American Journal of Agriculture and Forestry
2024, Vol. 12, No. 2, pp. 51-60
https://doi.org/10.11648/j.ajaf.20241202.11

Research Article

Habitat and Population Structure of Five Multipurpose Species in Forest Management Site of Tiogo, Burkina Faso

Bernadette Nitiema[1, *], Satassa Hien[1], Lassina Traoré[1], Issaka Joseph Boussim[2], Kuilpoko Marie Laure Guissou[1]

[1]Department of Training and Research in Science and Technology, University Norbert Zongo, Koudougou, Burkina Faso
[2]Department of Plant Biology and Physiology, University Joseph Ki Zerbo, Ouagadougou, Burkina Faso

Abstract

Understanding the dynamics of multipurpose species in savanna ecosystems is essential for their sustainable conservation. This study aims to assess the population structure of five target species (*Tamarindus indica*, *Vitellaria paradoxa*, *Detarium microcarpum*, *Anogeissus leiocarpa*, and *Crossopteryx febrifuga*) in the forest management site of Tiogo. Floristic inventory was conducted on 100 plots of 1000 m^2. Non-Metric Multidimensional Analysis was carried out to characterized the target species' habitats. A total of 70 species distributed in 23 families and 55 genera were recorded. Four groups of overlapping plant communities were identified. Each group constitutes a habitat of target species with diverse ecological drivers. Weibull distribution showed an overall good population structure for *Vitellaria paradoxa*, *Detarium microcarpum* and *Crossopteryx febrifuga*. However, *Tamarindus indica* and *Anogeissus leiocarpa* showed bad regeneration potential with lack of recruitment in the smaller diameter size classes. It is therefore important to increase the monitoring in the forest management site. This work has provides valuable information for better management of target species, aiding in effective forest management of Tiogo, subject to anthropic pressures.

Keywords

Woody Species, Conservation, Forest Management Site, Habitat, Burkina Faso

1. Introduction

Protected areas, especially savanna ecosystems, are crucial for the well-being of local populations in sub-Saharan Africa [1]. These ecosystems play a key role in biodiversity conservation, and local communities' well-being. The forest management site of Tiogo, designated for forestry purposes, faces challenges in plant dynamics due to human activities, as revealed in recent studies [1, 2]. Despite this, there remains a significant gap in understanding the population structure and habitat dynamics of multipurpose woody species within this ecosystem. Therefore, it is necessary to understand about the species which are daily used by local communities to achieve their needs, to ensure sustainable management.

Indigenous species contribute to local livelihoods, providing essential resources such as fruit, fodder, firewood, timber, and traditional pharmaceutical products. However, they are increasingly threatened by climate change and unsustainable

*Corresponding author: nitiemabernadette@yahoo.fr (Bernadette Nitiema)

Received: 9 February 2024; **Accepted:** 28 February 2024; **Published:** 13 March 2024

Copyright: © The Author(s), 2024. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

human actions, including overgrazing and unsustainable agricultural practices [3, 4]. This poses a significant risk to the vegetation cover and plant diversity, particularly impacting multipurpose plant species.

While ecological studies have explored the population structure and dynamics of classified forests vegetation where human actions are forbidden [5, 6], none have specifically considered potential variations in the population structure of multipurpose woody species in the forest management of Tiogo. In this forest some activities are authorized regarding its purpose for forestry [7]. In fact, Gouwakinnou et al., [6] emphasized the positive effects of species stands and structure as a reference for the conservation state of protected areas. Therefore, gathering information on vegetation dynamics, particularly of culturally important species, is crucial for developing appropriate land management strategies.

This paper aims to present the current population structure of five target species (*Tamarindus indica* L, *Vitellaria paradoxa* C. F. Gaertn, *Detarium microcarpum* Guill. et Perr, *Anogeissus leiocarpa* (DC.) Guill. et Perr., and *Crossopteryx febrifuga* Benth) at the Tiogo forest management site. The study specifically identifies the habitat of each target species, characterizes the vegetation of the management units, and determines the demographic structure of the five target species. The results are essential for developing efficient management practices and ensuring the conservation of these valuable species.

