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Distribution of Sahelian woody plants exploited in four plant formations of the Baguirmi department (Chad).

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ABSTRACT

Objective: The objective was to study the distribution and variability of the woody flora in this Sahelian region of Chad.

Methodology and Results: The study was conducted in the Baguirmi Department of Chari Baguirmi Province. The floristic inventory was carried out at 240 survey points measuring 30m x 30m (900m²), or 120 plots. Four plant formations (shrub savanna, wooded savanna, open forest, and gallery forest) were selected, and in each, 30 plots were installed every 200 meters along 2-km transects oriented north-south and east-west. The taxonomic analysis revealed a total of 31 species belonging to 23 genera and 15 families. Fabaceae and Combretaceae are the best represented families, with 33% and 13%, respectively. They are followed by Bignoniaceae, Caparaceae and Rhamnaceae which are weakly represented (6%). Diversity is noted in the shrub savannah with Shannon and Piélou equitability indices of 2.75 and 0.54 respectively. Individuals of *Senegalia senegal*, *Vachellia nilotica* and *Balanites aegyptiaca* are the most abundant in all the plant formations studied with a relative abundance of 17.69%, 16.66% and 15.69% respectively. The frequency showed that 15 inventoried species are the most frequent in the plant formations thus revealing their distribution ability. *Vachellia gourmaensis*, *Crateva adansonii, Kigelia africana* and *Ximenia americana* form the group of characteristic species recorded in a single plant formation.

Conclusion and application of results: This work made it possible to identify the most representative families in the plant formations studied. Individuals of *Senegalia senegal*, *Vachellia nilotica*, and *Balanites aegyptiaca* are the most abundant in these. Some species are ubiquitous, while others are characteristic of a specific formation. Thus, these interesting results suggest the possibility of encouraging natural regeneration in plant formations with rare species, particularly in agricultural operations and raising awareness within the local community about the need for management that respects the environment.

Keywords: Woody, distribution, plant formation, Baguirmi, Sahel, Chad.

INTRODUCTION

Woodland species provide numerous woody and non-woody forest products and services of plant origin. These woody species and their habitats are experiencing disturbances linked to human activities and climate change, which threaten their survival (Manzo *et al.,* 2017). Consequently, the degradation of these woody resources affects all agro- and socio-ecological domains of life, both locally and globally. In Chad, the situation is characterized by accelerated degradation of soils already weakened by a high number of climatic hazards, followed by population growth with its corollary growing demand for arable land and fuelwood (Djimadoum, 2015; Madjigoto *et al.,* 2015). This combination of factors undoubtedly influences the composition of woody species and the resulting vegetation structure. At the end of the 1992 Rio de Janeiro summit on biodiversity, it was perceived that human development was closely dependent on the conservation and good management of natural resources, including woody plants. However, the regeneration of woody plants is increasingly difficult in arid and semi-arid areas due to their biology and pedoclimatic factors (Traoré, 1998; Bationo *et al.,* 2001; Bationo, 2002). In addition, the regression of woody stands results from the absence of seedlings and young plants (Lykke, 1998; Lykke *et al.,* 1999). It is also important to note that in an ecosystem, the lack of renewal of woody individuals leads to the disappearance of species, or even the aging of several plant formations (Boussim *et al.,* 1998). Faced with this, the floristic potential is sometimes jeopardized. Previous work confirms that woody plants better reflect environmental factors (Higgins *et al.,* 1999; Toutain, 1999) and are also true indicators of the local environment. The structure and composition of woody plants are a function of locality and environmental realities in addition to anthropogenic disturbances (Huang *et al.,* 2002). Vegetation data are therefore of great use in solving ecological problems, including the prediction of possible future changes (Kent and Coker, 2003). Most studies conducted in the Sahel have so far remained limited to the local level and to a summary description of woody stands (Guinko, 1984; Grouzis, 1990; Ganaba, 1994; Thiombiano, 1996; Devineau, 2001). In Chad, few studies have been conducted on the diversity of woody strata to understand their dynamics. The objective of this study is to assess floristic diversity and characterize the ecological parameters of woody biodiversity in the Baguirmi Department, Chari Baguirmi Province.

