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Structure and phytodiversity of woody species in central Niger

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ABSTRACT

The agro-ecological zones of central Niger have been in decline since the drought of 1984. Determining the structures and diversity of current species is therefore essential for conserving and sustainably using these resources. The aim is to contribute to the sustainable exploitation of plant resources in this area. The methodology used involves conducting surveys in units according to land use types in order to determine the phytodiversity and structural parameters of the woody plants present. In fact, 43 woody species, divided into 20 families, including Mimosaceae, Caesalpiniaceae, and Capparaceae, represent nearly 50%. The structure is that of a young stand in all areas, with plant biodiversity increasing from north to south and 45% of species being rare. The regeneration rate is higher in Kantché (75%) than in Tanout (32%) and Gangara (40%), with little or no regrowth of emblematic species such as C. sinensis, F. albida, A. digitata, C. africana, D. mespiliformis, S. birrea, S. kunthianum, T. indica, V. doniana, and Z. spina-christi, which is a strong indicator and a challenge in the management of this plant diversity.

Keywords: *woody plants, diversity, dendrometry, regeneration, Zinder.*

INTRODUCTION

In rural areas, products derived directly from the ecosystem are the main source of income, with plants playing a crucial role in providing food for livestock, stabilizing soils, regulating the climate, and structuring landscapes. They also serve as a source of building materials and domestic energy, and help to improve rural incomes and secure farms. Understanding the normative relationship between human societies and the environment is particularly relevant in grasping the full complexity of the definition, construction, and relationships with the institutions and mechanisms of environmental management and access to the commons at the heart of our social mechanisms and our various environmental integrations, whether urban or rural [1]. Woody plants are plants that contain wood in their organs. In the natural environment, plants determine the appearance of an area. Far from being randomly distributed, plant groups follow a well-organized distribution based on the relationships between individuals and populations. In plants, the structure of species groups provides a basis for information about their experiences. Thus, structure can be influenced by the environment [2-4] or by human activity [5-8]. High diversity and a regular structure are good indicators of the stability and positive evolutionary dynamics of a population. Structure reflects the level of conservation and protection [9], [4], [10-11]. According to [2], local species richness and diversity in savanna ecosystems are generally maintained by a dynamic interaction between local colonization processes from larger-scale species pools and local extinction due to competitive exclusion processes. It is also an indicator for diagnosing the current conservation status of species and their interactions [4], [12-14], resistance and adaptation to climatic and edaphic conditions [15].

Thus, characterizing woody species in different agrosystems is becoming increasingly necessary because, since the 1992 Rio de Janeiro summit on biological diversity, Niger, like the international community, has been committed to a process of sustainable natural resource management to combat various factors of degradation [16]. This study was undertaken to improve sustainability in the exploitation of plant resources.

MATERIALS AND METHODS

STUDY AREA

This study was conducted in the Zinder region. It covers three agro-ecological zones: the pastoral/desert zone, the agropastoral zone, and the agricultural zone. The municipalities studied in the project are mainly concentrated in the agro-pastoral and agricultural zones (Figure 1). In these zones, rain-fed agriculture accounts for more than 80% of the population. This is more than just an activity; it is a way of life that is an integral part of parental education. The main crops are millet, sorghum, peanuts, and cowpeas, which are mainly intended for the consumption of a rapidly growing population. Meeting food needs remains a daily concern. Thus, current climatic and demographic dynamics place the study area at the heart of major agricultural changes, between adaptation, meeting food needs, and sustainable agriculture. The pastoral zone is only found on the northern margins of the municipalities of Tanout and Belbédji, where rainfall is around 150 mm, while the agricultural zone receives more than 600 mm of rain per year. In terms of phytogeography, the area comprises three compartments [17]:(i) the central North Sudanese compartment (A2), where the vegetation consists of low dry forest on the plateaus, gallery forests on the banks of watercourses, savannas on sandy terraces, dunes, and dry valleys, (ii) the central South Sahelian compartment (B2), with

vegetation consisting of Combretum thickets on lateritic plateaus, but with savannas on southern sandy terraces and steppes on dunes and in dry valleys, and (iii) the eastern North-Sahelian compartment (C3), which is characterized by steppe-type vegetation, the flora of which was dominated during the 1990s by Salvadora persica, Ipomoea kotchyana, Coccinia grandis, Corallocarpus sp, Commicarpus helenae, Pennisetum violaceum, Commiphora africana, etc.

