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Diversity and Distribution of Woody Species in Agrosystems in the Maradi Region along a North-Central-South Gradient

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study aims to characterize the diversity and distribution of woody forage species in the agrosystems of the Maradi region along a North-Central-South gradient. Data were collected in 187 plots of 50 x 50 m^2 each, i.e., 2500 m^2 in area. These data were subjected to a factorial correspondence analysis (FCA) followed by a hierarchical ascending classification (HAC) with 50%

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similarity, which allowed the identification of three plant groupings, G1, G2, and G3, that characterize the Dakoro, Guidan Roumdji, and Madarounfa sites respectively. The results showed that a total of 13 families were identified in all zones, with a predominance of Fabaceae in Guidan Roumdji (81.25%), Dakoro (70.68%), and Madarounfa (41.35%). The highest tree density was obtained in Madarounfa (10.43 individuals/ha), followed by Guidan Roumdji (7.76 individuals/ha), and finally Dakoro (7.6 individuals/ha). The most dominant biological types are microphanerophytes in Guidan Roumdji (92.19%), followed by Mesophanerophytes in Dakoro (65.05%) and Madarounfa (62%). For the phytogeographic type, Sudano-Zambezian-Saharo-Sindian (SZ-Sah.S) species are the most dominant, followed by Sudano-Zambezian (SZ) species for all zones with more than 84%. These results can be indicators for decision-making in the region's fight against the degradation of plant biodiversity.

Keywords: Distribution; tree fodder; Maradi; North-Central-South gradient.

1. INTRODUCTION

Tree fodder plants play a crucial role in the fodder balance of extensive livestock systems in the Sahelian zone, especially during the lean season [1,2]. They provide many products and services to the Nigerien population, including, among others, leaves, wood, fruits, gums, pods, seeds, etc. [3]. In the Sahelian zone, [4] noted that natural ecosystems and agrosystems provide most of the fodder consumed by animals. However, since the late 1960s in Niger, episodic droughts have led to the degradation of woody formations, manifested by changes in the floristic composition and structure of the vegetation [5,6]. The causes of the degradation in the Sahel are the harsh climatic conditions of the last decades, the increasingly high demand for agricultural land, the continuous pressure on livestock, and the inadequacy of natural resource management practices [7,8]. Also, the Sahelian zone constitutes the northern limit of the distribution area of many species [9]. In recent years with the southward shift of isohyets, the distribution area of some species is decreasing in its northern part [10,11]. Phytogeographic and phytosociological studies constitute accurate models to interpret the state and the phenomena of regression or progression of woody floristic diversity [11,13]. An inventory of this diversity will provide a better understanding of its constituent elements and allow monitoring of its dynamics over time [14]. However, the Maradi region, under solid anthropogenic pressure [15], is one of the areas where millions of hectares have been re-greened through assisted natural regeneration in recent years [16]. The importance of woody plants in satisfying the needs of rural populations and in animal feed, therefore, requires knowledge of the current state of this resource for grazing to carry out actions for its preservation and maintenance of all its functions [17]. Hence the need to know the distribution of fodder trees in agrosystems along a North-Central-South gradient to understand better the current status of the stand over the region. Thus, this study aims to determine the diversity and distribution of woody forage in the agrosystems of the Maradi region along the North-Center-South gradient. The results of this research will provide indicators for the protection and sustainable management of the woody forage resource of the agrosystems.

2. MATERIALS AND METHODS

2.1 Study Sites

This study was conducted in the Maradi region along a North-Central-South gradient (Fig. 1). In the north, the Ajekorya and Baban Kori sites were selected. Ajekorya has located about 25km south of the town of Dakoro at 6°47'24'' E longitude and 14°20'20.9'' N latitude, and Baban Kori is located 70km from Dakoro, at 6°58'36.4'' E longitude and 13°55'47.7'' N latitude. The population is estimated at 807,813 inhabitants [18]. The climate of the area is semi-arid Sahelian in the South and Sahelo-Saharan in the north, characterized by a long dry season (8 to 9 months) from October to May followed by a short rainy season (3 to 4 months) from July to September [10]. The average annual rainfall recorded during the last 30 years (1988 to 2018) was 378.4±90.9 mm/year. Three types of soils are tropical ferruginous soils or dune soils, which are the most dominant and are of crop production. Hydromorphic grounds are spread in depression and fossils [10]. In the phytogeographic subdivision [19], the zone's vegetation is characterized by the presence of Combretaceae thickets on the lateritic plateaus, savannas on the southern sandy terraces, and steppes on the dunes and in the dry valleys. The area's flora is dominated by xerophytic woody

species such as *Senegalia laeta (R.Br. ex Benth.) Seigler & Ebinger, Faiderbia albida* Del*., Boscia senegalensis*(Pers.) Lam. Ex Poir. , *Balanites aegyptiaca* (L.) Del., and Ziziphus mauritiana Lam.. The herbaceous stratum is dominated by therophytes such as *Cenchrus biflorus* Roxb., *Schoenefeldia gracilis* Kunth., and *Aristida mutabilis* Trin. & Rupr.