MATERIAL AND METHODS

Study Site: The N'Djamena fuelwood supply basin is located around the city of N'Djamena and covers approximately 7,290,000 ha. This basin includes 10 departments spread across 5 provinces: Batha, Chari-Baguirmi, Hajer-Lamis, Mayo Kebbi-Est and N'Djamena (AEDE, 2011a). The study site is located in the Department of Baguirmi, capital of Dourbali (15° 51' 58'' North and 11° 48' 13'' East) of the province of Chari-Baguirmi (Figure 1). The Department is located in two bioclimatic zones: in the North in the Sahelian zone with a rainfall between 250-600 mm and in the South the Sahelo-Sudanian zone with a rainfall between 600-800 mm.

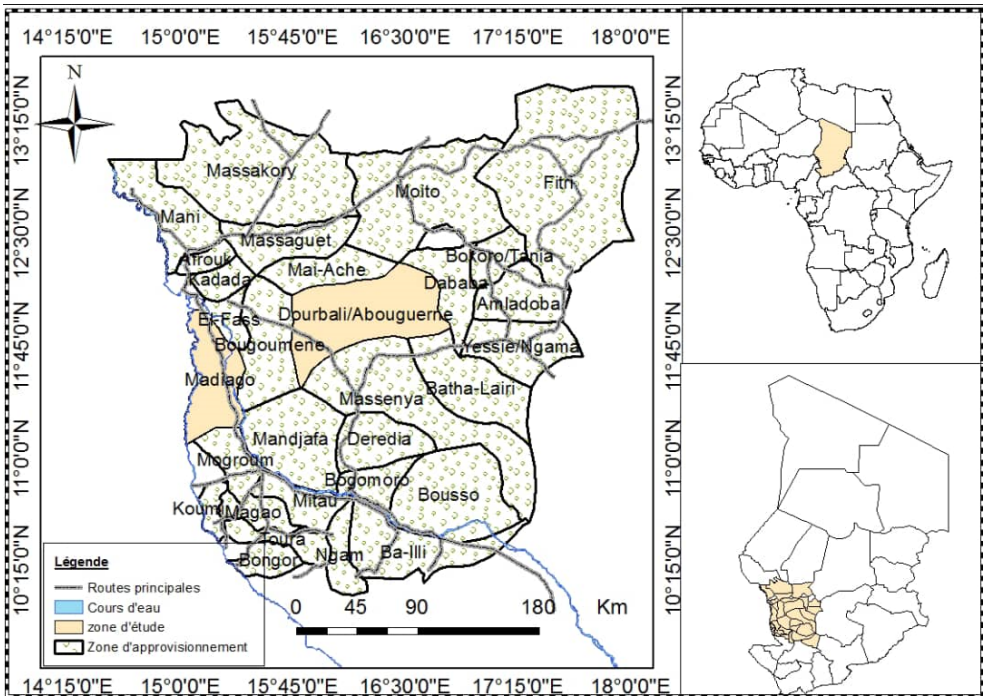

Figure 1 : Location of the study area

Methods: The sampling was stratified by plant formation type. The local representativeness of woody species was one of the main criteria for selecting the sampling site and plant formations. The floristic survey points were distributed among the different plant formations. Particular consideration was given to certain areas and sites likely to harbor unusual or rich flora. The physiological and floristic homogeneity of the facies of each plant formation was the basis for establishing the various floristic survey points. The flora inventory was carried out using a transect using the classic Brun-Blanquet method. A total of 240 survey points measuring 30m x 30m (900m²) were delineated for the study area. Thus, 30 survey points per plant formation were installed every 200 meters along 2 km transects oriented North-South and East-West in order to take into account the majority of the floristic and ecological diversity (Wala, 2004, 2010; Amégnaglo *et al.,* 2018b). The plots, whose center coordinates had been previously recorded, were located using the GARMIN 64S GPS. This method was successfully used by Tchiombiano (2016). In each plot, all woody species were recorded and the dendrometric parameters measured. In addition, the abundance-dominance coefficient was assigned. The catalogues of Lebrun and Stork (1991, 1992) were used for the determination and transcription of species names. The abundance-dominance scale considered is that of Brun-Blanquet by Wilmanns (1989) in Tchiombiano (1996).

