Published by Avanti Publishers

Global Journal of Agricultural Innovation, Research & Development

ISSN (online): 2409-9813

Influence of Land Tenure on Agroforestry Parkland Phyto-Diversity and Stand Structure in Sudanian Zone of Burkina Faso, West Africa

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ARTICLE INFO

Article Type: Research Article

Keywords:
Farmland
Biodiversity
Natural regeneration
Semi-arid ecosystems
Plant richness and diversity

Timeline:
Received: December 16, 2021
Accepted: February 09, 2022
Published: March 11, 2022

Citation: Sanou L, Koala J, Ouédraogo S, Ouattara B. Influence of Land Tenure on Agroforestry Parkland Phytodiversity and Stand Structure in Sudanian Zone of Burkina Faso, West Africa. Glob J Agric Innov Res Dev. 2022; 9: 20-34.

DOI: https://doi.org/10.15377/2409-9813.2022.09.3

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ABSTRACT

Savanna Zone of Burkina Faso is characterized by the increasing population growth due to human migration from the north and central regions of the country for cultivating agricultural land and pastures. This situation induced land-use changes, and social reorganization has led to new approaches to natural resources management. Tenure issues in natural resources management limit the adoption of agroforestry systems and effective land use scale. This paper describes the species composition, structure, and diversity of woody species on agroforestry parklands at Tiogo under two types of land tenures. Ecological and structural characteristics of vegetation patches were computed to characterize the species composition. A variety of diversity measures were calculated to determine the heterogeneity for each type of land tenure. A total of 49 woody species belonging to 19 families and 38 genera were identified, of which 44 and 48 species were recorded in non-landowners' farms and landowners' farms, respectively. Leguminosae, Combretaceae and Anacardiaceae were the most abundant families. The dominant species in agroforestry parklands were *Vitellaria paradoxa, Parkia biglobosa, Lannea microcarpa, Piliostigma reticulatum* and *Piliostigma thonningii*. Analyses of variance of the entire woody vegetation of agroforestry parklands revealed no significant differences in terms of all computed indexes but showed that the landowners' farms were the most diverse than non-landowners farms. The density of stems ≥5 cm dbh and the basal area were higher in landowner's farms than in non-landowners farms. In both types of farms, the size class distributions of the vegetation produced a reverse J-shaped curve, supporting that agroforestry parkland in Tiogo is dominated by young individuals. The spatial distribution of the seedling was mainly clumped, reflecting the dominance of clonal propagation. Security of land and tree tenure is a necessary condition for any land-based investment (planting and protection of preferred species and soil amendment). The challenge to maintain parklands' tree biodiversity in "good" condition also needs to consider the flexibility of land tenure and equitability sharing of the benefits from trees.

1. Introduction

Land tenure is defined as the legally or customarily relationship among people, as individuals or groups, with respect to land. It is an integral part of social, political, and economic structures regulated by the rules invented by the societies (www.fao.org). Rules of tenure define how property rights to land are allocated within societies [1]. These rights can also vary over time or space, which have implications on land management, individual/public development initiatives, agricultural production, and food security, especially among agro-based communities [2]. In Sub-Saharan Africa, particularly in Burkina Faso, the farmland is characterized by the cohabitation of trees and annual crops. The integration of trees into farming systems is a traditional land use developed by subsistence farmers to deliver multiple socioeconomic and environmental outcomes [3]. Sub -Saharan farmers' association of trees and annual crops has created the concept of parkland systems [4]. The parkland systems are a recognized agroforestry approach that helps increase productivity and sustain food security while also preserving the biophysical environment [5]. Trees on farmlands can serve as a 'saving account', providing for the owners a livelihood safety net, including a buffer against the shocks experienced during periods of food scarcity [6].

Thus, the rights to land and tree tenure are applied to regulate their uses by the non-landowners, especially migrants that are left in the case of Burkina Faso, the north and central regions, characterized by high land degradation and decrease of precipitation, to humid zones (southwest, west, and west-center of the country) in search for agricultural lands and pastures zone [7, 8]. In the latter zones, the immigrants do not have the same rights as the natives to use the land as in their origin villages. Also, indigenous farmers often have more rights to the land they cultivate than immigrants, especially regarding trees [7].