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In the center: the study was carried out in the village of Karazomé located 15 km from the town of Guidan Roumdji with geographic coordinates of 6°51'21.4'' East longitude and 13°39'31.2'' North latitude and the village of Karo Sofoua located 7km from the city of Guidan Roumdji at 6°37'09.3'' East longitude and 13°37'48.1'' North latitude. The population is estimated at 671,084 inhabitants [18]. The climate is Sahelian, semi-arid, characterized by three distinct seasons: a cold season from November to February with a minimum temperature of 15°C; a hot season from March to May with a maximum temperature of about 40°C; and a rainy season from June to September, sometimes until the second decade of October. The average annual rainfall recorded over the last 30 years (1988 to 2018) is 449.5±104.1mm/year. Minimum temperatures fluctuate between 15 and 20°C during the cold, dry season (December to February), and maximum temperatures reach 39 to 42°C during the hot, dry season (April to June) [20]. According to their agronomic aptitudes, two types of soils are mainly encountered in the department: sandy soils are the most dominant and are of low fertility. They are poor in organic matter due to water and wind erosion, the absence of fallow land and abusive land clearing [21], and hydromorphic soils, rich in mineral elements suitable mainly for irrigated crops. Generally speaking, the vegetation is of the grassy steppe type, with shrubs and trees on the sandy soils. The herbaceous stratum is dominated by the following species: *Cenchrus biflorus* (karanguiya in Hausa), *Zornia glochidiata* Rchb. ex DC. (Narak in Hausa).

To the north: the village of Safo, located 15km from Madarounfa with geographic coordinates 7°07'18.6'' East longitude and 13°24'28.4'' North latitude, and the village of Bargaja located 5km from Madarounfa with coordinates 7°05'48.8'' East longitude and 13°17'35.8'' North latitude. The population is estimated at 575,167 inhabitants [18]. The climate is of the Sahelo-Sudanese type, characterized by the alternation of two seasons: a rainy season that lasts 4 to 5 months and extends from May to September and a dry season that is subdivided into cold seasons from November to February and two hot interseasons (March, April, and May, then October and November). The average annual rainfall over the last 30 years (1988 to 2018) was 535.1 ± 93.5 mm. The average temperature varies quite a lot from one season to another: it ranges from 21.9°C in January to 38.6°C in May; the minima vary from 13.6°C in January to 26.9°C in May, while the maxima vary from 30.2°C in January to 40.4°C in April [22]. Two (2) types of soils are encountered in this area whose physical characteristics are as follows: Heavy soils found mainly in the valley of the Maradi goulbi formed of silty-clay allusion and have an excellent agricultural vocation, ferruginous soils are observed on the rest of the department which is classified into two (2) types namely: tropical ferruginous soils formed on a veneer of clayey sand located in the west, South and east and ferruginous soils that present another facies and are found mainly in the northeast. The area's vegetation is characterized by shrubby, wooded, and wooded savannahs and Combretaceae thickets. In the natural formations, there are also forest galleries along the watercourses. The flora is dominated mainly by Combretaceae (*Guiera senegalensis* J.F.Gmel*., Combretum micranthum* G. Don, *Combretum nigricans* Lepr. Ex Guil. Et Perr*.*, *Combretum glutinosum* Perr. ex Dc) associated, according to the topography and the type of soils, with species such as *Lannea macrocarpa* Engl. Et K. Krause, *Diospyros mespiliformis* Hochst ex .A. Dc and species of the Mimosaceae (*Senegalia macrostachya* (Rchb.exDC.) Kyal.& Boatwr, *Senegalia ataxacantha (DC.) Kyal.& Boatwr.*), Caesalpinioideae (*Piliostigma reticulatum* (Dc.) Hochst), Capparaceae (*Boscia senegalensis* (Pers.) Lam. Ex Poir.) and Tiliaceae (*Grewia bicolor* Juss.). In natural vegetation, the upper stratum is less and less present and is dominated by : *Prosopis africana* (G. et Poir.), *Isoberlinia doka* Choib et Stopf*, Afzelia africana* Sm*., Bombax costatum* Pell. Et Vuill*.* and *Sclerocarya birrea* (A. Rich.) Hochst.. The herbaceous cover is dominated by *Aristida adscensionis* L. and *Zornia glochidiata* Rchb. Ex DC*.*, the accompanying species are: *Schizachyrium exile* (Hochst) Pilg*., Diheteropogon hagerupii* Hitchc*., Pennisetum pedicellatum* Trin. [23].