Data Processing: To assess species distributions in plant communities, ecological parameters are calculated. The frequency of occurrence, expressed as a percentage, is determined using the following formula: **C (%) = (ni*100)/N**, where **ni** is the number of occurrences of a given species in a plant community and **N** is the total number of species present in the plant communities. The relative abundance, expressed as a percentage, is calculated as **AR (%) = (ni*100)/N**, where **ni** is the number of individuals of a species in a plant community and **N** is the total number of all individuals in the community. To determine the species diversity of the community, we calculated the Shannon-Weaver diversity index (H') and the Piélou Equitability index or

Equipartition index (E) using the following formulas:

$$H' = -\sum_{i=1}^{S} pi.log2(pi)$$

S is the number of species, **ni** is the number of individuals of species **i**, **N** is the number of individuals of all species, and **pi** is the proportion of individuals of each species in the total **(pi=ni/N).** The value of **H'** varies between 1 and 5.

E=H'/(log2(S))

This index **E** varies between **0** and **1**.

RESULTS

Composition of the Woody Flora: The woody flora of the Baguirmi department, across the four plant formations studied, is rich in 31 species belonging to 23 genera and 15 families. Figure 2 shows that Fabaceae and Combretaceae are the most represented families, with 33% and 13%, respectively. They are followed by Bignoniaceae, Caparaceae, and Rhamnaceae, which are poorly represented (6%). The SPP software (version 17.0) and Excel 2019 were used for data processing.

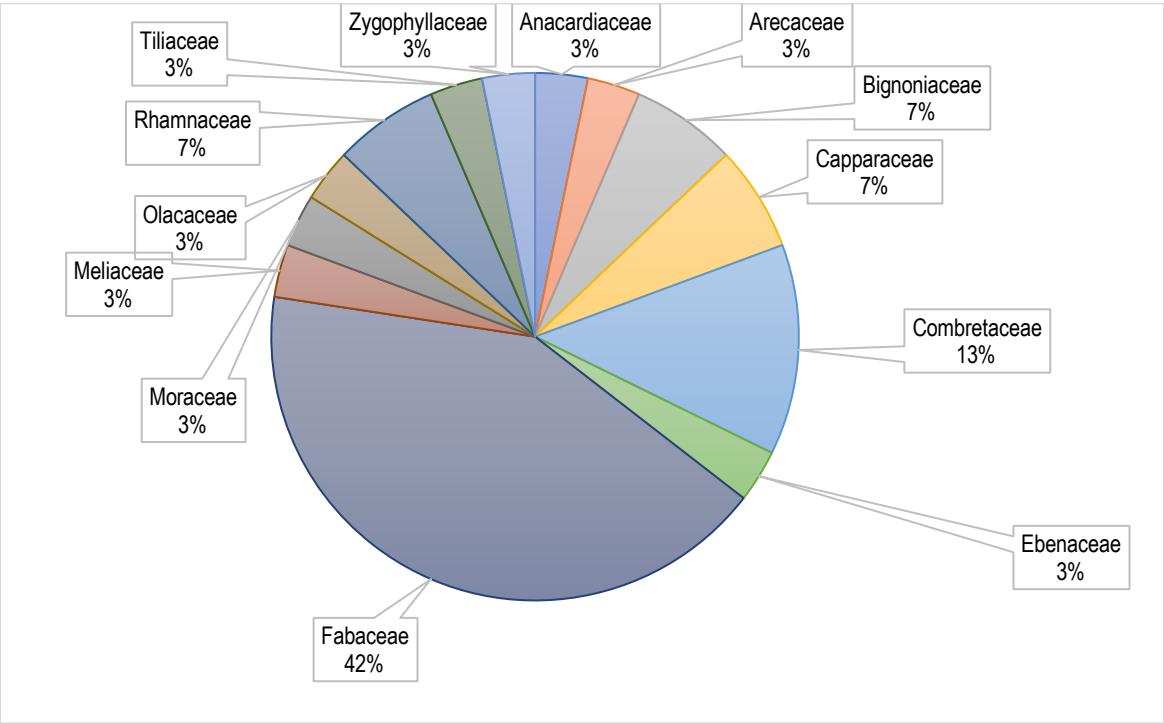

Figure 2 : proportion of families of species inventoried in the Baguirmi department

Species richness according to plant formations: The importance of genera and species varies according to the families as follows: Mimosaceae with 2 genera and 7 species, Combretaceae with 4 genera and 4 species, and Fabaceae with 3 genera and 3 species each. In the wooded and shrub savannas, the number of species inventoried is 26. This number decreases to 25 in the gallery forest and to 20 in the open forest (Table 1).

