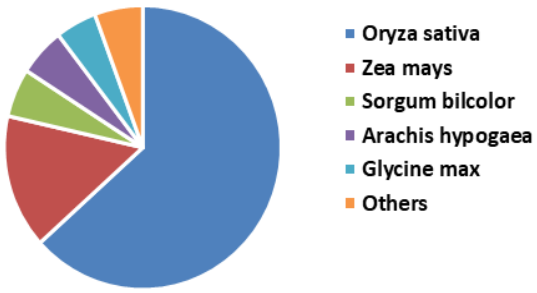


Figure 4. Crops grown in the OKMRB

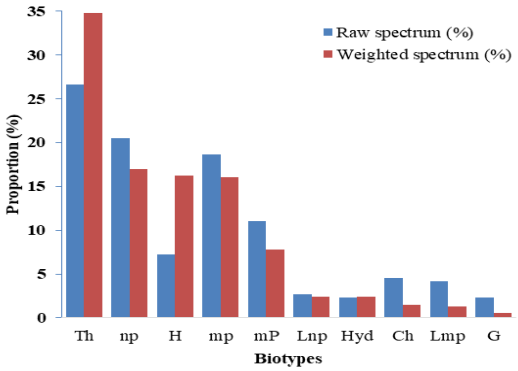


Figure 5. Recorded plants species biotypes.

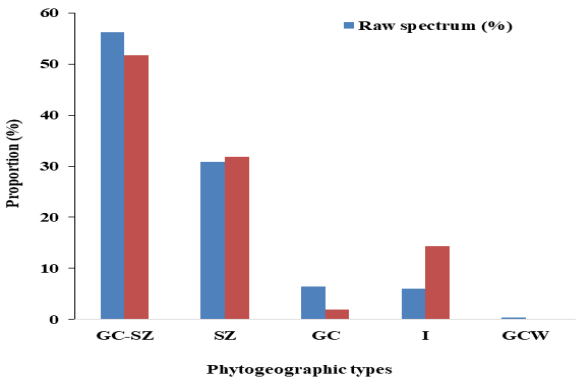


Figure 6. Phytogeographic types of OKMBR species
GC = Guinea-Congo species, WCW = Western Congo species, SZ = Sudan-Zambezian species, GC - SZ = transitional species, I = species introduced for agriculture, forestry or horticulture.