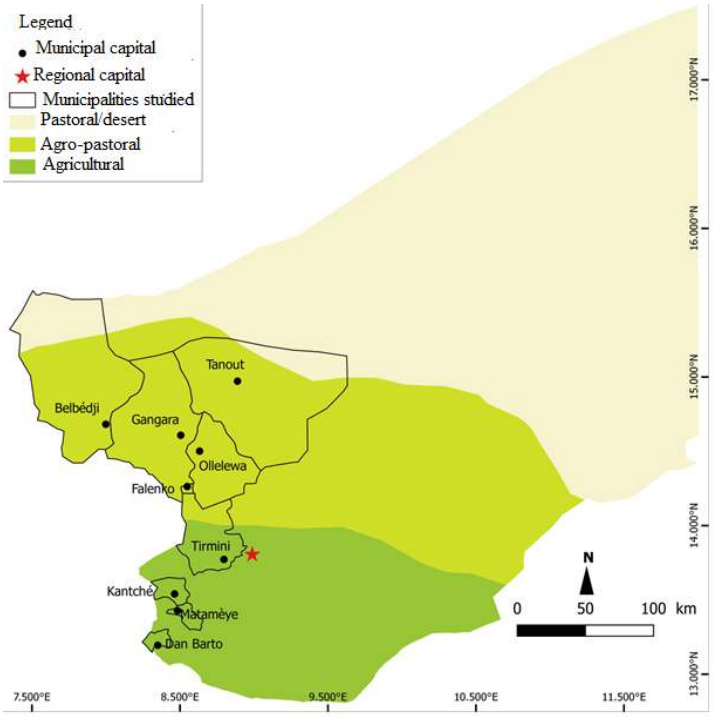

Figure 1: Agro-ecological zoning of the Zinder Region

STUDY AREA

SAMPLING

Dendrometric surveys were carried out in a few sample villages (ranging from 2 to 5) in each municipality. In each sample village, 1 to 3 plots were surveyed depending on land use types: fields, fallow land, pastoral areas/pastures, and natural vegetation/classified forest. The plots constitute the sampling units. Their dimensions vary according to the vegetation formations encountered. The dimensions of the plots selected are as follows: 50 m x 10 m for grasslands and forest galleries, 50 m x 20 m for savannas, and 50 m x 50 m for agroforestry parks. A total of 75 plots (Figure 2), divided into 19 in Tanout, 25 in Gangara, and 31 in Kantché, were sampled. In each plot, an exhaustive census of woody plants was carried out. The measurements focused on dendrometric characteristics such as tree height, the two perpendicular diameters of the crown, and the circumference at the base of the trunk.Thus, dendrometric measurements were taken on individuals with a diameter ≥ 5 cm. These measurements included diameter (measured at 1.3 m for trees and 0.2 m above ground for shrubs and bushes), and total height was estimated using a graduated pole. The species name of each individual measured was also noted. The regeneration of each species was assessed by an exhaustive count of individuals with a diameter of less than 5 cm resulting from regeneration (seedlings, stump sprouts, layering, or suckers).

For multi-stemmed individuals, the clump was considered as a single individual, and measurements were taken only on the dominant stem. The unique feature of this survey is that it was conducted on a north-south transect, utilizing the international corridor connecting Niger and Nigeria.

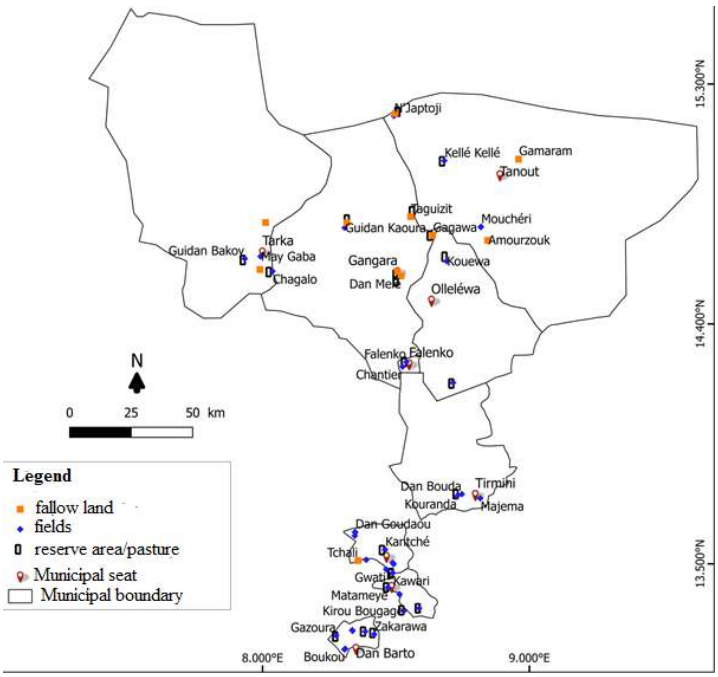

Figure 2: The plots localisation

floristic richness, which is the number of families, genera, and species found in the stand under consideration in a given ecosystem [18];

the specific regeneration importance (SRI), which is the percentage ratio between the number of young plants of a species and the total number of young plants counted [19];

(iv) Consistency (C) is the ratio of the number of surveys containing the species studied (Pi) to the total number of surveys (P); expressed as a percentage [20].