2.2 Data Collection and Sampling

To study the vegetation of the Maradi region, an inventory of woody species following a North-

Central-South gradient was carried out on a set of 187 plots, including 70 plots in Dakoro located in the north, 66 in Guidan Roumdji situated in the center and 51 in the South located in Madarounfa. The data was collected during April 2021 in plots of 50 x 50 m^2, i.e., 2500 m². Two perpendicular transects running east-west and north-south from the center to the outside of the village [14,24] were used to set up the plots. Plots were spaced 200 m apart along the transects. During the inventory, the scientific names of the species were determined in situ, unidentified species were photographed, and a portion of the leaves and inflorescences were collected to help identify them with the Flora of West Troical [25]. The dendrometric parametersmeasured on each tree were related to the total height of the trees with a graduated pole, the circumference at the base of the trunk at 1.30 m, and the two diameters of the crown in the two perpendicular directions (East-West and North-South) were determined with tape measures measuring 1.5 m and 50 m, respectively. Individuals with a diameter less than or equal to 2cm were considered sprouts or seedlings, and their number per species [26] was counted in each plot.

2.3 Data Processing

The floristic richness and the biological types were determined following the classification of Raunkiaer [27]. The phytogeographic type, the structure in diameter, and the height were determined. The index of species diversity and the index of importance values were calculated using the formulas below.

Shannon-Weaver (1949) diversity index (H) expressed in bits

$$H=-\sum_{i=1}^{s} pilog2pi \quad (1)$$

With S being the total number of species and pi the relative frequency of species.
Diversity is low when H is less than 3 bits, medium if H is between 3 and 4 bits, and high when H is greater than or equal to 4 bits.

The Pielou fairness was calculated from the formula(E)

$$E=\frac{H}{Hmax} \quad (2)$$

with H: Shannon diversity index

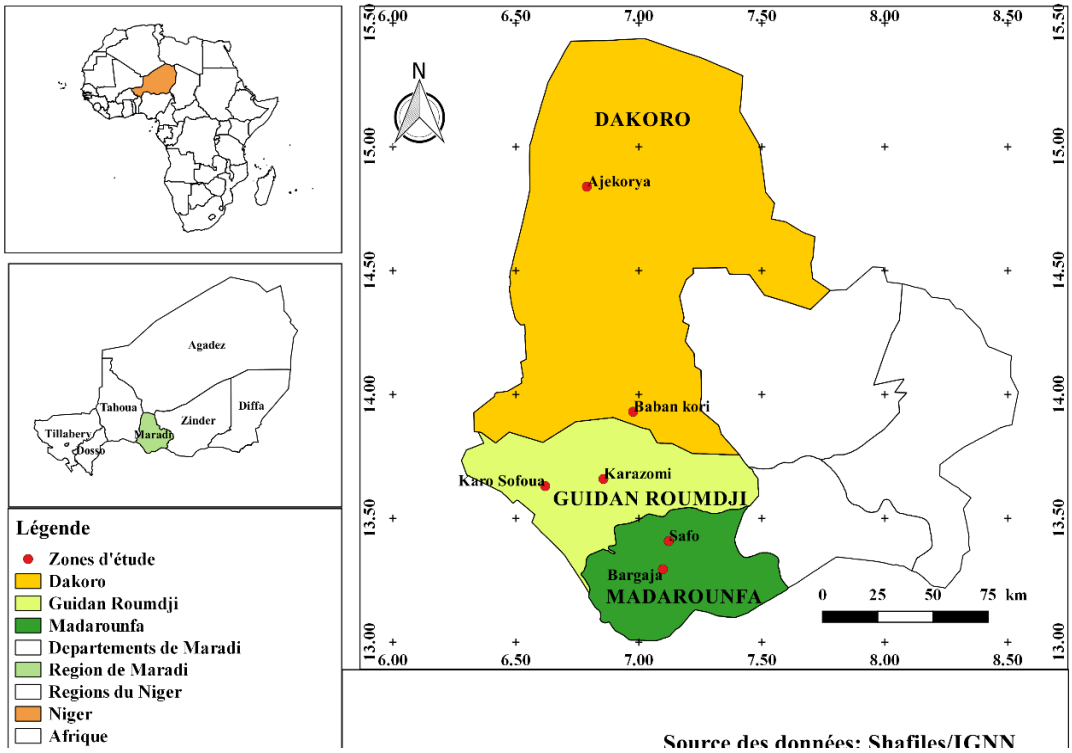

Fig. 1. Location map of the study area showing the sampling sites

The Pielou equitability reflects the way individuals are distributed across species.

