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Compositional and Structural Diversity of Woody Stands in the Community Forests of Rogho and Boala in Central-West Burkina Faso

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ABSTRACT

The biodiversity of community forests is poorly studied in Burkina Faso. This results in a lack of understanding of their ecological importance, which is characterized by neglect in their management. The main objective of this study is to characterize the flora and woody vegetation of the community forests of Rogho and Boala to demonstrate their importance. For this purpose, a forest inventory was conducted using stratified random sampling methods. Shannon, Simpson, Margalef, and Pielou diversity indices reveal significant biodiversity of the flora in both forests, with a better distribution of individuals within the species that make them up. The horizontal structure of the two woody populations is characterized by a predominance of individuals with small diameters (DBH € [5cm-25cm[) on either side, with respective regeneration rates of 58.36% and 22.46% for Rogho and Boala. Regarding the ecological importance of species, Lannea microcarpa has the highest Importance Value Index (IVI = 99.06) for the Rogho site, and Vitellaria paradoxa for the Boala site (IVI = 136.58). Phanerophytes dominate the flora of both forests with a strong presence of mesophanerophytes. The average density of woody plants is evaluated at 330.34 trees/ha and 742.01 trees/ha respectively in Rogho and Boala, with respective average land areas of 14.8 m2/ha and 119.78 m2/ha. This study highlights the strong ecological potential of the forests studied. Communal and regional authorities must develop strategies for the sustainable management of these forest areas.

INTRODUCTION

Natural resources, including forest ecosystems, are subject to climatic and anthropogenic disturbances (Assogba, 2016; Ouédraogo, 2016; Belem et al., 2018). These disturbances are characterized by a reduction in forest cover, loss of biodiversity (Sylla et al., 2019; Sultan and Pillai, 2023), and depletion of forest resources (FAO, 2010). These disturbances also affect Burkinabé forest resources. According to MECV (2007), the national forest cover experiences an annual decline of approximately 105,000 ha. However, it is undeniable that the benefits of forest reserves have been established for a long time (Nguemo et al., 2017; Gelan, 2023). They contribute to protecting land against water and wind erosion, regulating runoff water, and improving the fertility of agricultural soils (IFN 2, 2018).

This observation has spurred the dynamism of Burkinabe authorities in promoting forest spaces. This dynamism is manifested in initiatives such as "one department, one forest". Since then, there has been the creation and proliferation of forest areas in all directions. With the completion of the comprehensive decentralization process in 2006, the management of forest resources was transferred to municipal authorities. They took the opportunity to establish communal forests or rehabilitate existing village forests (Yanogo et al., 2023). Once established, these forest areas face rainfall variations and anthropogenic pressures (Traoré et Zongo, 2023) that lead to and accelerate their degradation (Sanogo et al., 2023).

However, they are not documented like other protected areas. So, they remain poorly understood, leading to insufficient enthusiasm for their management (Tamara et al., 2023). This situation hampers the implementation of sustainable management and development practices for these forest lands (Abdourhamane et al., 2013; Melom et al., 2015). Therefore, studies are needed on these forest areas to produce scientifically valid data for their sustainable management. The present study is conducted with this objective in mind. It aims to characterize the flora and woody vegetation of the communal forests of Rogho and Boala through (1) the analysis of the compositional diversity of woody populations, (2) the analysis of the structural diversity of woody populations, and (3) the analysis of the ecological importance of the species that make up the woody populations.

MATERIALS AND METHODS

Study area

This study takes place in two distinct sites: the communal forest of Rogho in the Sourgou commune and the communal forest of Boala in the Bieha commune (Figure 1). From a climatic perspective, these two communes are located in different climatic zones, with Sourgou in a sudano-sahelian zone and Bieha in a Sudanese zone. The seasons vary in duration and precipitation from one commune to another. Sourgou has a four-month rainy season, from June to September, with average annual precipitation of 780.9 mm (1991-2020), while Bieha has a six-month rainy season, from May to October, with average precipitation of 989.2 mm (1991-2020). Both communes experience a dry season that varies in duration and monthly average temperatures.

The vegetation in Sourgou is of the North Sudanian type, characterized by savanna formations dominated by natural species such as *Parkia biglobosa, Vitellaria paradoxa, Lannea microcarpa*, and *Bombax costatum*. Anthropogenic pressures on these formations have led to the creation of the communal forest of Rogho, which is the largest in terms of area and vegetation cover.

In contrast, the Bieha commune has vegetation of the South Sudanian type, consisting of significant savanna formations and some gallery forests along watercourses. The ongoing degradation of these resources has resulted in the establishment of protected areas, such as the Boala ZOVIC, which is comparable to a communal forest as it is managed by local communities (Yanogo et al., 2023).

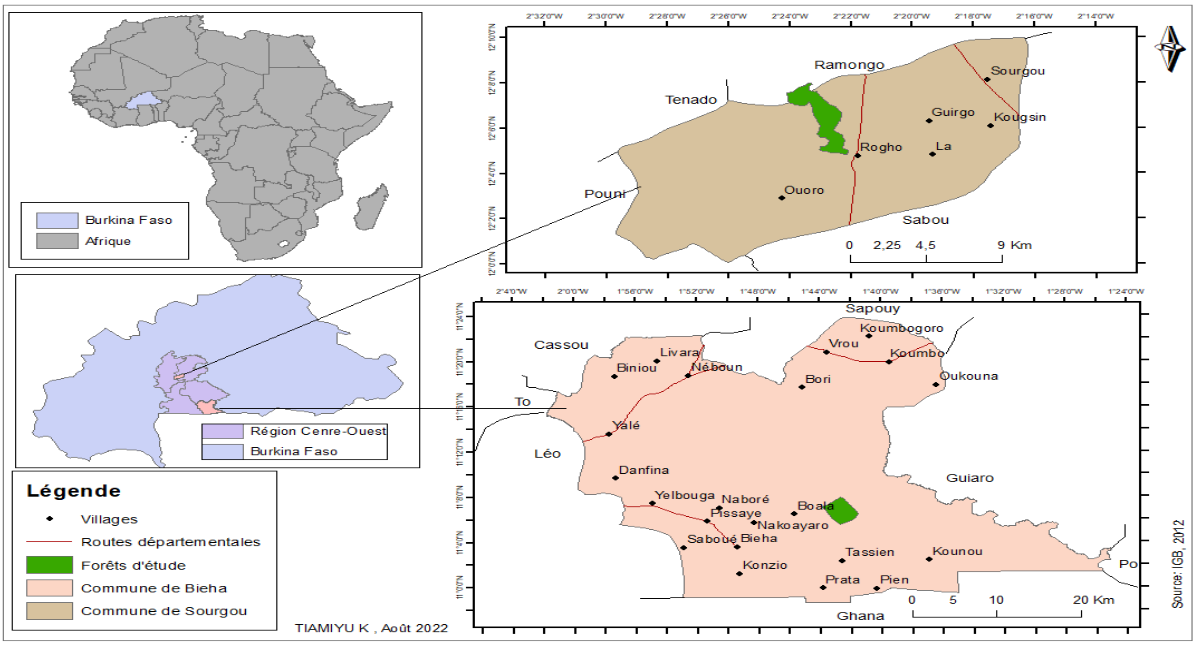

Figure 1. Map of the Study Area

Sampling Method

The random stratified sampling method was adopted to investigate both forests (Kaou et al. 2017 and Kpangui et al. 2019), with respective sampling rates of 0.48% and 0.44% for the Rogho and Boala forests. The sampling units delimited to investigate the forests are of fixed size and circular with an 17.85 -meter radius.

Materials

The materials include both the human capital mobilized and the equipment used. The human capital consists of a team of six individuals who brought with them equipment consisting of:

1. An 18.5-meter-long string and two small stakes for delimiting the sampling units.
2. A sliding decameter for measuring species height.
3. A measuring tape for measuring circumference.
4. A GPS for locating the center of the sampling units.
5. Paint for marking the starting point of the inventory for each sampling unit.
6. Inventory sheets.
7. A camera for taking pictures of unidentified individuals for later identification.