$C(\%)=Pi/P\times100$

Where Pi represents the total number of samples containing species i and P the total number of samples taken. Depending on the value of C, the following categories apply:

Omnipresent: if C% = 100%; Constant: if 75% ≤ C% < 100%; Regular: if 50% ≤ C% < 75%; Accessory: if 25% ≤ C% <50%; Accidental: if 5% ≤ C%< 25%; Rare species if C%< 5%.

(v) The stand regeneration rate (TRP) is given by the percentage ratio between the total number of young plants (diameter < 4 cm) and the total number of trees in the stand [21]. Woody plants with a diameter of less than 4 cm, corresponding to the minimum diameter for harvesting in contracted plant formations [22], are considered to belong to the regeneration. The characteristic values for this rate are: (a) a rate of 50% indicates a stand in equilibrium, where there are as many young plants as adults; (b) a rate of less than 50% indicates an aging stand; (c) a rate of more than 50% corresponds to a stand in full expansion as a result of strong regeneration.

These parameters were used to assess the ecological health of the vegetation types.

The general characteristics of plant formations defined by [23] were used to identify the different types of formations encountered (Table I).

Table I: General characteristics of the formations encountered in the study area

Type of vegetation	Characteristics
Gallery forest	It depends on nearby watercourses and bodies of water. This class includes riparian tree belts along temporary or permanent watercourses and semi-deciduous forest galleries.
Shrub savanna	Woody vegetation consisting almost exclusively of shrubs and bushes scattered throughout the continuous grass cover.
Shrub steppe	The tree cover is between 10 and 50% and the tree layer is less than 10%. The dominant height is less than 7 m. The ground cover is between 10 and 50% and the tree layer is less than 10%. The dominant height is less than 7m
Forest reserve	Grassy formation with very irregular cover where small trees, shrubs and bushes are present

Diversity and evenness indices

The richness and diversity of a territory's flora are very useful criteria, particularly from the perspective of historical phytogeography [24]. Diversity and evenness indices are calculated on the basis of surveys in order to assess the level of organization of the population.

Alpha diversity index and Pielou's evenness

The Shannon-Weaver diversity index (H') varies according to the number of species recorded and the abunda nce of each species. Diversity is low when H is less than 3, medium when H is between 3 and 4, and high when H is greater than or equal to 4 [25]. It is expressed in bits and its formula is:

$$H' = -\sum_{i=1}^{s} pilog_2pi$$

where S = total number of species and pi = relative frequency of species.

Piélou's equitability was calculated using the formula

$$E = \frac{H'}{H'max} \; et \; H'max = log_2S$$

Piélou's evenness index varies between 0 and 1. It tends towards 0 when there is a phenomenon of dominance and tends towards 1 when the distribution of individuals between species is regular.

Sorensen coefficient

The Sorensen coefficient (1948) was calculated to assess beta diversity, which allows habitats to be compared with each other. This index expresses the degree of similarity between two sites and is calculated using the following formula:

$$SI = \frac{2C}{A+B}$$

where A is the number of species belonging only to site 1, B is the number of species belonging only to site 2, and C is the number of species common to both sites.

RESULTS

Structure (height and diameter) of stands and regeneration

Figures 3 and 4 show the proportions of woody plants according to height and diameter classes in three municipalities representative of the rainfall gradients in the south (Kantché), center (Gangara), and north (Tanout).