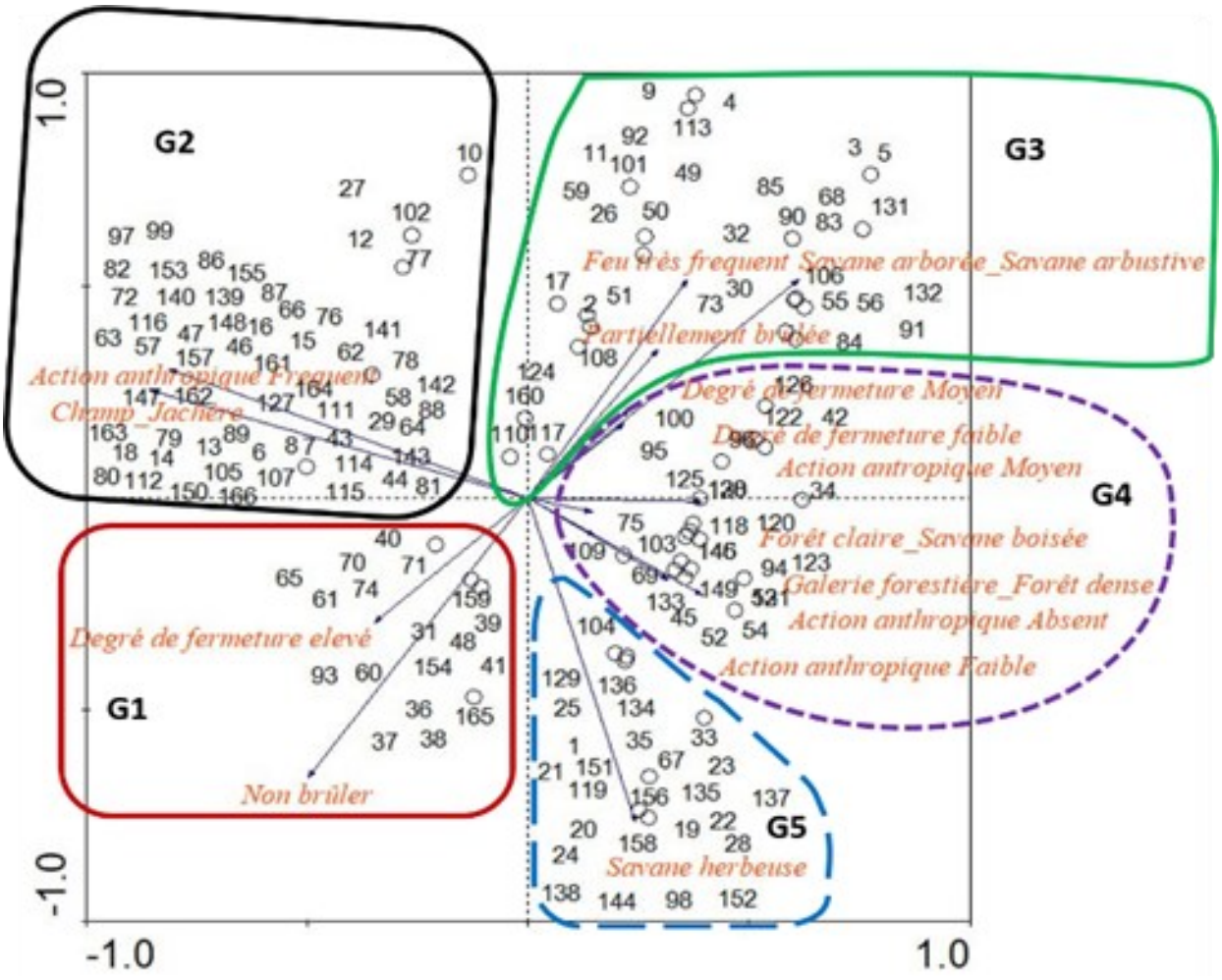


Figure 7. Canonical correspondence analysis (CCA) of the OKMRB plots

There was almost no presence of species from the western forest block.

3.2. Floristic and ecological characteristics

Five groups were identified by canonical correspondence analysis (CCA) (Figure 7). Group 1 consists of unburned floodplain shrub savannahs (G1). These are interspersed with fields and fallows. Fields and fallow lands comprise Group 2 (G2). Group 3 (G3) comprises tree/shrub savannahs, generally burned. Group 4 includes riparian forests, dense dry forests, open forests, and woodlands. Group 5 consists of grassy savannahs, which are generally flooded.

3.2.1. Unburned floodplain shrub savannahs (G1)

G1 consists of 19 plots of shrub savannah patches scattered amongst anthropogenic formations. Most of these are subject to flooding. This area contains 71 species, belonging to 54 genera and 24 families. Leersia hexandra Sw. (14.99%) was the most abundant species, followed by *Aspilia kotschyi* (Sch.Bip.) Oliv. *var. alba* Berhaut (11.01%). The most com-

mon species in terms of frequency of contact were: *Terminalia macroptera* Guill. & Perr. (31.58%) and *Leersia hexandra* Sw. (26.32%). Seven (7) species were found to be the most preferred: *T. macroptera*, *L. hexandra*, *Andropogon gayanus Kunth var. bisquamulatus* (Hochst.) Hack., *V. unguiculata*, *Faidherbia albida* (Delile) A.Chev., *Paspalum scrobiculatum* L., *Piliostigma thonningii* (Schumach.) Milne-Redh. The Shannon index and Pielou evenness index were 4.82 bits and 0.78 bits respectively.