Data Collection

A total of 77 circular plots with a radius of 17.85 meters were delineated, with 37 in the Rogho forest covering an area of 758.66 hectares, and 40 in the Boala forest covering an area of 909.4 hectares. The distribution of these plots was carried out using QGIS 3.20.3 software, randomly based on the two types of vegetation formations in proportion to their area. This was accomplished through the 'Vector-Research Tools' function (random points within polygons) of the software. The coordinates of these sampling units were generated and then transferred to the GPS Waypoints application installed on a smartphone.

These various points are connected through the 'Get me There' function of the application, using GMaps. The use of this application is justified by its operationalization and satisfactory precision level, capable of reaching resolutions down to one meter (1 m). All individuals encountered in the sampling units were inventoried. The collected data for each individual included the scientific name, circumference, and height. The nomenclature used is that of the Catalog of Vascular Plants of Burkina Faso by Thiombiano et al. (2012) (Traoré et Zongo, 2023). The height considered for measuring the circumference is 1.3 meters, and for individuals shorter than 1.3 meters or at the base, it is 20 cm, as applicable.

Data Analysis and Processing

For the compositional diversity of the studied forests, the following indices were calculated:

1. Species Richness (S): It represents the total number of inventoried species or the average number of species per unit area (Grall and Coïc, 2005). It provides an idea of the variety of ecological niches in an environment (Rocklin, 2003).
2. Simpson's Index (1-D): It measures the probability that two randomly chosen individuals in a sample belong to the same species. This index considers abundant species more than rare ones. Its value ranges from 0 to 1, where 1 represents high biodiversity.
3. Shannon's Index (H'): It assesses the heterogeneity and diversity of a biotope (Abdourhamane et al., 2013). Its value ranges from 0 to log2 S and is calculated as follows:

$H' = -\sum pilog2p$; Pi = relative abundance of each species; Log (2) = logarithm calculated with base 2; Pi = Ni/N with Ni = the population of species i; N = total population of species. The use of this index is often accompanied by Piélou's equitability index.

1. Piélou's Equitability (E): This index, unlike Shannon's, measures the distribution of individuals among species and thus reflects the degree of diversity in the studied population. Its value ranges from 0 to 1. It tends towards 0 when almost all individuals belong to a single species and takes the value of 1 when all species have exactly the same coverage (Mbaiyetom et al., 2021).

E = H' / H max with H max = log2 S; where S is the total number of species.

2. Brillouin's Index (HB): It calculates the diversity corresponding to the structure of the observed population on a delimited unit (Amandier et al., 2012). Its formula is as follows according to Danoff-Burg, 2003:

Where, HB = Brillouin's index; N = total number of individuals; ni = Number of individuals of species i; ln = natural logarithm.

3. Margalef's Index (DMg): This index provides information about the specific richness (S) of a given plant population (Moumouni et al., 2017). According to Soudant & Belin, (2011), the mathematical formula for its calculation is:

DMg = (S-1) / ln [(N)], with S as the number of species, ln as the natural logarithm, and N as the number of individuals.

4. Menhinick's Index (DMn): This index is similar to Margalef's and is based on the relationship between the number of species and the total number of observed individuals. It estimates absolute species richness independently of the sample size (Peet, 1974 cited by Grall and Coïc, 2005). The mathematical formula proposed for its calculation is as follows:

$DMn = S / \sqrt{N}$, where DMn = Menhinick's index, S = Species richness, and N = number of individuals.

The combined choice of these indices allows for a precise assessment of the diversity of each group based on the distribution of recorded species (Kassi & Decocq, 2006 cited by Mokoso et al., 2018). These indices were calculated using the PAST (PAleontological Statistics) 3.26 software.

The Jaccard similarity index (IJ) was used to study the similarity of different vegetation units in the area. This index is calculated using the formula: $IJ = 100x\ c / (a + b - c)$, where a = number of species in unit A, b = number of species in unit B, c = number of species common to both units. If IJ > 50%, the environments are similar, and if IJ < 50%, there is dissimilarity between the environments. In practice, when IJ > 45%, it is accepted that there is similarity between the relevant environments (Djego et al., 2012). All statistical tests are performed using the XLSTAT software (Ndiaye et al., 2014).

Structural Diversity of the Studied Forests and Dendrometric Characteristics of Woody Populations

The horizontal and vertical structure of woody species and the basal area were used to characterize the structural diversity of the discriminated plant formations. The diameter (D) of individuals was deduced from their circumference using the following formula: $D = C/\pi$. Histograms were used to visualize the horizontal and vertical structure of woody species. The basal area is a variable that incorporates other dendrometric parameters such as tree density and average tree diameter. Its formula is as follows:

$G = \sum \pi D^2/4$, where G = basal area expressed in m^2/ha and D = diameter at breast height of trees.

Ecological Importance of the Inventoried Species

The Importance Value Index (IVI), biological types, and the chorology of inventoried species were used to assess the ecological importance of the studied populations. IVI is frequently used to represent the importance of species in a plant community (Assogbadjo et al., 2009; Soro et al., 2019). The higher the IVI value of a species, the more ecologically important it is (Agbani et al., 2018). Its formula is as follows:

IVI = Relative Density + Relative Dominance + Relative Frequency

Biological and Phytogeographical Types

The biological types defined by Raunkier (1934) were used to establish the biological spectrum of the flora in the studied forests, while the phytogeographical spectrum drew inspiration from the work of White (1983) on chorological subdivisions for Africa (Tamara et al., 2023).

RESULTS AND DISCUSSION

Typology of Vegetation Units at the Study Sites

The 2012 Land Use Database (BDOT 2012) revealed two types of vegetation formations present at the Rogho site : a savannah formation (FS) and a complex of cultivated fields and natural areas (CCEN) (Figure 2). Floristic surveys were conducted within these two formations. As for the Boala site, the matrices of 40 surveys and 62 species were subjected to an agglomerative hierarchical clustering analysis using Ward's method based on species richness and individual density per survey. This allowed the discrimination of two main vegetation formations (Figure 3):

1. Formation G1 with *Vitellaria paradoxa* and *Pteleopsis suberosa*, comprising eighteen surveys (P1-P2-P3-P4-P5-P11-P12-P16-P17-P18-P19-P20-P21-P23-P31-P32-P35-P37).
2. Formation G2 with *Vitellaria paradoxa* - *Detarium microcarpum* - *Burkea africana*, comprising twenty-two surveys (P6-P7-P8-P9-P10-P13-P14-P15-P22-P24-P25-P26-P27-P28-P29-P30-P33-P34-P36-P38-P39-P40).