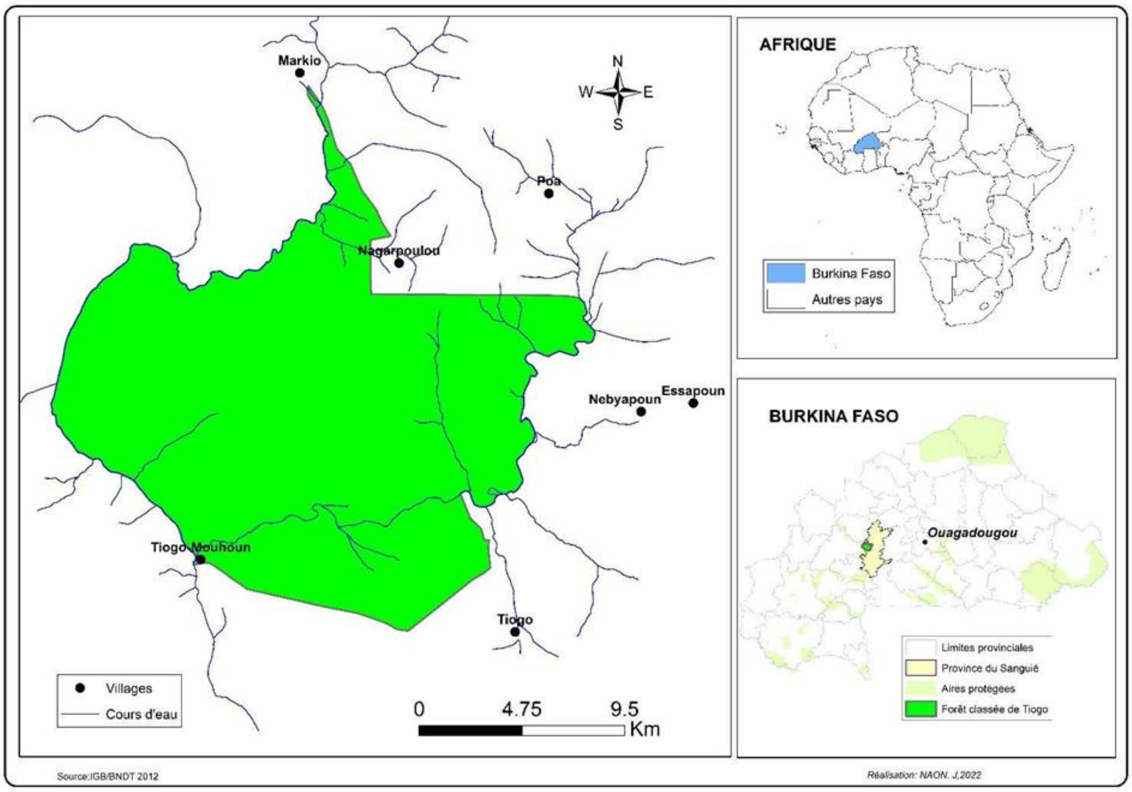

Figure 1. *Map of study area.*

2. Methodology

2.1. Study Site

The study was conducted at the Forest Management Site (CAF) of Tiogo. This forest is located in the province of Sanguie in the Centre-West region of Burkina Faso (12°10'0" N and 2°40'0" W) (Figure 1). Classified in 1940, CAF of Tiogo was 30,669 ha, characterized by flat relief with armored knolls. It is within the northern sudanian phytogeographic sector, experiencing an annual rainfall of 600-900 mm and temperatures of 20-30℃. Agriculture and livestock are the most socio-economic activities practiced [2].

As a category IV protected area, the CAF of Tiogo is divided into eleven (11) forest management units, each varying in size from 2,000 to 4,000 ha [7], managed by the state with local participation. Vegetation includes shrub savannas, tree savannas, shrub steppes, grassy savannas, and steppes, hosting dominant woody species like *Detarium microcarpum*, *Vitellaria paradoxa*, *Burkea Africana* Hook, *Anogeissus leiocarpa*, *Combretum micranthum* G. Don, and *Acacia macrostachya* Rchb. Ex DC. Herbaceous species include *Andropogon pseudapricus* Stapf, *Loudetia togoensis* (Pilg.) C. E. Hubb, *Pennisetum pedicellatum* Trin, and *Andropogon* *gayanus* Kunth. Ethnic groups Gourounsi (autochthones), Mossi, transhumant Peulh, and migrants (Dogon and Dioula). The majority of the local population consists of farmers [8].

2.2. Studied Species

2.2.1. *Anogeissus leiocarpa* (DC.) Guill. & Perr.

Anogeissus leiocarpa (Combretaceae) is a deciduous shrub or tree, ranging from 15 to 30 m in height, with alternate to almost opposite leaves. It produces yellow, bisexual, and apetalous inflorescences [9]. The globose, cone-shaped fruits are dark gray. It has great ecological plasticity to various soil types. *Anogeissus leiocarpa* serves as an indicator of fertile land and is utilized in traditional medicine for treating fever, diarrhea, and intestinal worms. Additionally, its wood is valuable for construction, art, and energy production [3].

2.2.2. *Detarium microcarpum* Guill. & Perr.

Detarium microcarpum (Fabaceae) is a deciduous tree reaching 25-30 m in height. Its paripinnate or imparipinnate leaves accompany creamy-white hermaphrodite flowers. The drupe fruit, typically with a single seed, is a crucial part of human diets and a significant income source for locals [9]. Its plant organs are employed in pharmacopoeia to treat various illnesses, including meningitis, dysentery, malaria, leprosy, and skin diseases. Additionally, it is widely used as firewood [10].

2.2.3. *Crossopteryx febrifuga* (Afzel. ex G. Don) Benth.

Crossopteryx febrifuga (Rubiaceae) is a versatile bush, shrub, or small tree, ranging from 1.5 to 5 meters in height. It features opposite leaves and terminal inflorescences with white or cream hermaphrodite flowers. The dry, dehiscent fruits have medicinal uses, treating fevers, diarrhea, malaria, chest pains, mental illnesses, and more. Leaves and fruit are also utilized in livestock feed, while wood is employed in traditional bed-making [11].

2.2.4. *Vitellaria Paradoxa* C. F. Gaertn.

Vitellaria paradoxa (Sapotaceae) is a deciduous tree, 10 to 15 m tall, native to sub-Saharan Africa [12]. Shea nuts from this tree are used to produce shea butter, a valuable cosmetic product. The leaves, bark, and roots are used in traditional medicine to treat skin diseases and other ailments. Shea butter production holds considerable economic importance for local communities, and the species is also culturally significant for ceremonies [13].

2.2.5. *Tamarindus Indica* L.

Tamarindus indica (Caesalpiniaceae) is an evergreen tree with yellowish flowers and pod-shaped, brown fruit containing numerous seeds. Drought-tolerant and widespread in the tropics, it is particularly found in Sudanian zone. Tamarind is a versatile fruit species, with various parts used by local populations to treat joint pain, body aches, back pain, urinary pain, childbirth difficulties, general fatigue, sexual impotence, ear and mouth lesions, blindness, headaches, stomach aches, persistent coughs, vomiting, fungal diseases, and dermatitis [14].