The immigrants must respect the rules to use natural resources in the host land. The natives define how access is granted to rights to use, control, and transfer land, as well as associated responsibilities and restraints. Usually, it is the chief of land or the landowners who determine the terms of use of lands (who can use what resources for how long, and under what conditions. Thus, the migrants acquire land by loan, gift, and rarely purchase. In these borrowed lands, the owner may reserve the right to exploit tree products, and in many cases, the usufructuary is prohibited from planting trees. Because, in many societies in Africa and Asia, trees are used as a mark of ownership rights [1]. Tenure issues in natural resources management limit the adoption of agroforestry systems and effective land use scale. The non-landowners have no right to plant trees on the farmland that they exploited for the annual crop production. Also, most of them do not benefit from the economic and other advantages (fruits, wood, fodder, pharmacopeia products) related to trees in the loaned farmlands. Paradoxically, it is rare to observe the landowners planting trees in the loaned farmlands while the usufructuaries do not have the right to plant. Thus, the residual trees that will exist in these farmlands are the old trees whose capacities to produce seeds for natural regeneration are very low. This situation may be a veritable obstacle in the adoption of agroforestry and the management of tree vegetation on farmland. It could affect the population structure of tree species and diversity on the agroforestry parklands.

This present study examined the influence of land and tree tenure on the agro-phytodiversity of parklands and stands structure. It seeks to point one hand, the importance of maintaining biodiversity and, on the other hand, the contribution of agroforestry parklands in the conservation and maintaining of agro-biodiversity. Based on the findings of this study, suggestions are presented to encourage flexibility of land tenure and tree security and to stimulate the promotion of agroforestry for sustainable livelihood and maintenance of biodiversity.

2. Materials and Methods

2.1. Description of the Study Site

The study was carried out in the four riparian villages near the Tiogo State Forest (12.13'N, 2.42'W), Burkina Faso (Figure **1**). The choice of the village was based on the presence of agricultural land use which incorporates trees with crop production. We also took into account the proximity of the village to the Tiogo Forest, where various projects dealing with sustainable forest management have been undertaken along with the promotion of buffer zones agroforestry as a conservation strategy because of the provision of alternative sources of forest products [5]. We assumed that the closer a village is to the forest, the greater the interaction between local people and the staff of the State forest, which has the potential of influencing the decision of the local people in adopting agroforestry [9]. The Tiogo State forest was designated by the French colonial administration in 1940 and covers an area of approximately 30,000 hectares. It is located along the only permanent river in the country (Mouhoun, formerly known as The Black Volta). Phytogeographically, it is situated in the Sudanian regional center of endemism in the transition from the north to the south Sudanian zone [10]. The Sudanian savanna is an area stretching across the African continent from Senegal in the west to the Ethiopian highlands in the east, which is characterized by a six to seven month dry season and a mean annual rainfall of between 700 and 1200 mm [11].