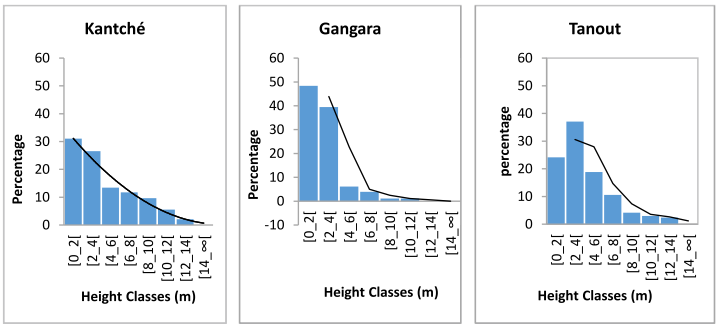

Figure 3: Height structure of woody plants in the three municipalities

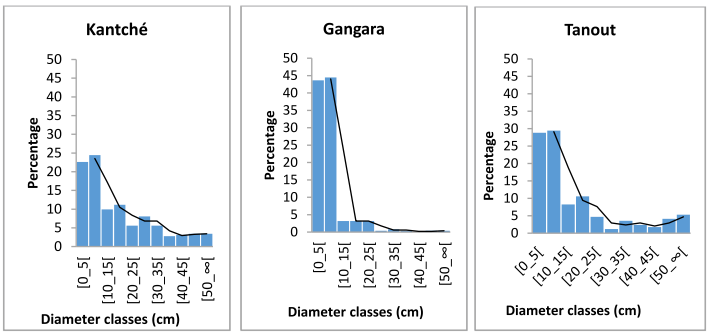

Figure 4: Diameter structure of woody plants in the three municipalities

It can be seen that the distribution of individuals by height shows an "L" shape. Trees with a height of ≤ 4 m are numerically more important. They represent at least 55% of trees. In Gangara, their proportion reaches nearly 90%. The tree stands are therefore relatively young. Tree species with a height of ≥ 10 m are more common in the south than in the north.

As for the diameter structure of the tree stands, there is a unimodal distribution. However, this is fairly well distributed in Kantché, and to a lesser extent in Tanout, where the distribution tends towards a bimodal structure. The diameter class ≥ 40 cm is larger than the class between 25 and 35 cm. Overall, an L-shaped structure is observed, reflecting a predominance of individuals with small diameters. Apart from the rejection (0–5 cm), the structure shows that more than one-third of individuals are found in the first two diameter classes (10–25 cm), with 34.36%, 47.61%, and 37.64% in Kantché, Gangara, and Tanout, respectively. Better still, the first class of adult individuals represents more than a quarter of the population, with 43.65% in Gangara. While in Gangara and Tanout, the nature of the species is the most plausible explanation, in Kanché, on the other hand, human activities better explain this situation, as trees are cut down not only for field development but also by artisans.

Finally, with regard to regeneration, its frequency and rate vary greatly depending on the site (Table II).

Table II: Regeneration rate (%) by site

Espèce	Sites			
	Kantché	Gangara	Tanout	Ensemble de sites
Acacia nilotica (L.) Willd. ex Del.	52,38	13,33	23,53	30
Acacia senegal (L.) Willd.	30,77	60	12,5	30,77
Acacia seyal Del.	46,88	27,27	100	43,18
Acacia tortilis subsp. raddiana (Savi) Brenan	50	9,52	20	12,24
Adansonia digitata L.	0			0
Albizia chevalieri Harms	62,5		66,67	65,22
Annona senegalensis Pers.	87,5	100		89,55
Azadirachta indica A. Juss.	18,52			18,52
Balanites aegyptiaca (L.) Del.	83,33	48,27		54,29
Bauhinia rufescens Lam.	42,85	50		43,18
Boscia salicifolia Oliv.			100	100
Boscia senegalensis (Pers.) Lam. ex Poir.		45,83	13,41	25,38
Calotropis procera (Ait.) Ait. f.	100	100	46,15	80
Capparis tomentosa Lam.		100		100
Cassia italica(Mill.) Lam. ex F.W. Andr.		100	100	100
Cassia sieberiana DC.	100			100
Chrozophora bracchiana ,Vis		100		
Combretum glutinosum Perr. ex DC.	96,15			96,15
Combretum micranthum G. Don	50	0		33,33
Commiphora africana (A. Rich.) Engl.		0		0
Cordia sinensis Lam.	0	53,85	47,37	47,06
Detarium microcarpum Guill. & Perr.	0			0
Dichrostachys cinerea (L.) Wight & Arn.	66,67			66,67
Diospyros mespiliformis Hochst. ex A. Rich.	0			0
Euphorbia balsamifera Ait.	30			30
Faidherbia albida (Del.) Chev.	35,71	28,95	21,43	31,55
Guiera senegalensis J.F. Gmel.	94,44			94,44
Hyphaene thebaica (L.) Mart.	96,26		100	96,31
Lannea microcarpa Engl. & K. Krause	0		100	50
Leptadenia hastata (Pers.) Decne.	100			100
Leptadenia pyrotechnica (Forssk.) Decne.	100	66,67	50	75
Maerua crassifolia Forssk.	92,31	48,39	100	65,31
Pergularia tomentosa L			100	100
Piliostigma reticulatum (DC.) Hochst.	74,49	0	100	74,51
Prosopis africana (Guill. & Perr.) Taub.	12,5			12,5
Prosopis juliflora (Sw.) DC		0	42,86	37,5
Sclerocarya birrea (A. Rich.) Hochst.	0	0	0	0
Senna singueana (Del.) Lock			100	100
Stereospermum kunthianum Cham.	0			0
Tamarindus indica L.		0		0
Vitex doniana Sweet	0			0
Ziziphus mauritiana Lam.	94,44	36,36		62,5
Ziziphus spina-christi (L.) Desf.	0			0
Total	**75,71**	**39,59**	**31,6**	**63,05**