Table 1 : Specific richness and presence of woody plants according to plant formations

N°	Specie	Family	Wooded savanna	Shrub savanna	Open forest	Gallery forest
1	*Vachellia ataxacantha* DC.	Fabaceae	+	+		+
2	*Vachellia gourmaensis* A. Chev.	Fabaceae		+		
3	*Vachellia nilotica* (L.) Willd. ex Del.	Fabaceae	+	+	+	+
4	*Senegalia senegal* (L.) Britton.	Fabaceae	+	+	+	+
5	*Vachellia seyal* Del.	Fabaceae	+	+	+	+
6	*Vachellia sieberiana* DC.	Fabaceae	+	+		+
7	*Anogeissus leiocarpa* (DC.) Guill. & Perr.	Combretaceae	+	+	+	+
8	*Azadirachta indica* A. Juss.	Meliaceae	+	+		
9	*Balanites aegyptiaca* (L.) Del.	Zygophyllaceae	+	+	+	+
10	*Bauhinia rufescens* Lam.	Fabaceae	+	+		
11	*Boscia senegalensis* (Pers.) Lam. ex Poir.	Capparaceae	+	+	+	+
12	*Combretum nigricans* Lepr. ex Guill. & Perr.	Combretaceae	+	+	+	
13	*Crateva adansonii* DC.	Capparaceae				+
14	*Dalbergia sissoo* Roxb.	Fabaceae			+	+
15	*Diospyros mespiliformis* Hochst. ex A. DC.	Ebenaceae	+	+	+	+
16	*Faiderbia albida* Del.	Fabaceae	+		+	+
17	*Ficus glumosa* Delile	Moraceae	+	+		+
18	*Grewia bicolor* Juss.	Tiliaceae	+	+	+	+
19	*Guiera senegalensis* J.F. Gmel.	Combretaceae	+	+	+	+
20	*Hyphaene thebaica* (L.) Mart.	Arecaceae	+	+	+	+
21	*Kigelia aethiopica* Baum oder.	Bignoniaceae		+		+
22	*Kigelia africana* (Lam.) Benth.	Bignoniaceae	+			
23	*Piliostigma reticulatum* (DC.) Hochst.	Fabaceae	+	+	+	
24	*Prosopis africana* (Guill. & Perr.) Taub.	Fabaceae	+	+	+	+
25	*Sclerocarya birrea* (A. Rich.) Hochst.	Anacardiaceae	+	+	+	+
26	*Sesbania sesban* (L.) Merr.	Fabaceae	+	+		+

27	*Tamarindus indica* L.	Fabaceae	+	+	+	+
28	*Terminalia glaucescens* Planch. ex Benth.	Combretaceae	+	+	+	+
29	*Ximenia americana* L.	Olacaceae				+
30	*Ziziphus mauritiana* Lam.	Rhamnaceae	+	+	+	+
31	*Ziziphus mucronata* Willd.	Rhamnaceae	+	+	+	+

Ecological parameters by plant formation: Analysis of the table showed that the shrub savanna exhibited greater diversity (2.75) than the other three plant formations: 2.66 in the wooded savanna, followed by 2.38 in the gallery forest, and a low 2.18 in the open forest. As for the Piélou equitability index, it was also higher in the shrub savanna (0.54). It was low for the open forest (0.37) and the gallery forest (0.38). However, individuals were more numerous in the gallery forest (597) and low in the shrub savanna (162).