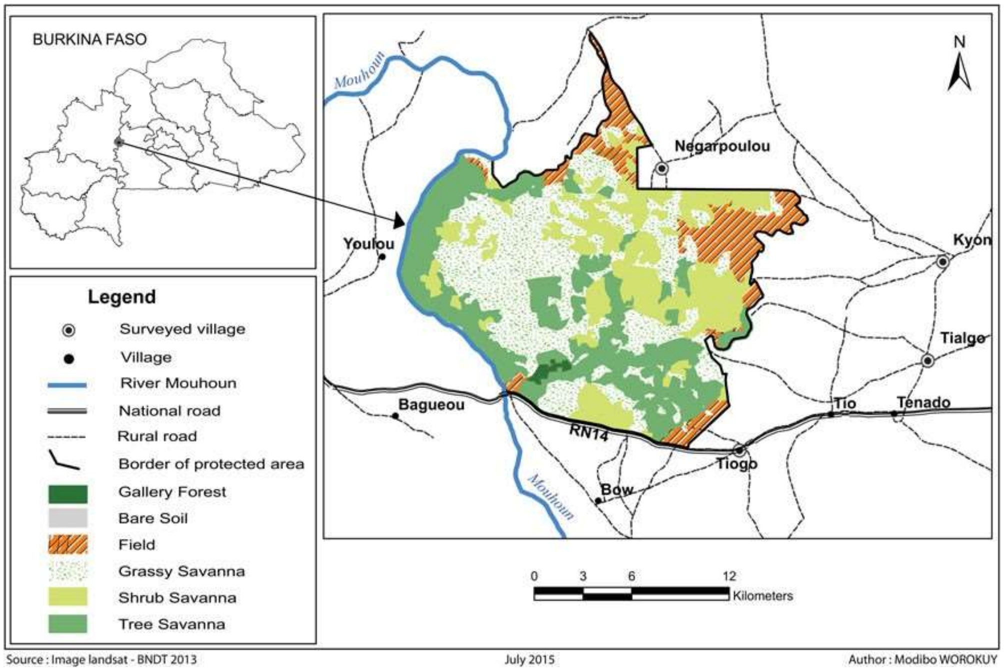

Figure 1: Location of study site.

The total population of the studied villages is approximately 45,506 [12]. The main livelihood activities of the residents include extensive livestock grazing and harvesting of various non-timber forest products such as fuelwood, thatching materials, poles for construction, and edible and medicinal plants. The main crops grown are *Sorghum bicolor*, *Panicum miliaceum*, *Zea mays*, *Arachis hypogaea*, *Vigna unguiculata,* and *Gossypium hirsutum*. The people mainly engage in subsistence agriculture which is entirely rainfall-fed [8]. On the farms, the farmers retain some trees when clearing land for agriculture. Commonly found tree species include *Adansonia digitata*, *Bombax costatum*, *Detarium microcarpum*, *Eucalyptus camaldulensis*, *Gmelina arborea, Lannea microcarpum*, *Mangifera indica*, *Moringa oleifera*, *Parkia biglobosa*, *Sclerocarya birrea*, *Tamarindus indica*, and *Vitellaria paradoxa* [5].

2.2. Data Collection

2.2.1. Socioeconomic Survey and Floristic Inventories

The findings discussed in this article are a combination of data derived through farmers' interviews and field surveys. Prior to selecting a representative parkland, samples for inventories, focus group discussions, and interviews with key informants were held. The focus group participants and key informants included local chiefs (chiefs of land and chiefs of the villages), government officials of land security, and members of development agencies. The primary aim of the discussions was to determine who could use what resources for how long and under what conditions. Information acquired during different discussions allowed us to identify the landowners and non-landowners. A total of 64 household heads were randomly selected, taking into account their land tenure status (landowners and non-landowners). For the factors of tree conservation on farmland, the interviewees were asked to rate them on a 4-point Likert-type scale [13] as 1 = not important, 2 = moderately important, 3 =

important, 4 = very important. An unbalanced Likert-type scale was used in this study in order to reduce the tendency of interviewees to choose the middle point scale. This is a means of reducing potential biases in the results of this study [5]. Interviewee reasons to incorporate and plant trees on their farms took a "yes' and 'no' answer. The farms of 30 natives (landowners) and 34 migrants (non-landowners) were considered inventories. Thus, the structure and tree biodiversity of *Vitellaria paradoxa* parklands that are the most common agroforestry parkland in the study site, were assessed at the household level differentiating between landowners and non-landowners [14]. A total of 64 samples of 50 m×50 m were marked in representative agroforestry parklands. Each plot was then systematically surveyed, and all woody species were marked and identified. The following variables were also recorded: number of stems, the height of the largest stem using a graduated pole, and circumference at 0.2 m and at breast height (1.3 m), using a measuring tape [15]. In this study, we considered mature trees attaining dbh >2.5 cm and height >1.5 m, and seedlings otherwise. All the trees and/or shrubs encountered were identified at species level and nomenclature following Arbonnier [16] and www.ipni.org.