2.3. Sampling and Data Collection

Between July and August 2022, a floristic inventory of five population stands was conducted within the Forest Management Site of Tiogo. Due to the absence of distribution maps for the target species, systematic exploration of the study area was undertaken to identify accessible populations. The inventory covered four out of the eleven (11) accessible management units. A random sample scheme based on the presence of the target species was employed. This involved the establishment of 25 plots of 1000 m^2 (50 m x 20 m), spaced 100 m apart, resulting in a total of 100 plots distributed throughout the forest. In each plot, dendrometric parameters, specifically trunk diameter at 1.30m (DBH), were measured for all adult trees of the five target species with a diameter greater than 5 cm (DBH> 5 cm). The height of each individual was estimated visually. Unfortunately, due to security concerns in the forest, an assessment of the regeneration dynamics of the five species was not done within the allocated timeframe. Companion species present in each plot were recorded to facilitate the creation of a vegetation map, drawing on the methodology outlined by Bonou *et al*.. [5]. The geographical coordinates of each plot were accurately recorded using a Garmin 62S GPS device. Additional data on soil texture and vegetation type were also documented. To compile the floristic list, the flora of Burkina Faso served as reference, with updates from the online world flora (http://www.worldfloraonline.org).

2.4. Data Processing and Statistical Analysis

2.4.1. Characterization of Habitat

A Non-Metric Multidimensional Analysis (NMDS) was carried out to compare the floristic composition between the management units. It was completed by a similarity analysis (ANOSIM) between the plant communities. The presence–absence data of all inventoried species within the 100 plots of 25 m x 20 m were grouped in a binary matrix and submitted to multidimensional scaling for mapping the plots according to their species composition.

2.4.2. Dendrometric Parameters

The following dendrometric parameters were used: The tree-density of the stands (N), i.e. the average number of trees per plot expressed in trees/ha: $N = \frac{n}{s}$; n is the overall number of trees in the plot, and s the area (s = 0.1ha).

To analyze the spatial distribution of each target species, the index of Green (IG) was used [15]: $IG: \frac{(IB-1)}{n-1}$, and $IB = \frac{S2_N}{N}$; with, IB representing the Blackman Index (IB), N and S^2_N are respectively, the mean and variance of a target species tree density of the stands. The IG value may range from 0 (random distribution) to 1 (maximal aggregative distribution of trees).

The mean diameter of the trees (Dg, in cm), i.e. the diameter of the tree with the mean basal area in the stand: $Dg = \sqrt{\frac{1}{n}\sum_{i=1}^{n} di2}$; where n is the number of trees found on the plot, and di the diameter of the i-th tree in cm.

The basal area of the stand (G), i.e. the sum of the cross-sectional area at 1.3 m above the ground level of all trees on a plot, expressed in m^2/ha as follow:

$$G = \frac{\pi}{40000\,S}\sum_{i=1}^{n} di2;$$

The Lorey's mean height (HL, in meters), i.e. the average height of all trees found in the plot, weighted by their basal area [16], was computed as follows:

$H_L = \frac{\sum_{i=1}^{n} gihi}{\sum_{i=1}^{n} gi}$ $avec\ gi = \frac{\pi}{4} d2_i$; gi and hi are the basal area (m^2/ha) and the total height (m) of tree i.

2.4.3. Ecological Parameters

The species richness (S) is the number of species recorded in the whole stand.

The Shannon's Diversity Index (H, in bits) is computed using the following formula:

$H = -\sum_{i=1}^{s}\left(\frac{n_i}{n}\right)\log_2\left(\frac{n_i}{n}\right)$; ni is the number of individuals of species i, n is the overall number of trees inventoried in the plot.

The Pielou's evenness (Eq) measures the diversity degree of a stand compared with the possible maximum and is computed as: $E_q = \frac{H}{H_{max}}$ $avec\ H_{max} = \log_2 S$;

To establish the stem diameter structure of *A. africana* stands, all individuals of the species were grouped into diameter classes of 10 cm in order to obtain enough diameter classes (at least 10). This allows the adjustment of Weibull theoretical distribution to the observed shape. The tree densities were assessed for diameter classes. As far as the height structure is concerned, classes with 2m amplitude were considered. The observed different diameter structures were adjusted to the 3-parameter-Weibull distribution because of its flexibility [17], whose density function, f is expressed for a tree-diameter x as follows:

$$f(x) = \frac{c}{b}\left(\frac{x-a}{b}\right)^{c-1} \exp\left[-\left(\frac{x-a}{b}\right)^{c}\right];$$

where x = tree diameter; a = 5 cm for the diameter structure and 2 m for the height structure; b = scale parameter linked to the central value of diameters and heights; c = shape parameter of the structure. All statistical analyses were performed using R software version 4.2.1 [18].

3. Results

3.1. The Diversity of the Forest Management Site of Tiogo

The results of the inventory revealed a total species richness of 70, distributed among 55 genera and 23 families. This species richness varied across different management units, with U1 and U2 recording the highest diversity follow by U3 and U4 (Table 1).

The assessment of diversity indices, particularly the Shannon diversity index and the maximum diversity index (Hmax > 1), indicated a robust diversity of woody vegetation within each management unit. Notably, the absence of dominance by any single species in the plant formations of each unit was confirmed by high Pielou index values (Eq > 0.6).