Table 2 : variations in ecological parameters according to plant formations

Ecological parameters	Wooded savanna	Open forest	Gallery forest	Shrub savanna
Number of individuals	411	277	597	162
Shannon index	2,66	2,18	2,38	2,75
Individuals per hectare	164,4	110,8	238,8	64,8
Piélou Fairness Index	0,44	0,38	0,37	0,54

Woody Plant Abundances: The occurrence distribution results in Table 3 show that individuals of *Senegalia senegal* (L.) Britton, *Vachellia nilotica* (L.) Willd. ex Del. and *Balanites aegyptiaca* (L.) Del. are the most abundant in all four plant formations studied, with a relative abundance of 17.69%, 16.66%, and 15.69%, respectively. They are distantly followed by those of *Guiera senegalensis* J.F. Gmel. (5.94%), *Ziziphus mauritiana* Lam. (5.32%), and *Vachellia seyal* Del. (3.04%).

Table 3: Variation in the frequency of occurrence and relative abundance of woody plants in the four plant formations of Baguirmi.

Species	Wooded savanna	Shrub savanna	Open forest	Gallery forest	Effective	Presence	Relative Abundance (%)
Vachellia ataxacantha DC.	8	1		7	16	3	1,11
Vachellia gourmaensis A. Chev.		13			13	1	0,90
Vachellia nilotica (L.) Willd. ex Del.	75	21	32	113	241	4	16,66
Senegalia senegal (L.) Britton.	87	37	116	16	256	4	17,69
Vachellia seyal Del.	18	7	17	2	44	4	3,04
Vachellia sieberiana DC.	5	1		5	11	3	0,76
Anogeissus leiocarpa (DC.) Guill. & Perr.	6	2	3	5	16	4	1,11
Azadirachta indica A. Juss.	2	2			4	3	0,28
Balanites aegyptiaca (L.) Del.	31	11	14	171	227	4	15,69
Bauhinia rufescens Lam.	7	3	15		25	3	1,73
Boscia senegalensis (Pers.) Lam. ex Poir.	8	5	3	33	49	4	3,39
Combretum nigricans Lepr. ex Guill. & Perr.	4	4	2		10	3	0,69
Crateva adansonii DC.				5	5	1	0,35
Dalbergia sissoo Roxb.			3	61	64	2	4,42
Diospyros mespiliformis Hochst. ex A. DC.	7	2	2	3	14	4	0,97
Faiderbia albida Del.	28		11	11	50	3	3,46
Ficus glumosa Delile	1	1		7	9	3	0,62
Grewia bicolor Juss.	7	5	4	10	26	4	1,80
Guiera senegalensis J.F. Gmel.	38	13	19	16	86	4	5,94
Hyphaene thebaica (L.) Mart.	13	6	11	5	35	4	2,42
Kigelia aethiopica Baum oder.		3		31	34	2	2,35
Kigelia africana (Lam.) Benth.	3				3	1	0,21
Piliostigma reticulatum (DC.) Hochst.	14	4	4		22	3	1,52
Prosopis africana (Guill. & Perr.) Taub.	3	3	1	1	8	4	0,55
Sclerocarya birrea (A. Rich.) Hochst.	5	5	3	18	31	4	2,14
Sesbania sesban (L.) Merr.	8	4		21	33	3	2,28
Tamarindus indica L.	9	1	2	3	15	4	1,04
Terminalia glaucescens Planch. ex Benth.	4	3	4	2	13	4	0,90
Ximenia americana L.				4	4	1	0,28
Ziziphus mauritiana Lam.	17	4	10	46	77	4	5,32
Ziziphus mucronata Willd.	3	1	1	1	6	4	0,41

The analysis of Figure 3 shows that in the gallery forests and the wooded savannah, woody plants are the most abundant with 41% and 28% of the population respectively. This population is low in the shrub savannah (11%) and average in the open forest (19%).