The average height is 6.01 m and the average diameter was 22.20 cm. The tree density is D = 15 stems/ha. The basal area was G = 0.57 m^2/ha.

3.2.2. Fields and fallow land (G2)

This group has 60 plots. The main crop was rice. Cowpea and maize are grown as secondary crops. The area's flora consisted of 195 species belonging to 144 genera and 47 families. The most abundant species were: *Oryza sativa* L. (14.22%), followed by *Vigna unguiculata* (L.) *Walp. ssp. unguiculata var. unguiculata* (4.55%) and *Zea mays* L. (3.59%). *Hyptis spicigera* Lam. is the most frequent species (41.66%). This group contains the largest number of preferred species, with 25 species. The most preferred species were: *H. spicigera*, *Piliostigma thonningii* (Schumach.) Milne-Redh., *Oryza sativa*, *Combretum glutinosum* Perr. ex DC., *Pennisetum polystachion* (L.) Schult. *subsp. polystachion*, *Terminalia macroptera* Guill. & Perr. The Shannon index is higher in this grouping (6.17 bits). The equitability is 0.81.

The average Lorey height is H = 4.77 m and the mean diameter is Dm = 22.77 cm. The tree density is 12 stems/ha and the basal area G = 0.48 m^2/ha.

3.2.3. Frequently burned savannahs (G3)

This group comprises 103 plants in 81 genera and 33 families across its 34 plots. The most abundant species were: *Loudetia togoensis* (Pilg.) C.E. Hubbard (10.48%) and *Andropogon gayanus* Kunth *var. bisquamulatus* (Hochst.) Hack. (8.94%). The most common species, with a frequency of 38.23%, were: *Loudetia togoensis* (Pilg.) C.E. *Hubbard, Acacia sieberiana* DC. *var. villosa* A. Chev., *Combretum glutinosum* Perr. ex DC., and *Acacia gourmaensis* A. Chev. These species were the most preferred, with a rarity index of 61.74%. They are followed by: *Piliostigma thonningii* (Schumach.) Milne-Redh., *Blepharis linariifolia* Pers., and *Andropogon gayanus* Kunth *var. bisquamulatus* (Hochst.) Hack. The values of the Shannon index and the Pielou evenness index correspond to 5.50 and 0.82 respectively.

The mean Lorey height is H = 5.11 m, the mean diameter is Dm = 22.15 cm. The timber density is D = 17 stems/ha and the basal area G = 0.37 m^2/ha.

3.2.4. *Mitragyna inermis* floodplain savannahs (G4)

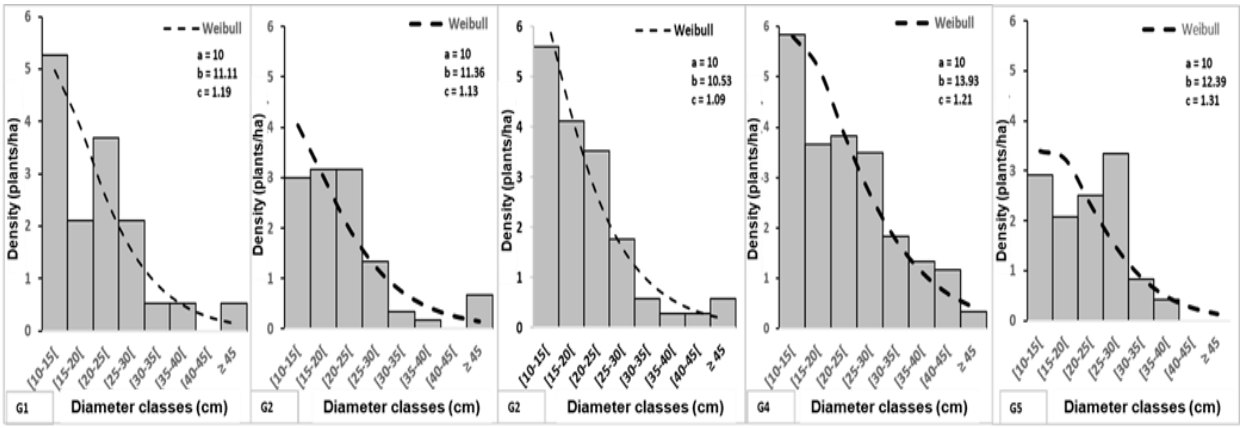
This group comprises 60 plots of floodplain wooded savannahs. These are under heavy human influence. A total of 70 plant species belonging to 54 genera and 27 families have been recorded. The most common and abundant species was *Mitragyna inermis* (Willd.) Kuntze. *M. inermis* (70%) was the only preferred species. The Shannon index and the Pielou evenness index were 5.82 bits and 0.82 bits, respectively.