Table 1. *Ecological parameters of the forest management site of Tiogo.*

Parameters	**U1**	**U2**	**U3**	**U4**	**Global**
Families	6	6	5	5	23
Genera	19	17	12	13	55
Specific richness (S)	57	57	46	49	70
Shannon diversity (H en bits)	3.35	3.24	2.86	3.07	3.23
Maximum diversity (Hmax)	5.83	5.83	5.52	5.61	3.93
Pielou equitability (Eq)	0.82	0.80	0.74	0.78	0.82

U1: habitat of *Detarium microcarpum* and *Crossopteryx febrifuga*; U2: habitat of *Vitellaria paradoxa*; U3: habitat of *Tamarindus indica* and *Anogeissus leiocarpa*; U4: habitat of *Anogeissus leiocarpa*

The non-metric multidimensional scaling analysis conducted on the identified species within various management units revealed the presence of four distinct yet overlapping groups of plant communities, as depicted in Figure 2 (ANOSIM; R = 0.36; p = 0.001). To discriminate between different habitats for the five target species, the probability of presence value was utilized. Figure 2 provides insight into a gradient of structural complexity associated with the species richness of the management units. Specifically, U1 stands out with its characterization by *Detarium microcarpum* and *Crossopteryx febrifuga*, accompanied by a diverse woody flora comprising 21 species (Table 2). The habitat of *Vitellaria paradoxa*, found characterized by U2, recorded a total of 17 species (Table 2). *Anogeissus leiocarpa*, identified as a ubiquitous species, was observed in at least three units (U2, U3, and U4). Within the habitat of *Tamarindus indica* and *Anogeissus leiocarpa* in unit U4, a total of 14 species were recorded (Table 2).

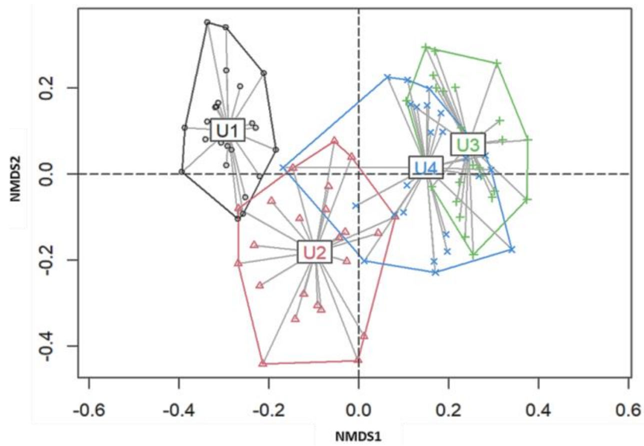

Figure 2. *Habitat characterization of the five target species using non-metric multidimensional in four groups of habitat.*

Table 2. *Habitat characteristics of five target species and companion species in the forest management site of Tiogo.*

Habitat	Target species	Companion species	Companion species in the habitat
Unit 1	*D. microcarpum, C. febrifuga*	21	*Terminalia avicennioides* Guill. & Perr., *Acacia dudgeoni* Holland, *Acacia seyal* Delile, *Albizia chevalieri* Harms, *Allophylus africanus* P. Beauv., *Annona senegalensis* Pers., *Anogeissus leiocarpus* (DC.) Guill. & Perr., *Baissea multiflora* A. DC., *Balanites aegyptiaca* (L.) Delile, *Bridelia ferruginea* Benth., *Capparis corymbosa* Lam., *Combretum fragans* F. Hoffm., *Combretum glutinosum* Perr. ex DC., *Combretum micranthum* G. Don, *Combretum nigricans* Leprieur ex Guill. & Perr., *Dichrostachys cinerea* (L.) Wight & Arn., *Diospyros mespiliformis* Hochst. ex A. DC., *Feretia apodanthera* Delile, *Flueggea virosa* (Roxb. ex Willd.) Royle, *Gardenia erubescens* Stapf
Unit 2	*V. paradoxa,*	17	*Acacia dudgeoni* Holland, *Anogeissus leiocarpus* (DC.) Guill. & Perr., *Bombax costatum* Pellegr. & Vuillet, *Entada africana* Guill. & Perr., *Feretia apodanthera* Delile, *Flueggea virosa* (Roxb. ex Willd.) Royle, *Holarrhena floribunda* T. Durand & Schinz, *Gardenia erubescens* Stapf & Hutch, *Gardenia sokotensis* Hutch., *Grewia flavescens* Juss., *Grewia mollis* Juss., *Piliostigma reticulatum* (DC.) Hochst., *Senegalia macrostachya* (Rchb. ex DC.) Kyal. & Boatwr, *Senegalia pennata* subsp. kerrii (I. C. Nielsen) Maslin, *Sterculia setigera* Delile, *Vitex doniana* Sweet.
Unit 3	*T. indica* et *A. leiocarpa*	18	*Adansonia digitata* L., *Terminalia avicennioides* Guill. & Perr., *Aganope stuhlmannii* (Taub.) Adema, *Allophylus africanus* P. Beauv., *Anogeissus leiocarpus* (DC.) Guill. & Perr., *Bombax costatum* Pellegr. & Vuillet, *Combretum micranthum* G. Don, *Detarium microcarpum* Guill. & Perr., *Entada africana* Guill. & Perr., *Guiera senegalensis* J. F. Gmel., *Lannea acida* A. Rich., *Ozoroa insignis* Delile, *Parkia biglobosa* (Jacq.) R. Br. ex G. Don, *Pteleopsis suberosa* Engl. & Diels, *Pterocarpus erinaceus* Poir., *Stereospermum kunthianum* Cham., *Strychnos spinosa* Lam., *Vitex doniana* Sweet, *Mitragyna inermis* (Willd.) Kuntze
Unit 4	*Anogeissus leiocarpa* (DC.) Guill. & Perr.,	14	*Bombax costatum* Pellegr. & Vuillet, *Diospyros mespiliformis* Hochst. ex A. DC., *Entada africana* Guill. & Perr., *Feretia apodanthera* Delile, *Flueggea virosa* (Roxb. ex Willd.) Royle, *Gardenia erubescens* Stapf & Hutch, *Gardenia sokotensis* Hutch., *Grewia flavescens* Juss., *Grewia mollis* Juss., *Mitragyna inermis* (Willd.) Kuntze, *Opilia celtidifolia* Endl. ex Walp., *Piliostigma reticulatum* (DC.) Hochst., *Piliostigma thonningii* (Schumach.) Milne-Redh., *Senegalia macrostachya* (Rchb. ex DC.) Kyal. & Boatwr, *Vitex doniana* Sweet