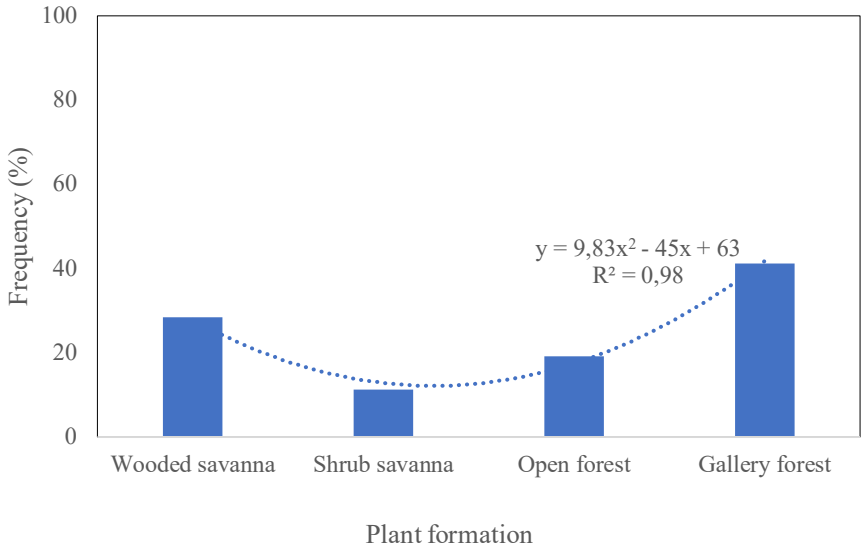

Figure 3 : Abundance of individuals according to plant formations

Frequency of occurrence of woody plants: Table 4 shows the 16 most frequent species inventoried in the four plant formations, with a proportion of 100%. These are followed by eight others considered frequent species, encountered in three out of four plant formations (75%). The three fairly frequent species (50%) are found in two plant formations. The four species are incidental in that they are found in one plant formation.

Table 4 : Frequency of occurrence of woody plants inventoried in the Baguirmi Department.

Species	Frequency of occurrence (%)	Frequency index
Vachellia nilotica (L.) Willd. ex Del.	100	Very common species
Senegalia senegal (L.) Britton.		
Vachellia seyal Del.		
Anogeissus leiocarpa (DC.) Guill. & Perr.		
Balanites aegyptiaca (L.) Del.		
Boscia senegalensis (Pers.) Lam. ex Poir.		
Diospyros mespiliformis Hochst. ex A. DC.		
Grewia bicolor Juss.		
Guiera senegalensis J.F. Gmel.		
Hyphaene thebaica (L.) Mart.		
Prosopis africana (Guill. & Perr.) Taub.		
Sclerocarya birrea (A. Rich.) Hochst.		
Tamarindus indica L.		
Terminalia glaucescens Planch. ex Benth.		
Ziziphus mauritiana Lam.		

Ziziphus mucronata Willd.		
Acacia ataxacantha DC.	75	Common species
Acacia sieberiana DC.		
Bauhinia rufescens Lam.		
Combretum nigricans Lepr. ex-Guill. & Perr.		
Faiderbia albida Del.		
Ficus glumosa Delile		
Piliostigma reticulatum (DC.) Hochst.		
Sesbania sesban (L.) Merr.		
Azadirachta indica A. Juss.	50	Fairly common species
Dalbergia sissoo Roxb.		
Kigelia aethiopica Baum oder.		
Acacia gourmaensis A. Chev.	25	Incidental species
Crateva adansonii DC.		
Kigelia africana (Lam.) Benth.		
Ximenia americana L.		

Stability of Plant Formations: Figure 4 reveals that species belonging to indices IV and V are the most highly represented in the four plant formations studied, with 9 and 15 species inventoried, respectively. The two frequency indices represented 11.61% and 79% of the populations, thus demonstrating the stability of the plant formations. Species with frequency indices II and III are poorly represented, with proportions of 1.74% and 7.09%.