The tree height was H = 5.30 m, the tree diameter Dm = 25.36 cm. Woody plant density was D = 22 plants/ha and basal area G = 1.09 m^2/ha.

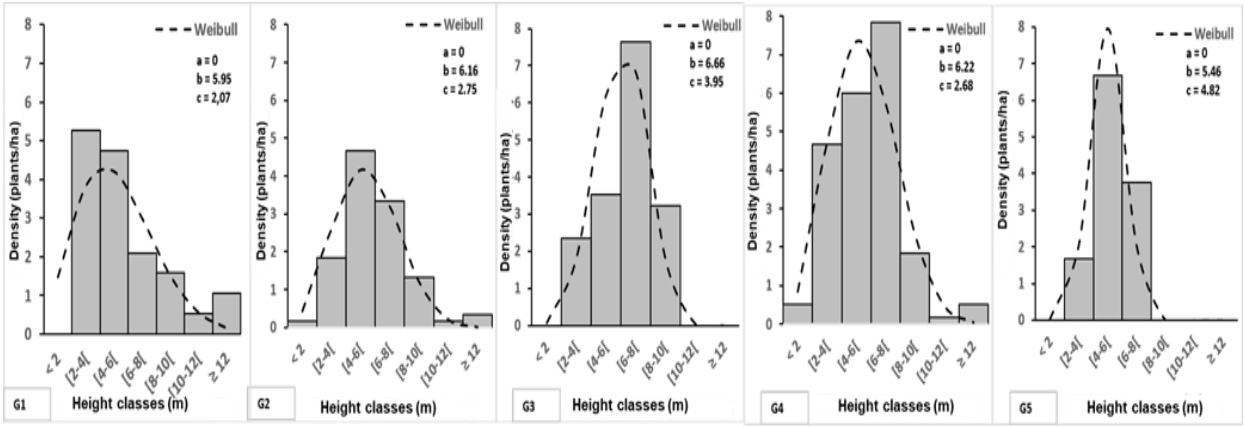
3.2.5. Shrub savannahs of Mitragyna inermis and Hygrophila auriculata (G5)

This group comprises a total of 24 plots. There were 70 species, 54 genera and 27 families in this group. The most common species were *Mitragyna inermis* (Willd.) Kuntze (50%) and *Hygrophila auriculata* (Schumach.) Heine (41.67%). In contrast, *Loudetia togoensis* (Pilg.) C.E. Hubbard was the plant with the greatest spatial representation (16.66%). *Hygrophila auriculata* and *Mitragyna inermis* are in second and third place with 14.15% and 10.11% respectively. The five preferred species were: *M. inermis*, *H. auriculata*, *L. togoensis*, *Acacia sieberiana* DC. *var. villosa* A. Chev., and *Coldenia procumbens* L. The respective rarity indices for these species were 50%, 58.33%, 62.5%, 75%, and 79.17%. There were 65 rare species. The lowest values for the Shannon index and Pielou evenness were found in this group, with 4.72 bits and 0.77 bits respectively.

The mean height was H = 5.38 m and the mean diameter Dm = 22.73 cm. The density of woody



Figures 8. OKMRB tree diameter structures



Figures 9. OKMRB tree height structures

plants was D = 12 stems/ha and the basal area G = 0.20 m^2/ha.