3.2. Structural and Dynamic Analysis of the Five Target Woody Species

The dentrometric characteristics of the five species are summarized in Table 3. *Vitellaria paradoxa* mean density was 79.1 stems/ha, with a mean diameter of 13.55 cm, a basal area of 1.97 m^2/ha, height of 7.88 m, and a green index of 0.08. *Tamarindus indica* exhibited density of 25.51 plants/ha, with an average diameter and basal area of 25.42 cm and 6.85 m^2/ha, respectively. The average Lorey height was 9.12 m, and the green index was 0.07. *Detarium microcarpum*, mean density, mean diameter, and Lorey height were recorded at 102.6 trees/ha, 6.67 cm, and 6.00 m, respectively. The basal area was 2.61 m^2/ha, with a green index of 0.08. *Anogeissus leiocarpa* presented an overall density of 146.76 feet/ha, a diameter of 13.02 cm, a Lorey height of 9.08 m, a basal area of 13.33 m^2/ha, and a green index of 0.08. As for *Crossopteryx febrifuga*, the average density stood at 41.42 ft/ha, with an average diameter of 7.31 cm, a Lorey height of 4.67 m, a basal area of 3.49 m^2/ha, and a green index of 0.06.

Table 3. *Dendrometric characteristics of five target multipurpose species.*

Species	Parameters	Unit1	Unit2	Unit3	Unit4	Global	P-value
Vitellaria paradoxa	Density (N, trees/ha)	23.6±65.69	127.6±143.07	49.2±45.17	56.0±50.82	79.1±91.88	0.001***
	Mean diameter (Dg, cm)	11.48±8.53	16.98±6.94	15.70±9.15	12.06±9.01	13.55±8.56	0.029*
	Lorey Heigh (HL, m)	6.48±1.72	8.60±1.55	7.85±3.42	8.50±1.87	7.88±2.47	0.001*
	Basal area (G, m^2/ha)	1.56±1.61	2.09±1.35	2.53±1.89	1.72±1.77	1.97±2.97	0.098
	Green Index (IG)	0.08	0.08	0.07	0.08	0.08	0,049ns
Tamarindus indica	Density (N, trees/ha)	28.92±22.25	21.83±15.81	25.34±14.08	25.3±13.22	25.51±15.85	0.72ns
	Mean diameter (Dg, cm)	27.48±44.64	15.36±27.06	25.84±33.15	33.00±38.95	25.42±15.7	0.78ns
	Lorey Heigh (HL, m)	9.00±51	8.9±3.80	9.03±3.56	9.45±3.85	9.12±3.83	0.98ns
	Basal area (G, m^2/ha)	7.97±1.27	4.73±0.69	7.51±0.52	7.55±0.52	6.85±0.94	0.65ns
	Green Index (IG)	0.06	0.07	0.06	0.07	0.07	0.38ns
Detarium micro-carpum	Density (N, trees/ha)	103.125±72.66	88.66±71.10	76.92±70.44	129.5±121.67	102.65±93.01	0.025**
	Mean diameter (Dg, cm)	6.67±5.92	5.19±5.05	7.14±7.59	7.69±4.49	6.67±5.94	0.005**
	Lorey Heigh (HL, m)	5.51±1.02	2.59±2.21	6.07±1.52	6.49±2.27	6.00±1.86	0.01**
	Basal area (G, m^2/ha)	1.53±0.07	1.01±0.04	2.08±1.01	1.63±0.5	2.61±0.53	0.45ns
	Green Index (IG)	0.08	0.07	0.07	0.08	0.08	0,57ns
Anogeissus leiocarpa	Density (N, trees/ha)	135.71±100.62	166.4±108.81	125.21±50.79	153.47±117.14	145.76±97.71	0.0068**
	Mean diameter (Dg, cm)	13.04±4.49	12.07±3.45	13.49±3.80	12.89±3.97	13.02±3.02	0.64ns
	Lorey Heigh (HL, m)	8.96±1.59	9.45±1.35	9.87±1.65	10.02±1.68	9.58±1.60	0.011*
	Basal area (G, m^2/ha)	3.12±0.09	3.39±0.07	3.54±0.84	3.20±0.92	10.33±0.74	0.79ns
	Green Index (IG)	0.08	0.09	0.08	0.09	0.08	0,78ns
Crossopter-yx febrifuga	Density (N, trees/ha)	45.38±36.65	40±26.38	43.88±21.99	36.36±25.00	41.42±26.88	0.007**
	Mean diameter (Dg, cm)	9.81±5.54	6.71±2.37	6.71±1.63	6.84±2.10	7.31±3.20	0.004**
	Lorey Heigh (HL, m)	4.66±0.80	4.39±0.65	4.54±0.94	5.94±0.43	4.67±0.97	0.0027**
	Basal area (G, m^2/ha)	1.27±0.10	1.11±0.03	0.67±0.02	0.43±0.02	3.49±0.05	0.003**
	Green Index (IG)	0.06	0.06	0.073	0.05	0.06	0,57ns

Code of significance: *** significant at 0.001; ** significant at 0.01, ns non-significant, p-value set at 0.05

The diameter structures of the five species were ajusted to Weibull distribution, and the results of the log-linear analysis indicated a broad consistency between the observed distributions and the respective Weibull distributions (P > 0.05). The shape parameter (c) values varied between 0.63 and 2.71 for all five species, providing insights into the structural characteristics of their populations (Figure 3). For *Crossopteryx febrifuga* and *Detarium microcarpum*, the diameter class structure revealed a predominance of individuals with smaller diameters (5-10 cm), reflected in c values of 0.63 and 1.29, respectively. *Anogeissus leiocarpa* and *Vitellaria paradoxa*, the predominance small class diameter was less pronounced, and for *Tamerindus indica*, it was practically non-existent. However, the c values of 2.44 for *Anogeissus leiocarpa* and 2.70 for *Tamarindus indica* indicated a positive asymmetric distribution, characteristic of monospecific stands with a relative abundance of young, small-diameter individuals.