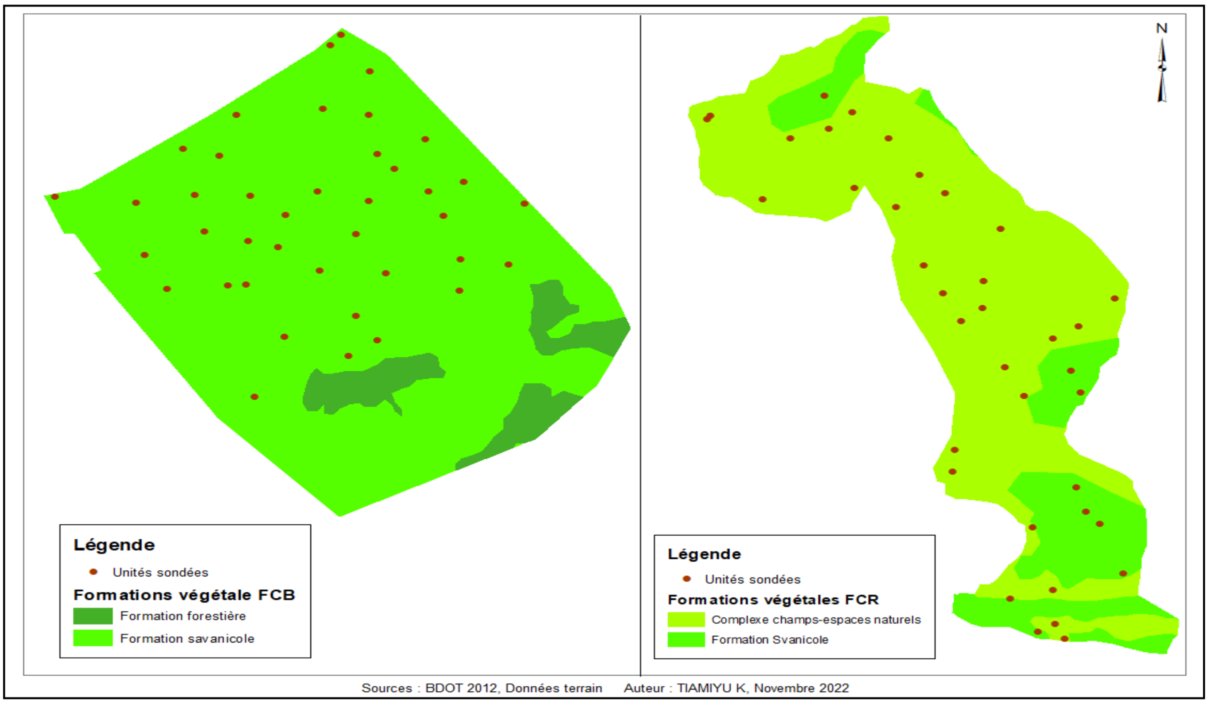

Figure 2. Unit of Land Use and Survey for the Study Forests

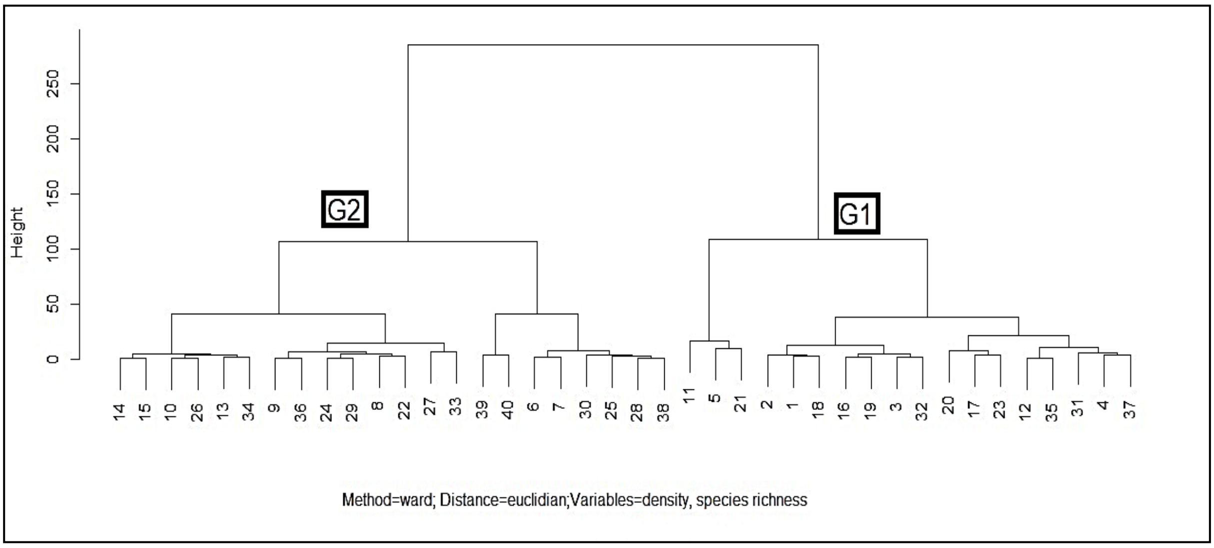

Figure 3. Dendrogram of Surveys from the Boala Site

Compositional Diversity of Identified Vegetation Units

Species Richness and Overall Species Diversity

Both sites exhibit an overall species richness of 80 species, distributed across 32 families and 61 genera (Table 1). It is similar to that observed in the Pama Reserve in Southeast Burkina Faso (Mbayngone et al., 2008) and in Northern Togo (Polo-Akpisso et al., 2015), but significantly lower than that of the classified forests of Besso and Badenou in Côte d'Ivoire (N'Guessan, 2015; N'dja et al., 2017; Gboze et al., 2020) and the Ouoghi Forest Reserve in Central Benin (Ahouandjinou et al., 2017). This difference could be explained by the varying size of these forested areas (Atakpama et al., 2022b; Bawa et al., 2022) and their protected status. The protected status enjoyed by classified forests and forest and wildlife reserves contributes to biodiversity conservation in these areas (Bawa et al., 2022) compared to community forests. The relatively larger size of classified areas compared to the forests in this study could also be an explanatory factor. This is supported by the comparison of the flora of the two study sites, which reveals species diversity proportional to their extent. The Boala site, larger in terms of area, contains 62 species grouped into 26 families and 48 genera, while the Rogho site, which is smaller in extent, has 54 species distributed across 25 families and 43 genera. However, site size is not the only explanatory factor for this situation. Climatic conditions are also factors to consider. The Boala site is located in the Sudanian zone, which experiences a wetter climate than the Sudan-Sahelian zone to which the Rogho site belongs. Atakpama et al. (2022b) have indeed justified the difference in species diversity in the community forests they studied based on climatic factors.

The dominant species in the flora of Rogho are *Vitellaria paradoxa* (10.3%), *Piliostigma reticulatum* (8.07%), *Diospyros mespiliformis* (7.11%), *Ficus ingens* (6.79%), and *Terminalia avicennioides* (6.63%), while those in Boala are *Vitellaria paradoxa* (11.50%), *Pteleopsis suberosa* (6.62%), *Detarium microcarpum* (6.19%), *Burkea africana* (5.55%), and *Terminalia brownii* (5.19%). The high presence of *Vitellaria paradoxa* in Rogho is due to the fact that this site is predominantly occupied by fields. Thus, farmers spare this species for its multiple benefits over crops. In Boala, the dominance of *Vitellaria paradoxa* is explained by the site being chosen for the production of organic almonds. Therefore, the species is more extensively planted and protected.

In terms of family representation, the Rogho site is dominated by Fabaceae-Mimosoideae (14%), Combretaceae (12%), Anacardiaceae (10%), and the Boala site is dominated by Combretaceae (12.5%), Fabaceae-Mimosoideae (12.5%), Fabaceae-Caesalpinioideae (10.71%) (Table 2). Fabaceae-Mimosoideae and Combretaceae are among the most well-represented families on both sides (Table 2). Combretaceae are characteristic of the North Sudanian region of Burkina Faso (Sawadogo, 1996). The predominance of Fabaceae and Combretaceae is also reported in Saré Yorobana in the Casamance agroecological zone of Senegal by Diedhiou et al. (2018), in central Togo by Atsri et al. (2018) and in the Agbandi community forest in central Togo by Bawa et al. (2022). In contrast, the Natural Forest of Mondah in Gabon is dominated by Myristicaceae, Burseraceae, and Euphorbiaceae (Ndjomba et al., 2022). This difference could be explained by the higher humidity conditions in Mondah under an equatorial climate compared to the study sites under a dry tropical climate. It should be noted that this floristic diversity varies depending on the types of vegetation formations.

Specific Richness and Diversity of Different Vegetation Formation Units

The analysis of specific richness per vegetation unit shows fairly consistent results among the Complex Fields-Natural Spaces (CCEN) unit, Savanna formation (FS) unit, and G2 vegetation formation unit: CCEN: 49 species, 24 genera, 42 families; FS: 50 species, 23 genera, 41 families; G2: 52 species, 25 genera, 43 families. The specific richness of the G1 vegetation formation is slightly different with 58 species, 25 families, 47 genera (Table 1). A similar observation was made in the woody populations of natural pastures in the Maradi region of Niger, where Alhassane et al., (2018) demonstrated fairly consistent specific diversity across bioclimatic zones. However, the floristic composition remains somewhat different from one site to another. Out of the 80 species inventoried, only 36 (45%) species are common to both sites.