3.3. Demographic structure

Overall, the distribution of the trees by diameter classes showed an L-shaped structure (Figure 8). In the most cases, the most abundant individuals were those between 10 and 15 cm in diameter. This explains the shape coefficient values ranging from 1.09 and 1.31. There were a very few large-diameter trees.

The vertical structure of all clusters is 'bell-shaped'. The highest densities are concentrated in the 2-4 m high class for cluster G1, the 4-6 m for clusters G2 and G5 and the 6-8 m for clusters G3 and G4 (Figure 9). The shape coefficients "c" from 1 to 3 show an asymmetric bell-shaped structure to the left within groups G1, G2 and G4. In contrast, the structure is an asymmetric, right-sided bell shape with a shape coefficient greater than 3 in groups G3 and G5. Individuals less than 2 m tall are virtually absent. There are very few in groups G2 and G4.

4. Discussion

4.1. Diversity of plant assembly

A previous study in OKMRB reported 116 woody species divided into 84 genera and 33 woody species families (Dimobe et al., 2012). This woody species diversity has been found to be higher than in this study. A further study recorded 320 herba-

ceous and woody species in 209 genera and 66 families (Polo-Akpisso et al., 2015). The observed difference can be explained by the slightly larger sample size and sampling methodology. Additionally, the degradation caused by the encroachment of riparian populations could lead to a loss of biodiversity. The anthropisation of natural vegetation usually results in an increase in chamaephytes and therophytes to the detriment of phanerophytes, which remain woody (Gnahoré et al., 2020).

Several anthropogenic formations were reported in this study. These include fallow land and fields. The most commonly recorded was rice cropland. This crop is most commonly grown in wetlands or lowlands. Wetlands are of particular interest due to their high carbon sequestration capacity and the unique biodiversity found in these ecosystems (Bouzille et al., 2014; Mabafei et al., 2021). Woody vegetation destruction during cultivation is a major cause of natural formation degradation and deforestation (Diwediga et al., 2012; Kokou et al., 2023; Kombate et al., 2023; Biah et al., 2024). Deforestation has become even more acute within the protected area under study, threatening the existence of almost all forest ecosystems and their flora and fauna, as reported in previous studies (Dimobe et al., 2012; Polo-Akpisso et al., 2018; Polo-Akpisso et al., 2020).

The dominance of Poaceae and Combretaceae in the studied area is characteristic of the relatively humid Sudan savannahs (Aubréville, 1950). The dominance of Poaceae, which are herbaceous plants, favours the occurrence of wildfires (Atakpama et al., 2019). Wildfires mainly occur in the savannahs and in the areas of human activity that are adjacent to protected areas. Natural ecosystems (open forests, gallery forests, and dense dry forests) can be invaded locally by fire from adjacent savannahs and anthropogenic formations (Dube, 2009; Atakpama et al., 2023b). The abundance of Rubiaceae, which ranks third, is favoured by humidity in the area (Folega et al., 2014; Polo-Akpisso et al., 2015).

The abundance of therophytes indicates human pressure on vegetation (Gnahoré et al., 2020). These therophytes include annual plants that are constantly burned. This finding is analogous to that observed in the Doung Pits Classified Forest in the same eco-floristic zone of Togo (Atakpama et al., 2023a). The dominance of therophytes and nanophanerophytes over mesophanerophytes shows the limited representation of the forest layer, particularly the regression of the open forests, which were once prevalent in this protected area (Adjonou et al., 2009).

The high representation of Guineo-Congolese/ Sudanese-Zambezi transitional species indicates the favourable conditions for the development of transitional savannahs. The zone is shown to be more humid than the general context of the Ecological Zone I in Togo, which is characterized by Sudanese savannahs (Atakpama et al., 2019; Folega et al., 2022). The dominance of these transitional species is comparable to that of the sacred groves and plant communities of the Doungh Pit Classified Forest in Ecological Zone I (Atakpama et al., 2022; Atakpama et al., 2023a). Despite being degraded, the study area is less susceptible to plant invasions than other plant formations in Zone I (Folega et al., 2019; Atakpama et al., 2021; Atakpama et al., 2022; Folega et al., 2022). This demonstrates the relative authenticity of the OKMBR in terms of its primitive character.