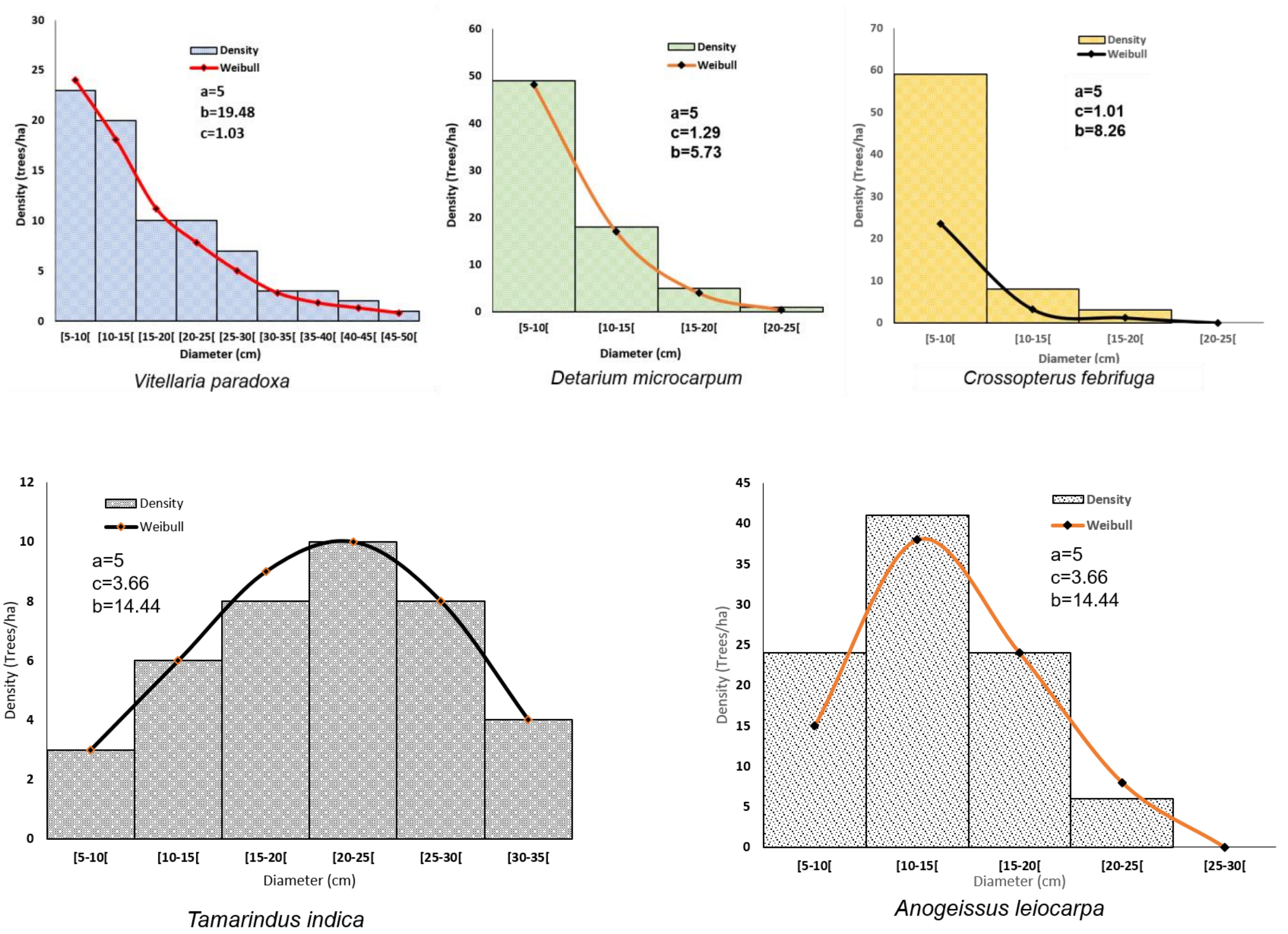

Figure 3. *Diameter size class adjusted to Weibull distribution of five target species.*

4. Discussion

4.1. Diversity and Specific Richness of the Forest Management Site of Tiogo

The specific richness of the region encompasses 70 woody species, with variations ranging from 46 to 57 across different management units. A slight difference in floristic composition was observed among the various management units, accounting for approximately 76% of the total specific richness of the forest reported by Sawadogo, [19] findings. This variance may be attributed to differences in substrate conditions influencing these vegetation groups. The distribution of woody species is known to be influenced by climatic and edaphic factors [20]. As noted by Ganame *et al.* [21], the composition and structure of woody vegetation exhibit considerable variability from one locality to another, influenced by environmental factors and anthropogenic disturbances. Nonetheless, this study has successfully characterized the stand structure of the main types of management units hosting target species, namely *Detarium microcarpum, Tamarindus indica, Vitellaria paradoxa, Anogeissus leiocapa, and Crossopteryx febrifuga*. In fact, *Anogeissus leiocarpa* emerges as the most frequently occurring species overall, marking the landscape with its strong presence in different management units. The calculated Shannon and Pielou diversity indices indicate high diversity and heterogeneity across the various management units. These findings contribute to a comprehensive understanding of the ecological dynamics and specific richness within the forest, emphasizing the importance of considering different management units for biodiversity conservation and sustainable forest management.