Overall, the regeneration rate is higher in Kantché (75%) than in Tanout (32%) and Gangara (40%). This may be linked to human activities (agropastoralism), which are more intense in the center and north. In addition, the supply of aerial fodder and the harvesting of fruit before maturity are factors explaining the low regeneration rate in these areas.

Floristic composition

Based on 75 surveys conducted, 43 woody species were counted (Table III).

Table III: Floristic composition of the surveyed sites

Species	Family	Presence of the species on the 3 sites		
		Kantché	Gangara	Tanout
Acacia nilotica (L.) Willd. ex Del. -	Mimosaceae	X	X	X
Acacia senegal (L.) Willd.	Mimosaceae	X	X	X
Acacia seyal Del.	Mimosaceae	X	X	X
Acacia tortilis subsp. raddiana (Savi) Brenan	Mimosaceae	X	X	X
Adansonia digitata L. -	Bombacaceae	X		
Albizia chevalieri Harms	Mimosaceae	X		X
Annona senegalensis Pers.	Annonaceae	X	X	
Azadirachta indica A. Juss.	Meliaceae	X		
Balanites aegyptiaca (L.) Del.	Balanitaceae	X	X	
Bauhinia rufescens Lam.	Caesalpiniaceae	X	X	
Boscia salicifolia Oliv.	Capparaceae			X
Boscia senegalensis (Pers.) Lam. ex Poir.	Capparaceae		X	X
Calotropis procera (Ait.) Ait. f.	Asclepiadaceae	X	X	X
Capparis tomentosa Lam.	Capparaceae		X	X
Cassia italica(Mill.) Lam. ex F.W. Andr.	Caesalpiniaceae	X	X	X
Cassia sieberiana DC.	Caesalpiniaceae	X	X	X
Chrozophora bracchiana ,Vis	Euphorbiaceaa	X	X	X
Combretum glutinosum Perr. ex DC.	Combretaceae	X	X	X
Combretum micranthum G. Don	Combretaceae	X		
Commiphora africana (A. Rich.) Engl.	Burseraceae	X		
Cordia sinensis Lam.	Boraginaceae	X		X
Detarium microcarpum Guill. & Perr.	Caesalpiniaceae	X		
Dichrostachys cinerea (L.) Wight & Arn.	Mimosaceae	X	X	X
Diospyros mespiliformis Hochst. ex A. Rich.	Ebenaceae	X	X	
Euphorbia balsamifera Ait.	Euphorbiaceae			X
Faidherbia albida (Del.) Chev.	Mimosaceae		X	X
Guiera senegalensis J.F. Gmel.	Combretaceae		X	X
Hyphaene thebaica (L.) Mart.	Arecaceae	X		
Lannea microcarpa Engl. & K. Krause	Anacardiaceae		X	
Leptadenia hastata (Pers.) Decne.	Asclepiadaceae	X		
Leptadenia pyrotechnica (Forssk.) Decne.	Asclepiadaceae		X	
Maerua crassifolia Forssk.	Capparaceae	X		
Pergularia tomentosa L	Sclepiadaceae	X	X	
Piliostigma reticulatum (DC.) Hochst.	Caesalpiniaceae		X	
Prosopis africana (Guill. & Perr.) Taub.	Mimosaceae	X		
Prosopis juliflora (Sw.) DC	Mimosaceae	X		
Sclerocarya birrea (A. Rich.) Hochst.	Anacardiaceae	X		
Senna singueana (Del.) Lock	Caesalpiniaceae	X		
Stereospermum kunthianum Cham.	Bignoniaceae	X		
Tamarindus indica L.	Caesalpiniaceae	X	X	X
Vitex doniana Sweet	Verbenaceae	X		X
Ziziphus mauritiana Lam.	Rhamnaceae	X		X
Ziziphus spina-christi (L.) Desf.	Rhamnaceae	X		X
Total	43	20	35	21	19

These species are divided into 33 genera, the most represented of which are Acacia (4 species) and Boscia, Combretum, Lannea, Prosopis, and Ziziphus, with 2 species each. There are 20 families, the most represented being Mimosaceae with nine species (21.42%), Caesalpiniaceae with seven species (16.67%), and Capparaceae with four species (9.52%). Overall, 43 woody species were recorded at the various sites, with significant variability between sites. Thus, the species diversity per site is 35, 21, and 19 species in Kantché, Gangara, and Tanout, respectively (Table IV).