If E [0 -0.6], the Pielou equitability is low (dominance phenomenon existing in the community).

If E [0,7 -0,8[, the Pielou equitability is average.
If E [0.8 -1], Pielou's equitability is high (lack of dominance in the community) [28].

Maximum diversity index (Hmax)

$$Hmax=\log_2 S \quad (3)$$

with **S** Total number of species

Average Lorey Height (HL)

The average height of Lorey expressed in (m) is the average height of individuals weighted to their basal area. The following formula calculates it:

$$HL=\frac{\sum_{i=1}^{n} gi*hi}{\sum_{i=1}^{n} gi} \quad (4)$$

$$\text{with } gi=\frac{\pi}{4} di^2 \text{ [29]} \quad (5)$$

Basal area

The global basal area (G) expressed in (m²/ha) and given by the formula below

$$G=\frac{\pi}{40000xS}\sum_{i=1}^{n} di^2 \text{ [30]} \quad (6)$$

S=Plot area in hectare and di=diameter of stem i (cm).

The density

Density (N/ha) is a simple index of average competition in the stand. It is defined as the number of individuals considered in the inventory per unit area per hectare [31]. It is a biological index that provides information on the abundance of individuals of a species in a given site and is obtained by the formula :

$$N=\frac{n}{S}x10000 \quad (7)$$

with S=Area of the plot (ha) and n number of trees in the plot

Wittig and Guinko (1995), cited by Traoré & Toé (2004), have established criteria for assessing regeneration capacity based on the number of seedlings (NP) per hectare. These criteria are :

-No regeneration if NP < 1 ;
- Poor regeneration if 1 < NP ≤ 1000 ;
- Regeneration good if 1000 < NP ≤ 10000;
- Very good regeneration if NP > 10000.

Cover

The cover corresponds to the surface of the ground that would be covered by the projection of the aerial parts of the individuals of the species [32]. It is expressed in percentage (%) and is calculated by the formula :

$$R=\frac{r}{s} \text{ avec } r=\frac{\pi}{4}\sum_{i=1}^{n} di^2 \quad (8)$$

With r=coverage of all individuals in the plot (m²); di=mean crown diameter of individual i (m); s=plot area (m²).

Biological type

The biological type is the set of morpho-physiological characteristics that allow enduring a determined climate, especially in the unfavorable season. They are also the parameters that better account for the physiognomy of plant formations [33,34,35,36]. These are the biological types in reference to [27] classification of phanerophytic woody vegetation (woody plants whose buds are located more than 50cm above the soil surface).

- ✓ Nanophanerophytes < 2 m height
- ✓ Microphanérophytes 2 - 8 m height;
- ✓ Mesophanérophytes 8 - 30 m height.

Phytogeographic type

The phytogeographic type adopted is that of the chronological subdivisions generally accepted for Africa [37] and widely used [14]:

- ✓ SZ: Sudanese-Zambezian;
- ✓ GC: Guinean-Congolese;
- ✓ Sah.S: Saharo-Sindian;
- ✓ GC-SZ: Guinean-Congolese-Sudanese-Zambezi
- ✓ GC-SZ-Sah.S: Guinean-Congolese-Sudanese-Zambezi-Saharan-Sindian
- ✓ I: Introduced

3. RESULTS AND DISCUSSION

3.1 Floristic Richness

The results of this study showed that Fabaceae on all the study sites dominates the floristic

richness. There are 13 families found in all the zones (Table 1). The table shows that the Fabaceae families are the most dominant in all the study areas, with 81.25% in Guidan Roumdji, 70.68% in Dakoro, and 41.35% in Madarounfa. The floristic richness results obtained for the whole study area are higher than those obtained by [17] on natural pastures in the Maradi region, which are 11 families. However, they are lower than the results obtained by [38] in the same area, but in the Goulbi Maradi where he counted 22 families, of which the most representative is the Mimosaceae (*Piliostigma reticulatum* and *Faidherbia albida*) , and in the Goulbi Kaba, which has 19 families also dominated by the Mimosaceae. This difference in the number of species could be due to the specific climatic conditions favorable to developing various species in the Goulbi Kaba and Goulbi Maradi valleys. In natural formations [39], the floristic richness is higher in the Sudano-Sahelian zone and [40] states that in Niger, the species richness is higher in the bioclimates of the southern part of the country, which are the most watered.