4.2. Characterization of Woody Vegetation in the Habitats of the Five Target Species

The lack of distinct identification for each type of management unit can be explained by a relative homogeneity observed in the floristic composition within each unit. The high specific diversity in management units U1 and U2 reveals the equiprobability of different species and underscores the significance of these habitat types in conserving biological diversity within the forest management site. Notably, these two sampling units were also employed for assessing carbon stock potential at the onset of forest management, potentially justifying their significant species richness. Moreover, the vertical organization of vegetation in this site resembles shrub savannah and tree savannah for U1 and U2, respectively. In tropical countries, likes Burkina Faso, the importance of forest management sites in preserving ancient forest relics and biodiversity is well-established. Beyond the daily harvesting of ecosystem services, this site contributes to biological diversity conservation us reported by Vizzarri *et al.* [22]. Within the considered plant formations, none of the target species is recognized as ecologically weak, implying that they contribute moderately to the ecological value of their respective habitats. Similar results have been reported for other tropical woody resources such as *Afraegle paniculata*, *Diospyros mespiliformis*, *Kigelia africana*, and *Vitex doniana* by Agbani *et al.* [20]. Each of these species holds socio-cultural significance among local populations and has been identified as providers of ecosystem services, emphasizing the importance of their preservation within the Forest Management Site of Tiogo.

4.3. Dendrometric Characteristics and Abundance of Populations of the Five Target Species

The populations of the five studied species exhibit varying densities of adult individuals (with stem diameters greater than or equal to 5 cm) across all plots, with no statistically significant differences at the 5% significance level. The study results indicate that, regardless of the target species, the density of adult individuals is noteworthy compared to previous studies [4] and other target species under similar ecological conditions and protection status. These findings suggest that the populations of the considered species are undergoing normal renewal, albeit with a limited capacity for recovery and survival. Regarding plants found in multiple habitats, the recruitment mode of seedlings varies. Overall, the analysis results show that the density of target species varies along a gradient of management units. Certain species are nearly absent in some management units but highly present in others, potentially explained by soil type and/or ecological conditions of the environment. However, to better understand the population dynamics of each species, a study of regeneration is essential to assess not only the resilience potential but also the recruitment potential. In general, there is a variation in dendrometric parameters such as basal area, density, and mean diameter among species and management units. This variation could be attributed to precipitation factors, the geomorphology of the management units, and/or linked to the biology and physiology of each species. Similar results have been reported for other species in previous studies by Houéto *et al.* [23].

4.4. Horizontal Structure and Dynamics of the Five Target Woody Species of the Tiogo

The diameter structures of *Vitellaria paradoxa*, *Detarium microcarpum*, *Crossopteryx febrifuga*, and *Anogeissus leiocarpa* exhibit a progressive decrease in the number of individuals as the diameter class increases, with a prevalence in the diameter class of 10-15 cm. This pattern, resembling an "inverted J," indicates a positive dynamic trend and suggests that the stands of these species are generally in good condition. However, the Population Index (PI) values for *Anogeissus leiocarpa* contradict these results in most units, indicating some challenges in the stands of this species. The abundance of young trees suggests potential repopulation and resilience to anthropogenic pressures, but the Weibull distribution's shape parameter ($c > 1$) for *Detarium microcarpum*, *Anogeissus leiocarpa*, and *Vitellaria paradoxa* reveals disturbed dynamics, likely due to anthropogenic actions such as wood cutting, grazing, and bushfires. *Vitellaria paradoxa* shows greater population stability, possibly due to its resilience to anthropogenic factors. However, the "bell-shaped" appearance of *Tamarindus indica* signals a disturbed and unbalanced stand, consistent with findings that its population is unstable despite being categorized as a "spared species" in the Tiogo CAF. Overall, the positive asymmetric distribution indicated monospecific stands with a relative abundance of young, small-diameter individuals. These structural patterns reflect the regeneration potential and age structure of each species within the forest ecosystem.

5. Conclusion

In conclusion, the study of the Forest Management Site of Tiogo revealed a rich diversity of 70 woody species distributed across various management units. Four different habitats, characterized by shrubs, plant savanna, and mixed savanna were determined for the five species, indicating specific vegetation characteristics of each habitat with ecological heterogeneity. However, *Anogeissus leiocarpa* is present in all of the habitats identified. The dendrometric analysis provides valuable insights into the structural attributes of the five target species, aiding in effective forest management. Understanding of population of regeneration potential of each species is important to developing good strategies of the conservation of these target species.

Abbreviations

CAF: Forest management site
DBH: Diameter at breast Height

Acknowledgments

The authors would like to thank John Bationo (guide, interpreter) for his help and guidance during the forest inventory. We would also like to thank the laboratory's PhD students for their support in processing and analyzing the data. No external funding was provided for this work.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Traoré, L., Sop, T. K, Dayamba, S. D, Traoré, S., Hahn, K., Thiombiano, A. Do protected areas really work to conserve species? A case study of three vulnerable woody species in the Sudanian zone of Burkina Faso. *Environment Development Sustainability*. 2013, 15(3), 663-686. https://doi.org/10.1007/s10668-012-9399-8

[2] Tankoano, B., Sanon, Z., Hien, M., Dibi N. H., Yameogo, J. T., Somda, I. Pression anthropique et dynamique végétale dans la Forêt Classée de Tiogo au Burkina Faso: apport de la Télédétection. *Tropicultura*. 2016. 34(2).