Table IV: shows the frequency of occurrence of species per site

Species	Consistency (%)				Frequency (%)			
	Kanché	Gangara	Tanout	sites	Kanché	Gangara	Tanout	sites
Acacia nilotica (L.) Willd. ex Del. -	26	20	68	35	1,74	5,4	13,71	4,03
Acacia senegal (L.) Willd.	16	12	16	15	2,15	1,8	2,82	2,19
Acacia seyal Del.	10	20	0	11	2,64	3,96	0,4	2,53
Acacia tortilis subsp. raddiana (Savi) Brenan	6	24	21	16	0,17	15,11	2,42	2,88
Adansonia digitata L. -	3	0	0	1	0,08			0,06
Albizia chevalieri Harms	13	0	0	5	0,66			0,46
Annona senegalensis Pers.	68	0	5	29	9,42		0,4	6,62
Azadirachta indica A. Juss.	19	0	0	8	2,31			1,61
Balanites aegyptiaca (L.) Del.	13	48	58	36	0,74	10,43	32,66	6,85
Bauhinia rufescens Lam.	16	4	0	8	4,05	0,72		2,94
Boscia salicifolia Oliv.	0	0	5	1			0,4	0,06
Boscia senegalensis (Pers.) Lam. ex Poir.	0	68	53	36		17,27	6,05	3,63
Calotropis procera (Ait.) Ait. f.	0	28	47	21		4,68	7,26	1,79
Capparis tomentosa Lam.	3	0	0	1	0,08			0,06
Cassia italica(Mill.) Lam. ex F.W. Andr.	0	4	0	1		0,36		0,06
Cassia sieberiana DC.	3	0	0	1				0,00
Chrozophora bracchiana ,Vis	0	4	0	1		0,36		0,06
Combretum glutinosum Perr. ex DC.	16	0	0	7	2,07			1,44
Combretum micranthum G. Don	6	4	0	4	0,5	1,44		0,58
Commiphora africana (A. Rich.) Engl.	0	4	0	1		1,08		0,17
Cordia sinensis Lam.	6	0	0	3	1,18			0,82
Detarium microcarpum Guill. & Perr.	3	0	0	1	0,08			0,06
Dichrostachys cinerea (L.) Wight & Arn.	10	0	0	4	0,5			0,35
Diospyros mespiliformis Hochst. ex A. Rich.	6	0	0	3	0,17			0,12
Euphorbia balsamifera Ait.	19	0	0	8	1,65			1,15
Faidherbia albida (Del.) Chev.	84	48	68	68	10,41	13,67	16,53	11,81
Guiera senegalensis J.F. Gmel.	48	0	16	24	25,29		1,61	17,86
Hyphaene thebaica (L.) Mart.	48	0	11	23	17,69		1,21	12,50
Lannea microcarpa Engl. & K. Krause	3	0	5	3	0,08		0,4	0,11
Leptadenia hastata (Pers.) Decne.	10	0	0	4	0,33			0,23
Leptadenia pyrotechnica (Forssk.) Decne.	16	8	16	13	0,25	1,08	0,81	0,46
Maerua crassifolia Forssk.	6	56	26	28	1,07	12,95	2,02	3,11
Pergularia tomentosa L	0	4	0	1		0,36		0,06
Piliostigma reticulatum (DC.) Hochst.	45	4	5	21	8,02	0,36	1,21	5,82
Prosopis africana (Guill. & Perr.) Taub.	29	0	0	12	0,66			0,46
Prosopis juliflora (Sw.) DC	10	4	32	13	1,49	0,36	2,82	1,50
Sclerocarya birrea (A. Rich.) Hochst.	3	4	16	7	0,17	0,36	1,21	0,35
Senna singueana (Del.) Lock	13	0	11	8	1,74		0,81	1,33
Stereospermum kunthianum Cham.	3	0	0	1	0,08			0,06
Tamarindus indica L.	0	4	0	1		0,36		0,06
Vitex doniana Sweet	3	0	0	1	0,08			0,06
Ziziphus mauritiana Lam.	19	32	37	28	1,49	7,91	5,25	3,05
Ziziphus spina-christi (L.) Desf.	3	0	0	1	0,96			0,67
Total	31	25	19	75	100	100	100	100