Table 1. Specific Diversity of Study Populations

Populations	Species richness	Family count	Genus count	Generality coefficient (GC)
Rogho	54	25	43	0,7962
Savanna formation	50	23	41	0,82
Complex Fields-Natural Spaces	49	24	42	0,8571
Boala	62	26	48	0,7741
Formation G1	58	25	47	0,8103
Formation G2	52	25	43	0,8269
Global	80	32	61	0,7625

Source: Field Data Processing

Table 2. Proportion of Families by Vegetation Unit

Familles	Complex Fields-Natural Spaces	Savanna formation	Formation G1	Formation G2
Anacardiaceae	10%	10%	5.17%	5.77%
Annonaceae	2%	2%	1.72%	1.92%
Apocynaceae	8%	8%	3.45%	3.85%
Bignoniaceae	-	-	-	1.92%
Bixaceae	2%	2%	1.72%	1.92%
Bombacaceae	-	-	1.72%	1.92%
Capparaceae	-	2%	-	-
Celastraceae	2%	2%	-	-
Combretaceae	12%	14%	12.07%	17.31%
Droseraceae	2%	2%	1.72%	1.92%
Euphorbiaceae	-	-	1.72%	1.92%
Fabaceae	2%	4%	5.17%	5.77%
Fabaceae-caesalpinioideae	8%	8%	10.34%	9.62%
Fabaceae-faboideae	2%	2%	5.17%	5.77%
Fabaceae-faboideae-mimosoideae	2%	2%	-	-
Fabaceae-mimosoideae	14%	14%	12.07%	9.62%
Lamiaceae	2%	2%	1.72%	1.92%
Loganiaceae	-	-	3.45%	3.85%
Malvaceae	2%	2%	5.17%	5.77%
Meliaceae-menispermaceae	2%	-	1.72%	1.92%
Moraceae	4%	2%	1.72%	1.92%
Myrtaceae	2%	-	-	-
Ochnaceae	-	-	1.72%	1.92%
Phyllanthaceae	2%	2%	5.17%	1.92%
Poaceae			1.72%	1.92%
Polygalaceae	2%	2%	1.72%	1.92%
Rhamnaceae	4%	2%	-	-
Rubiaceae	8%	10%	6.90%	3.85%
Salicaceae	-	-	3.45%	-
Sapotaceae-simaroubaceae	2%	2%	1.72%	1.92%
Ximeniaceae	2%	2%	1.72%	1.92%
Zygophyllaceae	2%	2%	-	-

Source: Field Data Processing

Global Diversity Indices

Floristic diversity indices provide an objective measure of the diversity within a plant community (Ramade, 1994, as cited by I. Tatila et al., 2017). The analysis of the Shannon, Simpson, and Margalef indices yields respective overall values of 3.46, 0.955, and 6.368 for the plant community in Rogho, and 3.532, 0.957, and 7.862 for Boala. These indices are quite similar across the various vegetation units identified in this study (Table 3). This indicates a good diversity of woody populations within these units. The very high values of the regularity index (>0.80), which are consistent across all vegetation units, suggest a well-distributed population of individuals within the species that make up each unit, both within each site. These findings align with those of Tatila et al. (2017) in Manda National Park in Chad. However, the Shannon and Margalef index values are higher (H'=5.25; MG=13.73) than those in our study sites, while Pielou's evenness is relatively lower (E=0.74). This difference could be explained by the higher number of species in the park (R=137) compared to our study sites.

Table 3. Specific Diversity Indices of Plant Populations

Populations	Simpson_1-D	Shannon_H'	Brillouin	Menhinick	Margalef	Equitbility_E
Rogho	0.955	3.46	3.416	0.9484	6.368	0.8758
F S	0.9525	3.298	3.219	1.441*	7.111	0.8347
C CEM	0.9399	3.268	3.202	1.235	6.72	0.8311
Boala	0.9579	3.532	3.491	1.058	7.862	0.8431
Formation G1	0.9607*	3.588*	3.519*	1.361	7.889*	0.8729*
Formation G2	0.9498	3.344	3.28	1.267	7.16	0.8345

Source: Field Data Processing

Similarity among Different Vegetation Units

Examination of the similarity index reveals a resemblance between the flora of the Complex Fields-Natural Spaces and the Savanna Formation (83.33%), on the one hand, and between the flora of Vegetation Formations G1 and G2 (77.42%), on the other hand. Between the flora of Rogho and that of Boala, the similarity index is 45%, indicating a low similarity between these two sites in terms of species composition (Table 4). The intra-biotope similarity observed in both sites is explained by the fact that the vegetation units share the same habitat and are subject to the same environmental conditions. The dissimilarity observed in the flora of the two sites could be justified by the fact that they are located in different climatic regions. The high level of human influence in the Rogho site, evidenced by the presence of imported species, may also contribute to this situation.

Table 4. Similarity among Vegetation Units in the Study Sites

	CCEN	FS	G1	G2	FCmR	FCmB
CCEN	100					
FS	83.33	100				
G1	42.66	47.95	100			
G2	36.49	45.71	77.42	100		
FCmR	83.92	89.09	40	41.33	100	
FCmB	42.31	45.45	87.5	75.38	45	100

Source: Field Data Processing

Structural Diversity of Identified Vegetation Formation Types

Horizontal Structure of Studied Woody Populations

Considering a minimum diameter of 5 cm for adult individuals, individuals with diameters below this threshold are consistently categorized as part of the regeneration flora. The horizontal structure takes into account the distribution of adult individuals by diameter class.

Diameter Class Structure of Savanna Formation and Complex Fields-Natural Spaces Populations

The distribution of individuals according to their diameter class exhibits significant variations. According to this distribution, savanna formations and Complex Fields-Natural Spaces are dominated by small-diameter individuals (DHP € [5cm-25cm[), representing over three-quarters of the population in both units (80.03% for the savanna and 75.67% for the complex). Large-diameter individuals (DHP≥95cm) are less abundant in these units, accounting for only 2.37% in the savanna and 1.5% in the complex (Figure 4).

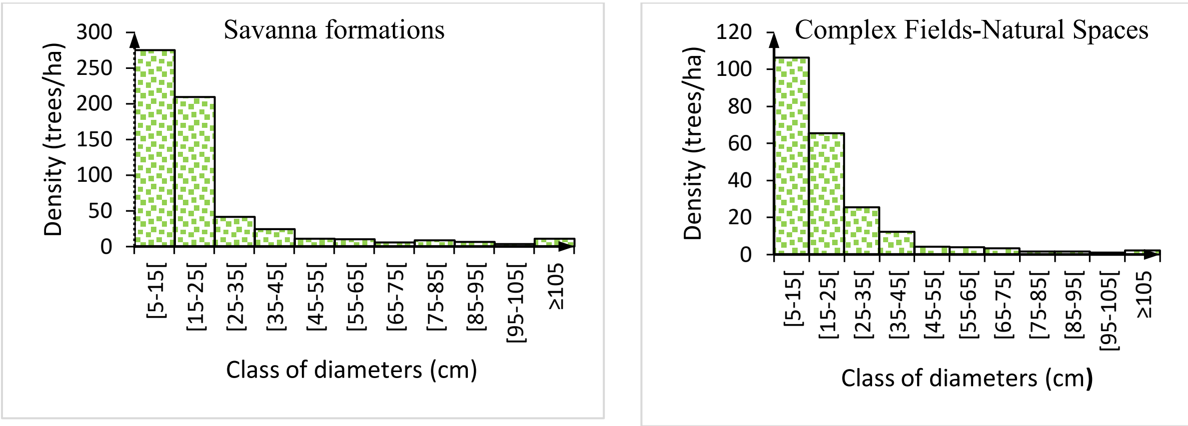

Figure 4. Distribution of individuals in the vegetation units of the Rogho Community Forest by diameter class. (Source: Field Data Processing)

Diameter Class Structure of Formations G1 and G2 Woody Populations

In contrast, there is a prevalence of medium-diameter individuals (ranging from 25cm to 54cm) and a significant presence of large-diameter individuals (DHP ≥ 95cm) in the G1 vegetation formation, representing 48.82% and 3.80% of the population, respectively, as shown in Figure 5. In the G2 vegetation formation, medium-diameter individuals are moderately represented, accounting for 37.26% of the population, while large-diameter individuals have a notable presence, comprising 5.85% of the population.