[3] Lykke, A. M, Kristensen, M. K, Ganaba, S. Valuation of local use and dynamics of 56 woody species in the Sahel. *Biodivesity Conservation*. 2004, 13(10), 1961-1990.

[4] Sop, T. K, Oldeland, J., Schmiedel, U., Ouedraogo, I. Thiombiano, A. Population structure of three woody species in four ethnic domains of the sub-sahel of Burkina Faso. *Land Degradation & Development*. 2011, 22(6), 519-529. https://doi.org/10.1002/ldr.1026

[5] Bonou, W., Kakaï R. G., Assogbadjo, A. E., Fonton, H. N., Sinsin, B. Characterisation of *Afzelia africana* Sm. habitat in the Lama forest reserve of Benin. *Forest Ecological Management*. 2009, 258(7), 1084-1092.

[6] Gouwakinnou, G. N., Biaou S., Vodouhe, F. G., Tovihessi, M. S., Awessou, B. K., Biaou, H. S. Local perceptions and factors determining ecosystem services identification around two forest reserves in Northern Benin. *J. Ethnobioogy & Ethnomedicine*. 2019. 15(1), 1-12, 2019.

[7] Yelkouni, M. La gestion communautaire: une alternative pour la forêt de Tiogo au Burkina Faso, *Rewe d'Économie Régionale Urbaine*. 2005, 4, 557-578.

[8] Ouédraogo, K., Dimobe, K., Zerbo, I., Etongo, D., Zare, A., Thiombiano, A. Traditional knowledge and cultural importance of *Gardenia erubescens* Stapf & Hutch. in Sudanian savanna of Burkina Faso. 2019. *Journal of Ethnobiology & Ethnomedicine*, 15(1), p. 28. https://doi.org/10.1186/s13002-019-0305-4

[9] Arbonnier, M. Arbres arbustes et lianes des zones sèches d'Afrique de l'Ouest, *Arbres Arbustes Lianes Zones Sèches Afrique de Ouest*. 2009. p. 1-100.

[10] Hassanin, H. A., Koko, M., Abdalla, M., Mu, W., Jiang, B. *Detarium microcarpum*: A novel source of nutrition and medicine: A review. *Food Chemical*. 2019. 274. p. 900-906,

[11] Sarr, O., Bakhoum, A., Diatta, S. Akpo, L. E. L'arbre en milieu soudano-sahélien dans le bassin arachidier (Centre-Sénégal). *Journal of Applied Biosciences*. 2013. 61, 4515-4529.

[12] Glèlè Kakaï R., Akpona, T. J. D, Assogbadjo, A. E, Gaoué, O. G, Chakeredza, S., Gnangle, P. C, Sinsin, B. Ecological adaptation of the shea butter tree (*Vitellaria paradoxa* C. F. Gaertn.) along climatic gradient in Bénin, West Africa: Ecological adaptation of the shea butter tree. *Afrrican Journal Ecology*. 2011. 49, 4, 440-449. https://doi.org/10.1111/j.1365-2028.2011.01279.x

[13] Savadogo, S., Traore, L., Thiombiano, A. Groupes ethniques et espèces végétales à hautes valeurs socio-culturelles au Burkina Faso. *International journal in Tropical Ecology and Geography*. 2018. 42(1), 207-226.

[14] Fandohan, B., Assogbadjo, A. E., Glèlè Kakaï R. L., Sinsin, B. Effectiveness of a protected areas network in the conservation of *Tamarindus indica* (Leguminosea-Caesalpinioideae) in Benin: Tamarind conservation in protected areas. *African Journal Ecology*. 2011. 49(1), 40-50. https://doi.org/10.1111/j.1365-2028.2010.01228.x

[15] Jayaraman, K. A statistical manual for forestry research. FORSPA-FAO Publication 2001. p. 239.

[16] Philip, M. S. Measuring trees and forests. CAB international, 1994.

[17] Glèlè-Kakaï R., Salako V. K, Lykke, A. M. Techniques d'échantillonnage en étude de la végétation. *Annales des Sciences Agronomiques*. 2016. p. 1-13.

[18] R Core Team. A language and environment for statistical computing. R Foundation for Statistical Computing. 2022. https://www.R-project.org/

[19] Sawadogo, L. Docteur d'Etat en Sciences Naturelles, Université Joseph Ki-Zerbo. Burkina Faso. 2009. p. 181.

[20] Agbani, P. O., Amagnide, A., Goussanou, C., Azihou, F., Sinsin, B. Structure des peuplements ligneux des formations végétales de la forêt sacrée de Nassou en zone soudanienne du Bénin. *International Journal of Biological and Chemical Sciences*. 2018. 12(6), 2519-2534.

[21] Ganamé, M., Bayen, P., I. Ouédraogo, I., Dimobe, K., A. Thiombiano, A. Woody species composition, diversity and vegetation structure of two protected areas along a climatic gradient in Burkina Faso (West Africa), *Folia Geobotique.* 2019. 54(3-4), 163-175. https://doi.org/10.1007/s12224-019-09340-9

[22] Vizzarri, M., Tognetti, R., Marchetti, M. Forest Ecosystem Services: Issues and Challenges for Biodiversity, Conservation, and Management in Italy. *Forests*. 2015. 6. https://doi.org/10.3390/f6061810

[23] Houéto G., Fandohan, B., Ouédraogo, A., Ago, E. E, Salako, V. K, Assogbadjo, A. E, Sinsin, B. Floristic and dendrometric analysis of woodlands in the Sudano-Guinean zone: a case study of Belléfoungou forest reserve in Benin. *Acta Botanic Gallica*. 2012. 159(4), 387-394. https://doi.org/10.1080/12538078.2012.735124