The ten most common species are Guiera senegalensis, Hyphaene thebaica, Faidherbia albida, Balanites aegyptiaca, Annona senegalensis, Piliostigma reticulatum, Acacia nilotica, Boscia senegalensis, Maerua crassifolia, and Ziziphus mauritiana. Eleven (11) woody species, namely Faidherbia albida, Balanites aegyptiaca, Boscia senegalensis, Acacia nilotica, Annona senegalensis, Maerua crassifolia, Ziziphus mauritiana, Guiera senegalensis, Hyphaene thebaica, Piliostigma reticulatum, Calotropis procera, and Acacia tortilis subsp. Raddiana are present in 1/5 of surveys, four are present in 1/3 of surveys, and only one species, Faidherbia albida, is present in more than 50% of surveys. It should also be noted that Boscia senegalensis is not present in the wettest areas due to its habitat preferences, such as compact sandy-clay soils, termite mounds, and floodplains, which are indicators of overgrazing. The absence of Guiera senegalensis and Hyphaene thebaica populations can also be explained by the practice of assisted natural regeneration, which selects the species to be conserved in the field.

Alpha diversity is high throughout the area but average in agricultural, agropastoral, and pastoral areas (table V).

Table V: Species diversity index and evenness

Site	Number of plots	Number of species	Number of families	H'	H'max	E
Kantché	**31**	**35**		3,63	5,13	0,71
Gangarara	**25**	**31**		3,35	4,39	0,76
Tanout	**19**	**19**		3,18	4,25	0,75
Total	**75**	**43**		4,04	5,43	0,74

The beta (β) diversity index (Table VI) is higher in Kantché. There is greater similarity between Gangara and Tanout, as they share 13 of the 27 species. This could be explained by climate variability, with Kantché being more humid than the other two sites and Tanout and Gangara being more arid.

Table VI: Specific diversity index per site (IS)

	A	B	C	*IS*
Tanout_Gangarara	6	8	13	**0,65**
Tanout_Kantché	4	18	15	0,58
Gangara_Kantché	9	21	12	0,44

A is the number of species belonging only to site 1; B is the number of species belonging only to site 2; and C is the number of species common to both sites.

DISCUSSION

The surveyed site is rich in 43 woody species, with significant variability depending on the agro-ecological zones. The specific diversity per zone is 35, 21, and 19 species in Kantché, Gangara, and Tanout, respectively. These species are divided into 33 genera, the most represented being Acacia (4 species) and Boscia, Combretum, Lannea, Prosopis, and Ziziphus with 2 species each. There are 20 families, the most represented being Mimosaceae with nine species (21.42%), Caesalpiniaceae with seven species (16.67%), and Capparaceae with four species (9.52%). This specific diversity appears to be a function of agro-ecological zones, with relatively greater diversity in agricultural zones, followed by agro-pastoral and pastoral zones. The dominance of the genera Acacia and Boscia reflects the aridification of the area, as these genera are highly adapted to high temperatures and low rainfall. This logic is in line with the general trend of biodiversity variation in Niger, where soil, geomorphology, and cumulative rainfall are the main factors influencing species richness [4, 17]. Nearly 25% of species are common to all agro-ecological zones, including A. senegal, A. seyal, A. Raddiana, B. aegyptiaca, F. albida, L. pyrotechnica, M. crassifolia, P. reticulatum, S. birrea, and Z. mauritiana. These are species with a wide ecological distribution spectrum [26]. Better still, this result also shows that the north-south barrier is a determining factor in the ecology of woody species in Niger.

The most common species are G. senegalensis, H. thebaica, F. albida, B. aegyptiaca, A. senegalensis, and P. reticulatum. Comparing this with the work of [17,27], it suggests that thirty years is sufficient to initiate ecological succession, as these species were the most common and characteristic of the area in 1990.