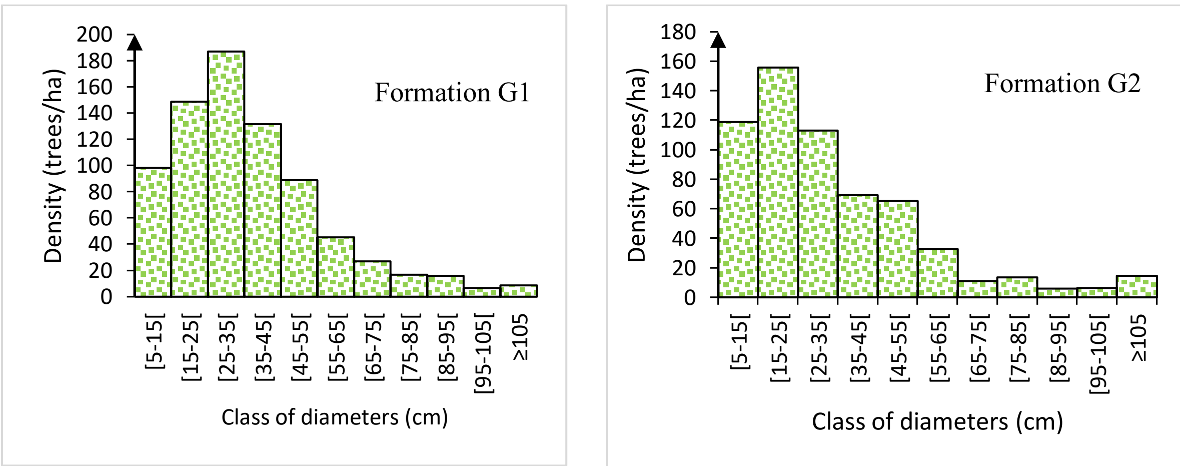

Figure 5. Distribution of individuals in the vegetation formations of the Boala Community Forest by diameter class. (Source: Field Data Processing)

This figure reveals a similarity between the two vegetation formations in the CFmB in terms of diameter class distribution.

At the scale of land use units, small-diameter individuals (DHP Є [5cm-25cm [) overwhelmingly dominate the savannah and complex field-natural space units of Rogho. Large-diameter individuals (DHP≥95cm) are poorly represented there. This is in contrast to what is observed in the G1 and G2 vegetation formations of Boala, where there is a notable presence of large-diameter individuals. The difference in the timing of the forest boundaries' delineation, with Boala established in 1989 and Rogho more recently in 2012, may explain this contrast. However, T. Whitmore (1990) argues that the prevalence of small-diameter classes ensures the future of natural formations, while the limited representation of large-diameter individuals results from natural selection. According to this author, these individuals are the seed bearers that ensure the population's longevity. For Mbayngone et al. (2008), such a distribution is characteristic of stable population capable of renewing themselves through natural regeneration. However, this can conceal a process of degradation of populations of species with strong socio-economic potential (Sambou, 2004). These results are in contrast to those found by Mbaiyetom et al. (2021) in the wooded parks of the Sudanese zone in Chad, where adult individuals dominate the woody population. This difference may be related to the divergent statuses of the objects of study. The representation of individuals with a small diameter in the savannah unit is significantly higher than in the complex field-natural space, as shown in Figure 3 below. Similarly, individuals with a diameter greater than or equal to 105cm are also more represented in the savannah unit than in the complex field-natural space.

Vertical Structure of Studied Woody Populations

Height Class Structure of Savanna and Complex Field-Natural Space Populations

The distribution of individuals by height class shows significant differences. According to this distribution, savanna formations as well as the complex field-natural space mainly consist of very small individuals. The class (]0-2[) alone accounts for 64.62% of the individuals present in the savanna formation and 75.09% of those present in the complex field-natural space. Individuals of relatively medium size ([4-6[) represent only 3.39% and 3.71% of these two populations, respectively. Large individuals (≥10m) are rare in these formations (Figure 6).

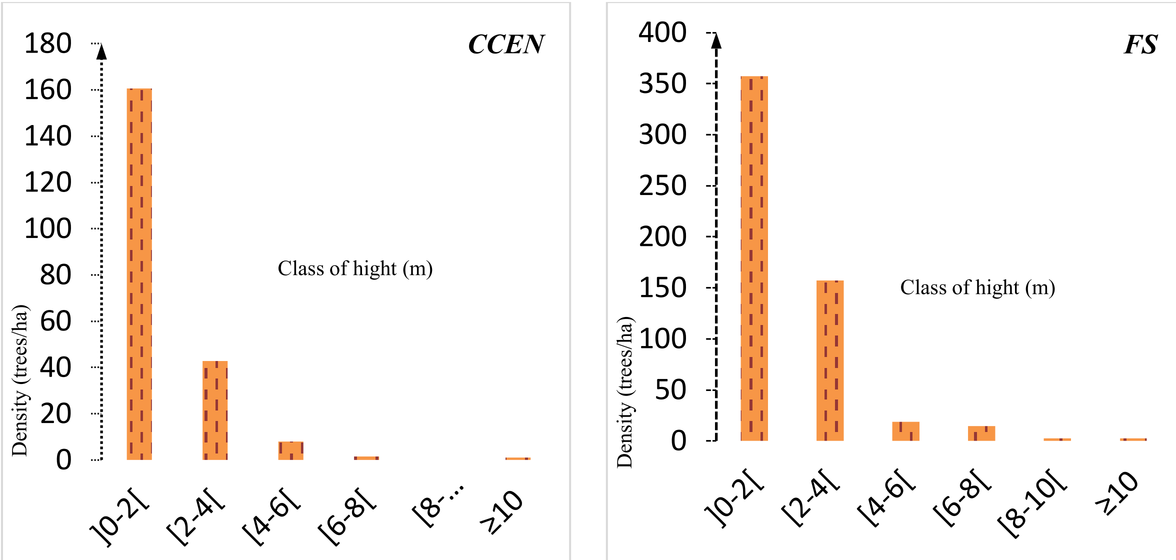

Figure 6. Distribution of individuals in the vegetation units of the Rogho Community Forest by height class. (Source: Field Data Processing)

Height Class Structure of G1 and G2 Vegetation Formations

The vertical distribution pattern of G1 and G2 vegetation formations is slightly different from that observed in the Rogho site. Although dominated by relatively small individuals ([2-4[), accounting for 41.93% and 35.87% of the two respective populations, it highlights a substantial presence of medium-sized individuals ([4-6[). These individuals occupy 21.99% and 20.10% of the respective groups. Large individuals (≥10 m) are rare in these formations (Figure 7).

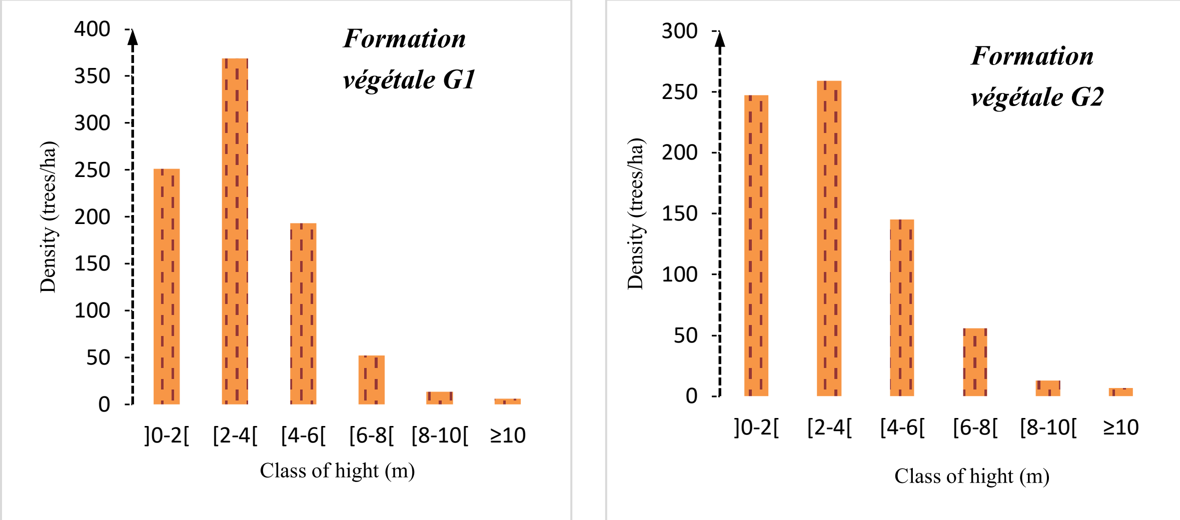

Figure 7. Distribution of individuals in the vegetation formations of the Boala Forest by height class. (Source: Field Data Processing)