3.2 Specific Diversity

The diversity indices of all the sites are presented in Table 2. The Shannon diversity index is average at Madarounfa, with 3.01 bites, but low at Dakoro and Guidan Roumdji, with values of 2.27 bites and 1.76 bites, respectively. These low values could be due to anthropogenic activities, particularly the abusive cutting of old individuals to manufacture mortars, pestles, and wooden chairs in these areas. This result corroborates that obtained by [28], which reveals that the low diversity of grouping is mainly due to anthropogenic factors because, in Niger, the problem of natural resource management is characterized by an imbalance between the increased needs of rapidly growing populations and the search for a general improvement of their living conditions. Thus, many species that have become rare or disappeared from natural pasture formations due to destructive anthropic practices are maintained by farmers in agrosystems for multiple benefits, which has changed the landscape of the fields [41]. The high value of the Shannon diversity index in the Madarounfa area is due to the practice of ANR advocated by Projects and NGOs, which is protected and monitored by village monitoring committees [42]. The Pielou equitability index is average in all sites and varies from 0.44 to 0.73. The highest value of this index is obtained at Madarounfa (0.73) and the lowest at Guidan Roumdji (0.44). The maximum diversity index is the highest in Madarounfa (4.08), followed by Guidan Roumdji (4) but is low in Dakoro (3.58). It is noted that the Madarounfa zone has the highest species diversity parameters of all the zones studied. These results are lower than those obtained by [43] in the Mainé Soroa area, where the Pielou equitability index is higher than 0.8. This difference is due to the high diversity within the grouping and the fact that many species participate in the cover in this area.

Table 1. Distribution of families by zone expressed in percentage

Families	Dakoro	Guidan Roumdji	Madarounfa	Total (%)
Fabaceae	70,68	81,25	41,35	64,21
Arecaceae	0,75	1,56	28,57	10,41
Zygophyllaceae	15,04	-	3,76	6,35
Meliaceae	-	4,69	9,02	4,57
Malvaceae	-	0,78	10,53	3,81
Anacardiaceae	2,26	5,47	3,01	3,55
Combretaceae	6,02	2,34	-	2,79
Ebenaceae	-	2,34	2,26	1,52
Rhamnaceae	4,51	-	-	1,52
Capparaceae	0,75	0,78	-	0,51
Bignoniaceae	-	-	0,75	0,25
Lamiaceae	-	-	0,75	0,25
Moraceae	-	0,78	-	0,25
Total	100	100	100	100

Table 2. Species diversity at the three sites

Area	S	H	Hmax	E
Dakoro	12	2,27	3,58	0,63
Guidan Roumdji	16	1,76	4	0,44
Madarounfa	17	3,01	4,08	0,73
Probability		0,198	0,00	0,125

S: species richness; H: Shannon diversity index; Hmax: maximum diversity; E: Pielou equitability

3.3 Biological Distribution of the Raw and Weighted Spectrum

The biological distribution of the raw and weighted spectrum is presented in Fig. 2. The results show that in the Guidan Roumdji area, microphanerophytes are the most dominant biological types in the gross spectrum (92.19%) and the weighted spectrum (82.53%). On the other hand, in Dakoro, Mesophanerophytes are the most dominant biological types for the gross spectrum (58.65%) and the weighted spectrum (65.05%). As for the Madarounfa area, microphanerophytes (49.62%), followed by Mesophanerophytes (48.87%), dominate in the raw spectrum and Mesophanerophytes in the weighted spectrum (62%). Finally, nanophanerophytes are poorly represented in all areas (less than 1%). This could be explained by the anthropic pressure exerted on the large trees. This dominance of microphanerophytes characterizes the predominance of shrubs in this area. These results are similar to those found by [8], who reported that shrubby formations are the most prevalent physiognomic types in this area. Microphanerophytes dominate due to the low rainfall observed at the site [44]. Mesophanerophytes are the most represented in the Dakoro and Madarounfa areas compared to the other types. This dominance of Mesophanerophytes is due not only to the presence of large trees in these areas but also to the climatic conditions that are more favorable to them.

3.4 Phytogeographic Distribution

The phytogeographic type is shown in Table 3. This table shows that Sudano-Zambezian-Saharan-Sindian (SZ-Sah.S) species are the most dominant for both the gross and weighted spectra, followed by Sudano-Zambezian (SZ) species for all zones with over 84%. Guinean-Sudanese-Zambezi (GC-SZ) and Guinean-Congolese-Sudanese-Zambezi-Saharan-Sindian (GC-SZ-Sah.S) species are poorly represented at all sites (less than 5%). These results are consistent with the results found by [28], which presents a dominance of Sudano-Zambezian species followed by Sudano-Zambezian-Saharo-Sindian species in the Tahoua region.