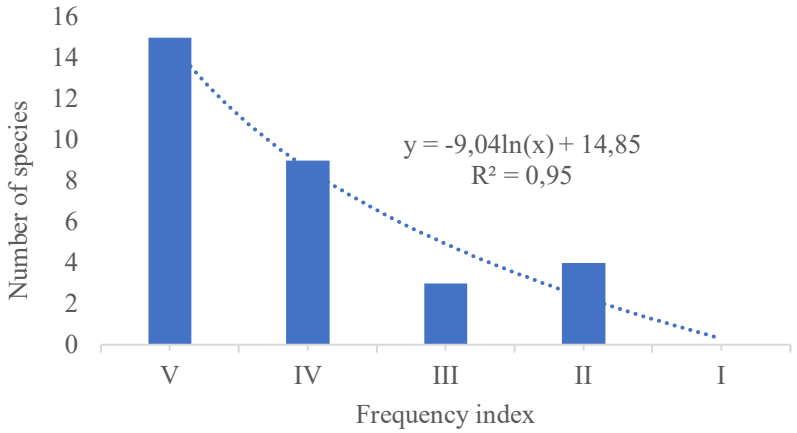

Figure 4 : Frequency histogram of woody plants

DISCUSSION

This study, conducted on the distribution of woody plants in four plant formations within the N'Djamena fuelwood supply basin, revealed the presence of 31 identified species distributed across 23 genera and 15 families. The woody flora offers notable diversity, with a floristic richness of 26 species inventoried in the wooded and shrub savannahs and 20 species in the gallery forest. Fabaceae and Combretaceae are the best-represented families. This observation was previously made by Alhou Amoude *et al.* (2021) in their

description of the ecological characteristics of forest ecosystems in the Dosso Partial Wildlife Reserve in Niger. This dominance of Fabaceae demonstrates that these woody plants exhibit adaptive characteristics to the Sahel, which is their natural distribution area par excellence. This representativeness of Fabaceae was noted by Kebyei *et al.* (2022) as part of the work on the socioeconomic contributions of woody plants exploited in the Sahel and in several works on the Sahelian flora (Biga *et al.,* 2020). The dominance of these two families can serve as an indicator of a dry climate. For Alhou Amoude *et al.* (2021), this distribution would be favored by transhumance which constitutes one of the factors of dissemination of certain woody plants in the Sudanian zone (Hahn-Hadjali, 1998). The distribution by plant formation shows a dominance of shrub savannah and gallery forest with 93% of the family. Analysis of species abundance in the four plant formations allows us to establish their extent of ubiquity (Le Bourgeois and Guillerm, 1994). Thus, individuals of *Senegalia senegal*, *Vachellia nilotica* and *Balanites aegyptiaca* are the most abundant, characterizing common species. Through their abundance, they contribute to imprint their physiognomy on the entire ecological landscape. Similar observations were made by Traoré *et al.* (2022) as part of their work on the morphological variability of *Balanites aegyptiaca* in the Ouaddaï province of Chad. This species with thorns and photosynthetic branches is active all year round and has reduced leaves (Niang *et al.,* 2014). The Shannon Weaver index values of 2.75 and Piélou equitability of 0.54 show a diversity of the shrub savannah while the proportion of individuals of all species is estimated at 11.20%. These values are close to those of Sanogo *et al.* (2020) with a Shannon index of 2.52 bits and a Piélou equitability of 0.54 in the study of the diversity of natural formations with Senegalia senegal observed in Nioro du Sahel. The study of the frequency of presence reveals 4 categories of species that are distinguished by their specific richness. The first consists of 15 most frequent species inventoried in the different plant formations. This presence reflects the extent of distribution and or specificity as reported in previous studies by Le Bourgeois and Guillerm (1994) on the distribution and degree of infestation of weeds in the cotton rotation in North Cameroon. The second category consists of 9 frequent species found in three formations. The 3 frequent species forming the third category are found in 2 plant formations. The fourth category is made up of 4 accessory species found in a single plant formation: *Vachellia gourmaensis, Crateva adansonii, Kigelia africana* and *Ximenia americana*. These are characteristic species revealing by their presence an ecological specificity of the biotope (Akpo, 1998).

CONCLUSION AND APPLICATION OF RESULTS

The study on the distribution of woody plants in the Baguirmi Department revealed approximately thirty woody species belonging to 23 genera and 15 families inventoried in the four plant formations. The 16 most common species are common to all four sites, thus proving their widespread distribution. The four accessory species found in a single plant formation are characteristic of the formation: *Vachellia gourmaensis, Crateva adansonii, Kigelia africana,* and *Ximenia americana*. These interesting results suggest the possibility of encouraging natural regeneration in plant formations with rare species, particularly in agricultural operations and raising awareness within the local community about the need for management that respects the environment.

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