Vertical Structure of Studied Woody Populations

Height Class Structure of the Savanna Formation and Complex Field-Natural Space

The analysis of vertical distribution at the scale of vegetation units reveals a significant prevalence of very short populations (]0-2m [) within the Savanna and Complex Field-Natural Space units. This indicates the importance of the shrub layer in these vegetation units of the Rogho Community Forest. In contrast, the vertical structure of both Vegetation Formations is dominated by medium-sized individuals ([3-8m [), characterizing the significance of the tree stratum within them. This contrast could be attributed to the heavy anthropogenic pressure on the Rogho site compared to Boala.

Basal Area, Density, and Relative Dominance of Species

Savanna Formation and Complex Field-Natural Space

In the Savanna vegetation unit, the total basal area is 30.84 m2, equivalent to an average of 27.56 m2/ha. The predominant species in this unit is *Mitragyna inermis*, occupying a basal area of 5.73 m2 and a relative dominance of 18.58%. It is followed by *Vitellaria paradoxa* and *Lannea microcarpa*, which occupy 4.76 m2 and 4.04 m2 of basal area, respectively, with relative dominance values of 15.43% and 13.09%. The other species are less dominant, with less than 3 m2 of basal area.

In the Complex Field and Natural Space unit, the total basal area is 25.27 m2, with an average of 9.55 m2/ha. The population of this unit is mainly dominated by *Vitellaria paradoxa*, occupying a basal area of 10.96 m2 and a relative dominance of 43.38%. It is followed by *Mitragyna inermis*, with a basal area of 5.7 m2 and a relative dominance of 22.57%, and *Cassia sieberiana* with a basal area of 1.02 m2 and a relative dominance of 4.03%. The other species are less represented, with less than 1 m2 of basal area.

The population density calculated for both vegetation formations is 582.66 trees/ha for the savanna and 227.59 trees/ha for the complex field and natural space. In the savanna formation, the highest density is 65.23 trees/ha (*Piliostigma reticulatum*), while the lowest is 0.89 trees/ha (*Saba senegalensis, Entada africana,…*). In the complex formation, the highest density is 32.13 trees/ha (*Vitellaria paradoxa*), while the lowest is 0.38 trees/ha (*Leptadenia hastata, Crossopteryx febrifuga*, …).

Both Vegetation Formations G1 and G2 in Boala are characterized by a strong dominance of *Vitellaria paradoxa*, representing 57.36 m2 and 44.12 m2 of basal area in the two groupings, with relative dominance values of 17.58% and 25.14%, respectively. In Formation G1, the species *Terminalia brownii* and *Pterocarpus erinaceus* follow *Vitellaria paradoxa* in terms of basal area, with 18.25 m2 and 16.58 m2, and relative dominance value of 7.99% and 7.27%, respectively. In Formation G2, the species *Burkea africana* and *Isoberlinia doka* have the largest basal areas, with 43.12 m2 and 20.09 m2, and relative dominance value of 17.183% and 8%. The other species have lower dominance. The total basal areas are 228.168 m2 for Formation G1 and 250.95 m2 for Formation G2, with respective averages of 124.613 m2/ha and 112.13 m2/ha (Table 5). The population density is 834.97 trees/ha for Formation G1 and 667.56 trees/ha for Formation G2. In Formation G1, the highest density is 89.02 trees/ha for *Vitellaria paradoxa*, while the lowest is 1.09 trees/ha for species like *Combretum micranthum* and *Ximenia americana*. In Formation G2, the highest density is 76.85 trees/ha for *Vitellaria paradoxa*, while the lowest is 0.47 trees/ha for *Cassia sieberiana*.

At the scale of vegetation units, basal area and population density are higher in Formation G2 (112.13 m2/ha and 667.56 trees/ha) than in the Savanna Formation (27.56 m2/ha and 582.66 trees/ha). They are even higher in Formation G1 (124.61 m2/ha and 834.97 trees/ha) and lower in the Complex Field-Natural Space (9.55 m2/ha and 227.59 trees/ha). These results indicate a predominance of small-diameter individuals in the Savanna Formation and Complex Field-Natural Space compared to Vegetation Formations G1 and G2. The significant basal area in the two Vegetation Formations reflects the high density of large-diameter populations. These results are similar to those obtained by Mahamat-saleh et al. (2015) for woody populations of the Great Green Wall in Chad and contrary to those of Tamara et al. (2023). They explained the importance of basal area in Kanem by the high density of certain species and the presence of large-trunked trees. However, these results differ from those of Diouf et al. (2019) in the Noflaye Botanical Reserve in Senegal, where the population's basal area is low at 4 m2/ha. This difference indicates a strong predominance of a small-diameter community in the reserve, unlike our study sites.

Ecological Importance of Inventoried Species

The Importance Value Index (IVI) of species varies depending on the forests and the vegetation formations present.

Savanna Formation and Complex Field-Natural Space of Rogho

The Importance Value Index (IVI) values range from 99.06 to 9.17 in the Savanna vegetation unit. Species with the highest IVI values include *Lannea microcarpa*, *Piliostigma reticulatum* and *Vitellaria paradoxa*, while species with the lowest IVI values are *Crossopteryx febrifuga*, *Capparis corymbosa*, *Sarcocephalus latifolius*, and others, with IVI values below 10. In the Complex Field-Natural Space unit, IVI values range from 98.36 to 3.94. The species with the highest IVI values are *Vitellaria paradoxa*, *Piliostigma reticulatum*, and *Vachellia nilotica*, with values of 98.36, 88.41, and 75.66, respectively (Table 5). Species with the lowest IVI values include *Crossopteryx febrifuga*, *Azadirachta indica*, *Eucalyptus camaldulensis*, and others, with IVI values below 5. No species clearly dominates the composition of populations in these two vegetation units, as the differences between IVI values are less significant.

G1 and G2 Vegetation Formations of Boala

The IVI values range from 136.58 to 5.65 and from 120.06 to 0.04 in G1 and G2 vegetation formations, respectively. In Formation G1, species with the highest IVI values include *Vitellaria paradoxa*, *Pterocarpus erinaceus Poir*, and *Terminalia brownii*. In Formation G2, the species with the highest IVI values are *Vitellaria paradoxa*, *Burkea africana*, and *Detarium microcarpum* (Table 5). Species with the lowest IVI values in Formation G2 include *Senegalia macrostachya*, *Piliostigma thonningii*, *Oncoba spinosa* and *Hymenocardia acida*, with IVI values below 1. In Formation G1, species with the lowest IVI values include *Vachellia seyal*, *Parkia biglobosa*, *Cassia sieberiana*, and others, with IVI values below 10. Similar to the vegetation units in the Rogho Forest, no species clearly dominates the composition of G1 and G2 vegetation formations in the Boala Forest, as the differences between IVI values are also less significant.

High IVI values are recorded for species such as *Vitellaria paradoxa, Lannea microcarpa, Piliostigma reticulatum,* and *Vachellia nilotica* in the Rogho Community Forest. The first two species owe their high IVI values to the size of their trunks (large DBH), while the latter two owe their high IVI values more to their relative frequencies. This could be related to their strong reproductive capacity through both vegetative and seed means (M. Habou et al., 2020). In Boala, in both vegetation formations, species with high IVI values are *Vitellaria paradoxa*, *Pterocarpus erinaceus*, *Terminalia brownii*, *Burkea africana*, and *Detarium microcarpum*. Unlike the species *Piliostigma reticulatum* and *Vachellia nilotica* in the Rogho

Community Forest, which owe their high IVI values to their relative frequency, this suite of species with high IVI values owes it to the importance of their basal area, and hence the size of their trunks (DBH). In terms of species with high IVI values, these results differ from those of Abdourhamane et al., 2013 in the complex of classified forests of Dan kada Dodo-Dan Gado in Niger. In this complex, the suite of species with high IVI values includes *Guiera senegalensis*, *Sclerocarya birrea*, *B. senegalensis*, *Senegalia senegal*, *Combretum micranthum*, and *B. Rufescens*. This difference could be explained by climatic and soil conditions favoring the flourishing of these species.