Plant communities on the islands within the anthropised areas (fields and fallow land) seem to be the most diverse. They provide an ideal environment for preserving the biodiversity of both savannah and wooded species. The surrounding fields of the islands act as natural barriers, preventing fires from spreading. Preserving these islands is important for implementing the restoration policy within the OKMBR. Akodéwou and Godron (2022) have shown that anthropisation can increase floristic diversity. This seems to be the case. The fields and fallows are mostly diversified amongst the plant communities identified in the present study. Exposure due to human threats aids the development of both savannah and forest species. In undisturbed plant communities, especially forests, the development of herbaceous and heliophile species is not favoured.

The preferred species can indicate the typology of the discriminated plant communities. The more herbaceous a plant community is, the more vulnerable it is to vegetation fire (Atakpama et al., 2019). Herbaceous plants are a dominant feature of shrub savannahs, which are frequently burned. Conversely, increasing woody cover reduces the availability of herbaceous biomass, which is consumed primar-

ily during vegetation fires (Afelu and Kokou, 2015; Atakpama et al., 2019). Each floodplain grouping is unique, as revealed by the flora. *H. spicigera*, an invasive Lamiaceae, is highly abundant in fields and fallows. This species has also been reported in the degraded pastures in the Eburnean basement in northern Togo (Ibrahim-Naim et al., 2021).

4.2. Vegetation demographic structure

The diameter structure of individuals in a forest provides information on stand and species population dynamics (Adjonou et al., 2009). It gives information on the conservation status of woody species and their regenerating processes (Dimobe et al., 2014). The present study distinguishes two types of stem diameter distribution. In general, several diameter classes are absent, evidently influenced by anthropogenic pressures. Woody species are most often harvested as firewood or transformed into charcoal, and sometimes sold by local people (Dimobe et al., 2012). Farming and settlements are also major causes (Diwediga et al., 2012; Polo-Akpisso et al., 2020). Comparing the demographic structure obtained in this study with that of a previous study in the OKMBR, it seems that these different causes of population degradation mentioned in the previous study are more pronounced now (Dimobe et al., 2014).

Moderately burned areas showed an 'L' structure with a high proportion of small-diameter individuals. This distribution appears similar to that described by scholars in the study area and the sub-region (Awokou et al., 2009; Folega et al., 2022). The same observation was made in the Abdoulaye Wildlife Reserve (AWR) in the centre of the country (Adjonou et al., 2010). Partially burned areas exhibit an asymmetric bell-shaped structure on the left, dominated by medium-diameter individuals. According to Morou et al. (2016), the presence of a high number of small- or medium-diameter individuals guarantees the future of natural plant communities. The low proportion of large-diameter individuals indicates the presence of many anthropogenic pressures (Lykke et al., 2025).

5. Conclusion

A total of 263 plant species belonging to 56 families and 169 genera were identified in the OKMBR. This flora includes 105 woody species. This diversity is less significant than that observed in previous studies in the same reserve. The most represented families are: Poaceae, Combretaceae, and Rubiaceae. The floristic composition is dominated by therophytes and microphanerophytes, highlighting the anthropogenic pressures. The transitional nature of the vegetation in this area is evident in the phytogeographical types that are dominated by the Guineo-Congo/Sudano-Zambezi species. Human activity has greatly reduced the capacity of woody formations to regenerate. This is due to erratic demographic structures and a lack of individuals with large diameters. To efficiently manage this protected area, human activities must be regulated. Converting areas currently occupied by fields into agroforestry parks would contribute to the reduction of greenhouse gas emissions. This would also provide an effective means of restoring the ecosystem. The preserved vegetation relics should be protected.

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