Specifically, in the agricultural zone, the most common species are G. senegalensis, H. thebaica, F. albida, A. senegalensis, P. reticulatum. In the agropastoral zone, they are B. senegalensis, A. raddiana, F. albida, M. crassifolia, B. aegyptiaca, while in the pastoral zone, they are B. aegyptiaca, F. albida, A. nilotica, C. procera, B. senegalensis. Species diversity is low, and even lower in the agro-pastoral zone, with a correspondingly higher degree of evenness, showing that there is no phenomenon of species dominance in the zones. Comparison between the zones shows that species similarity is greater between the pastoral and agro-pastoral zones, but very low between the agro-pastoral and agricultural zones. This is an indicator of the effect of agricultural practices on biodiversity, as farming practices reduce the biodiversity of woody plants either by selecting species to be spared or by reducing the number of individuals to make way for crops. In terms of consistency, F. albida is the only woody species found throughout the study area, and 44.18% are rare species (C. micranthum, D. cinerea, L. hastata, C. sinensis, D. mespiliformis, L. microcarpa, A. digitata, B. salicifolia, C. tomentosa, C. italica, D. microcarpum, P. tomentosa, S. kunthianum, T. indica, V. doniana, Z. spina-christi). The proportion of rare species is 43% in Kantche, 24% in Gangara, and 20% in Tanout, showing a very high degree of irregularity in the area and indicating that species consistency is inversely proportional to the rainfall gradient. This can be explained by the fact that disturbance is the determining factor in this area and that agricultural areas are more disturbed. Even though, according to [28], the rarity of a species is linked to its location in the sense that the density of the species at the center of its geographical range is different from that at the periphery. Depending on the site, this rarity can be explained by adaptation. However, species rarity is not synonymous with lesser importance, because according to [29], in arid environments, the effects of richness become more important when seeking to maximize several ecosystem functions simultaneously, and rare species are important predictors of multifunctionality in terrestrial ecosystems. Hence, the importance of these species in the environment.

The density and structure of stands are parameters that justify the sparing treatment of these formations by humans and their socioeconomic activities [2].

The structure (height and diameter) of the stands is reversed in all agroecological zones of the Zinder region, but shows a significant imbalance in Gangara (agropastoral zone), with results falling within the same ranges as those obtained by [2,9,30], even though in the most irrigated areas, there are species with large diameters (greater than 60 cm). Regeneration is significant throughout the area, which is a strong point in the restoration of the population. These results corroborate those obtained by [7] Yaya et al. 2017 in more rainy areas and also those found by [3,31], even though the species are not the same. The discrepancy between the rejection logic and adult growth can be explained not only by the availability of soil water during the dry season, which is a factor limiting the growth of species in arid environments, but above all by anthropogenic activities such as RNA in the best-case scenario or the cutting of wood for various uses of woody species. [31], the regeneration potential increases with the rainfall gradient and decreases when the site is more anthropized. Some species, such as A. digitata, C. africana, D. mespiliformis, S. birrea, S. kunthianum, T. indica, V. doniana, and Z. spina-christi, do not produce offshoots, which is a major problem in the recruitment of adults for these species. Other species, such as Cordia sinensis and Faidherbia albida, have very low regeneration rates. On the one hand, Cordia sinensis is a species that is highly prized by the rural population but threatened with extinction, and on the other hand, Faidherbia albida is best managed through Assisted Natural Regeneration (ANR) in agricultural and agropastoral areas [32].

CONCLUSION

The surveyed site is rich in 43 woody species divided into 20 families and 33 genera, with significant variability depending on the agro-ecological zones. Thus, the specific diversity per zone is 35, 21, and 19 species in Kantché, Gangara, and Tanout, respectively. The Shannon diversity index is 4.04 bits, which is average in the three agro-ecological zones and varies slightly, with 3.63, 3.35, and 3.18 in Kantché, Gangara, and Tanout, respectively, with a Pielou equitability greater than 70% in all these sites. The most common species are G. senegalensis, H. thebaica, F. albida, B. aegyptiaca, A. senegalensis, and P. reticulatum. In terms of consistency, F. albida is the only woody species that is regular throughout the study area, and 44.18% are rare species (C. micranthum, D. cinerea, L. hastata, C. sinensis, D. mespiliformis, L. microcarpa, A. digitata, B. salicifolia, C. tomentosa, C. italica, D. microcarpum, P. tomentosa, S. kunthianum, T. indica, V. doniana, Z. spina-christi). The structure (height and diameter) of the stands is reversed in all agro-ecological zones in the Zinder region, but is particularly unbalanced in Gangara (agropastoral zone). Some species, such as A. digitata, C. africana, D. mespiliformis, S. birrea, S. kunthianum, T. indica, V. doniana, and Z. spina-christi, do not produce offshoots, which is a major problem in the recruitment of adults for these species. Other species, such as Cordia sinensis and Faidherbia albida have very low regeneration rates. On the one hand, Cordia sinensis is a species that is highly prized by the rural population but threatened with extinction, and on the other hand, Faidherbia albida

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