Table 5. Importance Value Indices (IVI) of the Top Five Species with the Highest IVI per Vegetation Unit

Vegetation units	Savanna Formation				Vegetation units	Formation G1			
Espèces	Dsr	Fr	Dmr	IVI	Espèces	Dsr	Fr	Dmr	IVI
Lannea microcarpa	4.14	81.82	13.09	99.06	*Vitellaria paradoxa*	11.443	100.00	25.139	136.582
Piliostigma reticulatum	9.44	63.64	4.81	77.88	*Pterocarpus erinaceus Poir*	4.975	94.44	7.267	106.687
Vitellaria paradoxa	5.76	54.55	15.43	75.73	*Terminalia brownii*	5.025	88.89	7.999	101.912
Strophanthus sarmentosus	1.92	72.73	0.17	74.82	*Isoberlinia doka*	4.129	83.33	3.866	91.329
Terminalia avicennioides	7.44	54.55	7.33	69.32	*Detarium microcarpum*	4.080	77.78	5.994	87.851
Vegetation units	Complex fields natural spaces				Vegetation units	Formation G2			
Vitellaria paradoxa	4.99	50.000	43.376	98.364	*Vitellaria paradoxa*	11.565	90.909	17.583	120.057
Piliostigma reticulatum	17.25	69.231	1.925	88.409	*Burkea africana*	8.435	86.364	17.183	111.982
Vachellia nilotica	6.40	69.231	0.030	75.658	*Detarium microcarpum*	8.435	81.818	6.467	96.720
Ficus ingens	5.46	53.846	1.490	60.793	*Lonchocarpus laxiflorus*	5.358	77.273	7.415	90.046
Terminalia avicennioides	6.51	46.154	1.878	54.546	*Terminalia brownii*	5.358	81.818	0.915	88.092

Legend: RD=Relative Density; RF=Relative Frequency; RDm=Relative Dominance; IVI=Importance Value Index. (Source: Field Data Processing)

Looking at the table, it is evident that *Vitellaria paradoxa* is well represented among the top five species with the highest IVI values. Indeed, this species is among the top five species with the highest IVI values in each vegetation unit, with the highest IVI value, except for the savanna formation unit where it ranks third in terms of IVI value.

Biological Types and Phytogeographic Types of Species

Biological Types of Species

Savanna Formation and Complex fields natural spaces

The analysis of the biological types of the two vegetation formations revealed the presence of two biological types: phanerophytes and chamaephytes. Phanerophytes overwhelmingly dominate both vegetation units with a raw spectrum of 98% for phanerophytes and 2% for chamaephytes in the savanna. In the natural field complex, phanerophytes have a raw spectrum of 97.96%, while chamaephytes make up 2.04%. Within the phanerophyte category, mesophanerophytes dominate over microphanerophytes in both units, with nanophanerophytes being poorly represented (Figure 8).

G1 and G2 Vegetation Formations in Boala

In contrast to the biological spectrum of vegetation formations at the Rogho site, which is composed of two main biological types, the vegetation formations in Boala consist of three main biological types : chamaephytes, hemicryptophytes, and phanerophytes, with percentages of 1.72%, 1.72%, and 96.55% for Formation G1 and 1.92%, 1.92%, and 96.15% for Formation G2, respectively. Among the phanerophytes, mesophanerophytes dominate in both groups over microphanerophytes, with megaphanerophytes being present in low proportions (Figure 7).

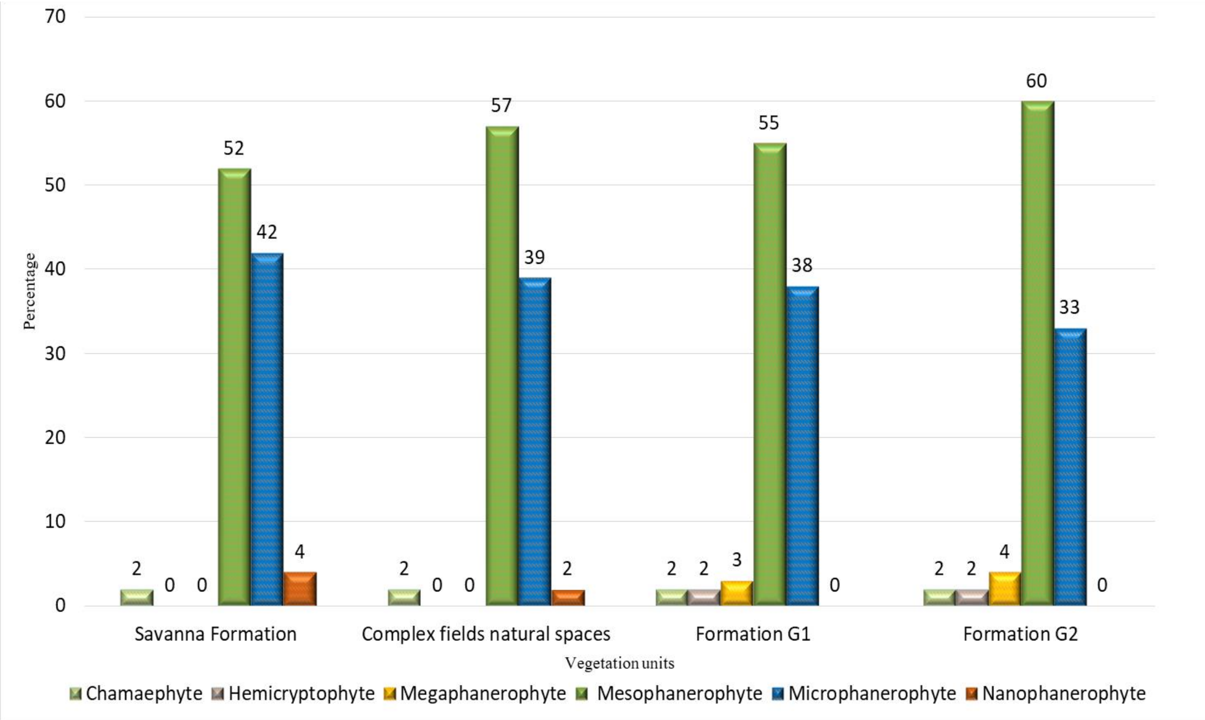

Figure 8. Biological Spectrum of Different Studied Vegetation Formations (Source: Field Data Processing)

The analysis of the biological spectrum shows that FCmR consists of two biological types, in contrast to FCmB, which contains three. Two of these types, phanerophytes and chamaephytes, are common to both sites, while hemicryptophytes are unique to FCmB. The flora of these two forests is largely dominated by phanerophytes. This predominance of phanerophytes has been highlighted by previous studies, including those of Ouoba (2006) and Nguinambaye et al. (2015). At the level of vegetation units, the analysis within phanerophytes indicates that mesophanerophytes dominate all these units. This confirms the woody potential of both sites (Folega et al., 2017b). These results are similar to those of Bawa et al. (2022) in the Agbandi Community Forest in central Togo. However, other studies conducted in Sudanian and Sahelian zones (Mbayngone et al., 2008 ; Abdourhamane et al., 2013 ; Melom et al., 2015) show a dominance of microphanerophytes over mesophanerophytes. This difference could be explained by the contrast of region (Adingra, 2017) or anthropogenic activities. Through these agricultural activities, humans make choices about which species to cut down and favor certain plant species, thus influencing the physiognomy of the original vegetation (Mbayngone et al., 2008, p.23).