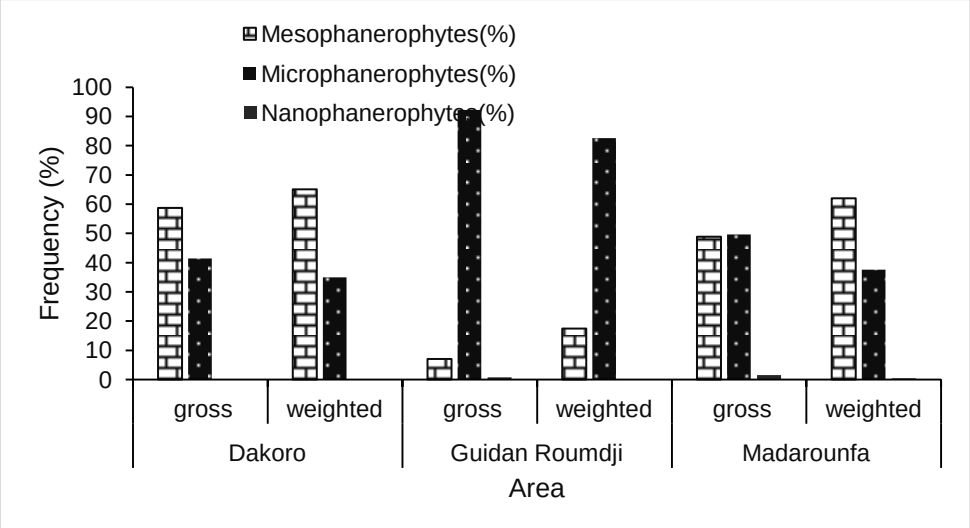

Fig. 2. Frequency of raw and weighted spectra by area

Table 3. Phytogeographic type

Area	Dakoro		Guidan Roumdji		Madarounfa	
Phytogeographic type	**Gross**	**Weighted**	**Gross**	**Weighted**	**Gross**	**Weighted**
SZ-Sah.S	88,72	91,94	78,91	77,45	39,85	46,14
SZ	11,28	8,06	13,28	10,65	46,62	38,78
I			4,69	4,45	9,02	10,31
GC-SZ			2,34	4,57	3,01	3,72
GC-SZ-Sah.S			0,78	2,88	1,50	1,06

Table 4. Density of regeneration of all species by area

	Regeneration density (trees /ha)			
Species	**Dakoro**	**Guidan Roumdji**	**Madarounfa**	**Total**
Senegalia laeta (R.Br. ex Benth.) Seigler & Ebinger	1,94	-	-	0,73
Acacia nilotica subsp. Adanonii (Guill.& Perr.) Brenan	0,69	2,42	0,78	1,33
Acacia radiana savi	-	-	0,55	0,15
Adansonia digitata L.	-	-	0,39	0,11
Albizia chevalieri Harms.	1,20	3,94	17,80	6,70
Annona senegalensis Pers.	10,40	9,88	17,18	12,06
Azadirachta indica A.Juss.	0,46	20,48	111,53	37,82
Balanites aegyptiaca (L.) Del.	19,60	7,70	8,31	12,32
Bauhinia rufexens Lam.	9,83	9,09	-	6,89
Boscia salicifolia Oliv.	0,00	0,48	-	0,17
Boscia senegalensis(Pers.) Lam. Ex Poir.	178,74	-	9,10	69,39
Calotropis procera (Ait.) R. Br.	7,89	2,91	20,71	9,63
Cassia singueana Delile	0,34	-	-	0,13
Combretum glutinosum Perr. ex Dc	24,17	21,33	-	16,58
Combretum micranthum G. Don	17,49	0,91	-	6,87
Commiphora africana (A.Rich.) Engl.	0,11	-	11,76	3,25
Dichrostachys cinerea (L.) Wight et Arn.	-	51,58	4,71	19,49
Diospiros mespiliformis Hochst ex .A.	-	-	3,14	0,86
Euphorbia Balsamifera Aiton	-	0,85	11,37	3,40
Faidherbia albida Del.	22,97	39,27	70,59	41,71
Ficus thonningii Blume	-	-	1,57	0,43
Guiera senegalensis J.F.Gmel.	354,40	478,12	119,61	334,03
Hyphaene thebaica (L.) Mart.	7,14	822,85	321,88	380,88
Lannea fruticosa (Hochst. Ex A.Rich.) Engl.	-	0,61	-	0,21
Maerua angolensis DC.	0,06	-	-	0,02
Maerua crassifolia Forssk.	5,60	3,52	-	3,34
Moringa oleifera Lam.	-	-	0,94	0,26
Piliostigma reticulatum (Dc.) Hochst	19,54	555,76	181,33	252,92
*Sclerocarya birrea (*A. Rich.) Hochst.	10,63	7,76	4,16	7,85
Sterculia setigera Delile	-	-	0,08	0,02
Stereospermum kunthianum var.dentatum (A.Rich.) Fiori	-	2,12	-	0,75
Tamarindus indica L.	-	-	2,82	0,77
Vitex doniana Sweet	-	-	3,92	1,07
Ziziphus mauritiana Lam.	48,91	94,18	91,61	76,53
Total	747,31	2135,76	1017,65	1311,08