Phytogeographic types of species

The phytogeographic types of woody species in the FCmB flora is mainly dominated by Guineo-Congolese, Sudanian-Guinean, and Sudanian-Sahelian species, representing 29.68%, 18.50%, and 18.29%, respectively, of the weighted spectrum of phytogeographic types present. Sudanian, Guinean, Sudanian-Zambezian, Sahelo-Sudanian, Sahelian, and Saharan-Sahelian species are also present but in less significant proportions, representing 10.33%, 7.55%, 6.54%, 3.81%, 3.53%, and 1.75%, respectively (Figure 9).

On the other hand, the phytogeographic types of woody species in the FCmR flora is dominated by Sahelo-Sudanian, Guineo-Congolese, and Sudanian-Guinean types, representing 25.25%, 24.33%, and 15.51% of the weighted spectrum, respectively. Sudanian-Sahelian, Sudanian, Saharan-Sahelian, Sudanian-Zambezian, Sahelian, Tropical Oriental, and Australian species are also present but in smaller proportions, with percentages ranging from 12.82% to 0.06% (Figure 10).

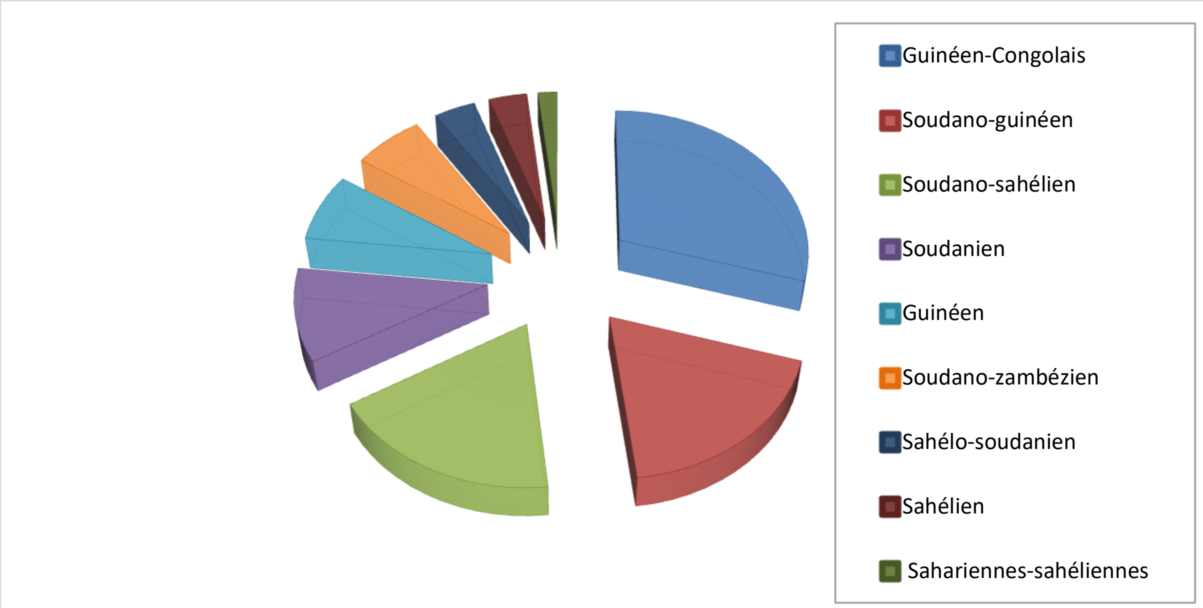

Figure 9. Phytogeography of the Flora in FCmB. (Source: Field Data Processing)

Figure 9 illustrates that the phytogeography of the flora in the Boala forest consists of nine (09) phytogeographic species.

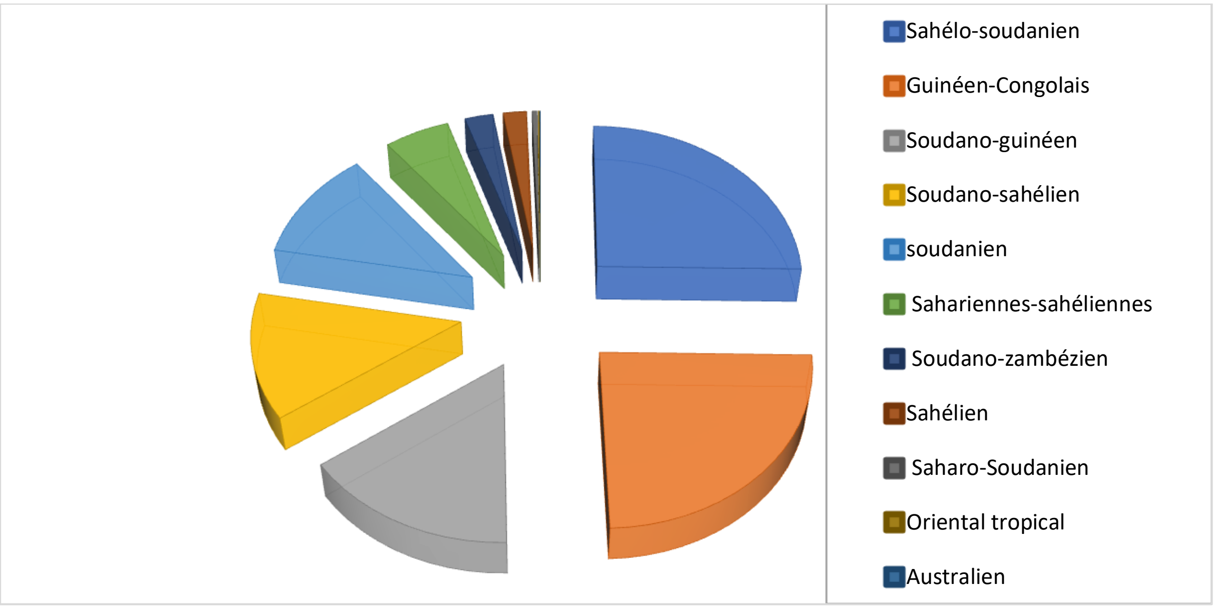

Figure 10. Phytogeography of the FCmR Flora. (Source: Field Data Processing)

Figure 10 shows that the phytogeography of the flora in the Rogho forest consists of eleven (11) phytogeographic species, including two imported species, namely Oriental Tropical and Australian species, each representing 1.85% of the raw spectrum.

The chorological analysis of the flora in FCmB and FCmR presents slightly different results, with a similar dominant cohort of species for both sites. This cohort consists of Guineo-Congolese, Sudanese-Guinean, and Sudanese-Sahelian species for the Boala site and Sahelo-Sudanese, Guineo-Congolese, and Sudanese-Guinean species for the Rogho site, each accounting for over 60% of the inventoried species. These results contrast with those revealed by Mbayngone et al. (2008) and Dimobe et al. (2014) respectivly in the Pama Reserve in Burkina Faso and in the wildlife reserve of Oti-Mandouri in Togo. These authors indeed highlighted the dominance of Sudanese species, followed by Sudanese-Zambezian and Afrotropical species with respective proportions of 35.87%, 21.74%, and 13.04%. Pantropical, Paleotropical, and Guineo-Congolese species are weakly represented with the same proportion of 5.43%. However, the predominance of Guineo-Congolese species is also highlighted in the Yakandjido forest in Togo by Atakpama et al. (2022). The present study focused only on woody species and adult individuals, limiting the analysis of the floristic diversity of the studied forests. Therefore, it is necessary to conduct another study that considers herbaceous plants and regenerative flora.

Conclusion

The analysis of compositional diversity revealed an overall floristic richness composed of 80 species distributed across 32 families and 61 genera, with relatively higher floristic richness in FCmB than in FCmR. Dominant species in FCmB include *Vitellaria paradoxa, Piliostigma reticulatum, Diospyros mespiliformis, Ficus ingens,* and *Terminalia avicennioides*. FCmR, on the other hand, is dominated by *Vitellaria paradoxa, Pteleopsis suberosa, Detarium microcarpum, Burkea africana,* and *Terminalia laxiflora.* The analysis of the flora structure of the two forests highlighted the predominance of young individuals characteristic of the shrub layer. Municipal and regional authorities should develop strategies for sustainable management of these forest areas.

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