3.5 Density of Regeneration of Species by Area

The regeneration density of all woody species in all zones is presented in Table 4. The results show that 34 regenerating plant species were found in all sites, with the highest number of species in Madarounfa (24 species), followed by Dakoro (22 species), and finally, Guidan Roumdji (21 species). The dominance of species depends on the zone. Nevertheless, the Guidan Roumdji zone has the highest regeneration density compared to the other two zones, with the species Hyphaene thebaica (822.85 trees/ha) followed by *Piliostigma reticulatum* (555.76 trees/ha) and *Guiera senegalensis* (478.12 trees/ha). According to the criteria for assessing regeneration, except the Dakoro zone, all the

study areas show good regeneration with density values between 1000 < NP ≤ 10000. This could be due to the favorable soil and climatic conditions for developing woody species. Also, [45] reported that variations in juvenile density could be related to the complex interaction between factors involving species characteristics, soil types, as well as the capacity of the species to dispose of stump offsets.

3.6 Density of Individuals per Hectare

The density of individuals per hectare of all the species by zone is represented in Table (5). The results show that the Madarounfa zone has the highest density (10.43 individuals/ha) followed by the Guidan Roumdji zone (7.76 individuals/ha) and finally the Dakoro zone (7.6 individuals/ha).

3.7 Distribution of Woody Species by Area

The 26 species found in 187 plots were subjected to a factorial correspondence analysis (FCA). Factor axes 1 and 2 explained 100% of the total variance, with contributions of 66.9% and 33.1%, respectively (Fig. 3). The hierarchical ascending classification (HAC) at 50% similarity identified three plant groupings which are G1, G2, and G3, as shown in the dendrogram in Fig. 4. The species of the G1 grouping characterize the Guidan Roumdji area. This zone includes the following species: *Piliostigma reticulatum, Lannea fructicosa* (Hochst. Ex A.Rich.) Engl.*, Detarium microcarpum* G. Don*, Diospyros mespiliformis* Hochst ex .A.*, Ficus thonningii* Blume*, Prosopis africana* (G. et Poir.)*.*

Table 5. Density of individuals per hectare

		Density (individuals/hectare)			
Scientific names	**Famillies**	**Dakoro**	**Guidan Roumdji**	**Madarounfa**	**Total**
Senegalia laeta (R.Br. ex Benth.) Seigler & Ebinger	Fabaceae	0,23	-	-	0,09
Acacia nilotica subsp. Adanonii (Guill.& Perr.) Brenan	Fabaceae	0,34	-	0,08	0,15
Adansonia digitata L.	Malvaceae	-	0,06	0,94	0,28
Albizia chevalieri Harms.	Fabaceae	-	0,06	0,31	0,11
Annona senegalensis Pers.	Fabaceae	-	0,06	0,16	0,06
Azadirachta indica A.Juss.	Meliaceae	-	0,36	0,94	0,39
Balanites aegyptiaca (L.) Del.	Zygophyllaceae	1,14	-	0,39	0,53
Bauhinia rufexens Lam.	Fabaceae	0,06	-	-	0,02
Bombax castatum Pell. Et Vuill.	Malvaceae	-	-	0,16	0,04
Combretum glutinosum Perr. Ex Dc	Combretaceae	0,34	0,12	-	0,17
Detarium microcapum G. Don	Fabaceae	-	0,06	-	0,02
Diospyros mespiliformis Hochst ex .A.	Ebenaceae	-	0,18	0,24	0,13
Entada abyssica Steud. Ex A.Rich.	Fabaceae	-	-	0,08	0,02
Faidherbia albida Del.	Fabaceae	4,23	0,36	0,63	1,88
Ficus thonningii Blume	Moraceae	-	0,06	-	0,02
Guiera senegalensis J.F.Gmel.	Combretaceae	0,11	0,06	-	0,06
Hyphaene thebaica (L.) Mart.	Arecaceae	0,06	0,12	2,98	0,88
Lannea fruticosa (Hochst. Ex A.Rich.) Engl.	Anacardiaceae	-	0,30	0,08	0,13
Maerua crassifolia Forssk.	Capparaceae	0,06	0,06	-	0,04
Piliostigma reticulatum (Dc.) Hochst	Fabaceae	0,51	5,70	2,90	2,99
Prosopis africaina (G. et Poir.)	Fabaceae	-	0,06	-	0,02
Sclerocarya birrea (A. Rich.) Hochst.	Anacardiaceae	0,17	0,12	0,24	0,17
Stereospernum kunthianum var.dentatum (A.Rich.) Fiori	Bignoniaceae	-	-	0,08	0,02
Tamarindus indica L.	Caesalpiniaceae	-	-	0,16	0,04
Vitex doniana Sweet	Lamiaceae	-	-	0,08	0,02
Ziziphus mauritiana Lam.	Rhamnaceae	0,34	-	-	0,13
Total		7,60	7,76	10,43	8,43

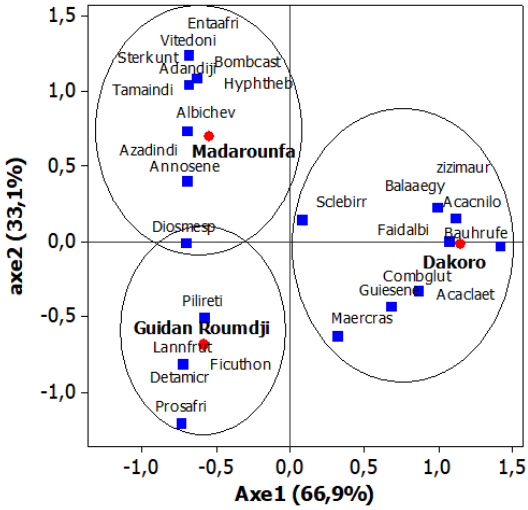

Fig. 3. Correspondence factor analysis of woody species, frequency by zone Dendrogram readings

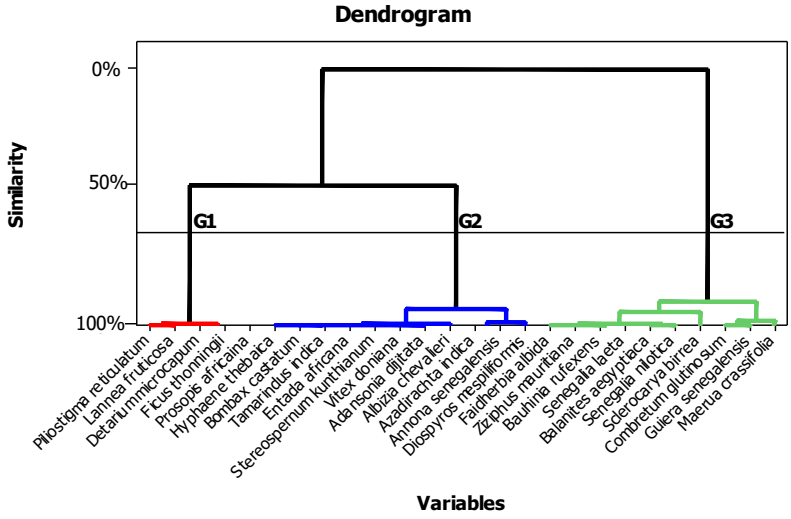

Fig. 4. Hierarchical bottom-up classification of plant groupings across the study area

The G2 grouping characterizes the dakoro zone. It is constituted in the majority of thorny species: *Faiderbia albida* Del., *Balanites aegyptiaca* (L.) Del., *Combretum glutinosum* Perr. Ex Dc, *Sclerocarya birrea* (A. Rich.) Hochst., *Acacia nilotica subsp. Adanonii (Guill.& Perr.) Brenan, Ziziphus mauritiana, Senegalia laeta* (R.Br. ex Benth.) Seigler & Ebinger, *Guiera senegalensis* J.F.Gmel., *Maerua crassifolia* Forssk., *Bauhinia rufescens* Lam.

The G3 grouping represents that of the Madarounfa zone, made up of species such as *Hyphaene thebaica* (L.) Mart., *Azadirachta indica* A.Juss., *Diospyros mespiliformis* Hochst ex .A., *Albizzia chevalieri* Harms., *Annona senegalensis* Pers., *Bombax costatum* Pell. Et Vuill., *Tamarindus indica, Entada abyssica* Steud. Ex A.Rich., *Stereospernum kunthianum* var.dentatum (A.Rich.) Fiori, *Vitex doniana* Sweet.

4. CONCLUSION

The study of the floristic diversity of the Maradi region according to the North-Central-South gradient allowed the identification of 32 families. Indeed, the Madarounfa zone abounds in the most significant number of species, followed by Guidan Roumdji and Dakoro. The Fabaceae

families are the most dominant in all zones. The most represented biological types are microphanerophytes in Guidan Roumdji, followed by Mesophanerophytes in Dakoro and Madarounfa. Still, for phytogeographic types, Sudano-Zambezian-Saharan-Sindian species are the most dominant, followed by Sudano-Zambezian species on all sites. Thus, we note a re-greening through young shoots in the whole region [46-48]. To safeguard the woody species identified in the agroforestry parks, the village committees for monitoring assisted natural regeneration must be strengthened to perpetuate this already threatened woody resource.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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