2.2.2. Data Analysis

Vegetation Species Composition

The species composition of the plots was described by the following parameters: Relative dominance (RD), Relative density (RDs), Relative frequency (Rf), Relative diversity (RDi), and Importance value index (IVI). Each variable was calculated based on the specific equation mentioned below:

Relative Dominance

$$RDo = \left(\frac{Total\ basal\ area\ of\ a\ species}{Total\ basal\ area\ of\ all\ species}\right) x100 \tag{1}$$

Relative Density

$$RD = \left(\frac{Number\ of\ individuals\ of\ a\ species}{Total\ number\ of\ individuals}\right) x100 \tag{2}$$

Relative Frequency

$$RF = (\frac{\text{Frequency of a species}}{\text{Sum of all frequencies}})x100 \tag{3}$$

Relative Diversity

$$Rd = (\frac{\text{Number of a species in a family}}{\text{Total number of species}})x100 \tag{4}$$

Importance Value Index

$$IVI = \text{relative dominance} + \text{relative density} + \text{relative frequency} \tag{5}$$

Structure of Agroforestry Parklands

Structural characteristics (stem density, basal area, diameter, and height class distributions) were computed for each plot and averaged per ownership for all individuals with a dbh≥ 5 cm. The analysis of the diametric structure of the woody vegetation by ownership was carried out through the histograms of relative frequency distribution.

Measurement of Diversity

To compare diversity within each type of land use plot, we calculated diverse indices that are widely used for biological diversity measurements [17], such as McIntosh's index, Menhinick's index, Pielou's index of equitability, McIntosch's index, Shannon's measure of evenness, Shannon-Wiener index, and Fisher index of diversity. For β - diversity (similarity between vegetation patches) evaluation, Jaccard's similarity index and Horns' modification of Morisita's index were computed. Jaccard's coefficient of similarity was calculated based on the presence and absence data of the species, while Horn's modification of Morisita's index takes into account species abundance. Both indices potentially vary between 0 and 1, and a value close to 1 indicates greater similarity between patches, and hence low β- diversity [17].

Density and Spatial Distribution of Seedling Populations

The spatial distribution patterns of the seedling for each species in the grazing gradients are obtained from the calculation of the standardized Morisita's index (Ip) [18] since it is relatively independent of population density. First, the Morisita's index was computed as:

$$I_d = \frac{n \times \left(\sum x^2 - \sum x\right)}{\left[\left(\sum x\right)^2 - \sum x\right]} \quad (6)$$

Where n is the sample size, ∑x and ∑x^2 are the sums of the quadrat counts, and the sum of the quadrat counts square, respectively.

Then two critical values for the Morisita's index were calculated using the following formulas:

Uniform index (M_u);

$$Mu = (\chi^2_{0,975} - n + \sum xi)/(\sum xi - 1) \quad (7)$$

Clumped index (M_c);

$$Mc = (\chi^2_{0,025} - n + \sum xi)/(\sum xi - 1) \quad (8)$$

Where $\chi^2_{0.975}$ and $\chi^2_{0.025}$are values of chi-squared with (n-1) degrees of freedom that has 97.5% and 2.5% of the area to the right, respectively; x_i = given a set of counts of organisms in a set of quadrats and n = number of quadrats.

Finally, the standardized Morisita's index was calculated using the relevant formula out of the following four:

(i) When $I_d \geq M_c > 1{,}0$; $I_p = 0{,}5 + [0{,}5(I_d - M_c)/(n - M_c)]$ (9)

(ii) When $M_c \geq I_d \geq 1{,}0$; $I_p = 0{,}5\,(I_d - 1)/(M_u - 1)$ (10)

(iii) When $1{,}0 > I_d > M_u$; $I_p = -0{,}5(I_d - 1)/(M_u - 1)$ (11)

(iv) When $1{,}0 > M_u > _d$; $I_p = -0{,}5 + [0{,}5\,(I_d - M_u)/M_u]$ (12)

The standardized Morisita's index of dispersion (I_p) ranges between -1 and +1. A value of zero indicates a random dispersion pattern, a value higher than zero indicates a clumped pattern, and a value below zero indicates a uniform pattern.

Statistical Analysis

The calculated parameters for the vegetation composition and structure were first subjected to a one-way analysis of variance to test the difference among plots associated with differences in land and tree tenure and type of farm. When a significant difference was detected, a pair-wise comparison was made using Tukey's test at the 5% level of significance. Descriptive statistics were used to analyze the data of the socioeconomic survey. For Likert response scales (four-point scales: 1 = not important, 2 = moderately important, 3 = important, 4 = very important), the values on the Likert type scale were added to obtain 10 and then divided by 4 to get a mean score which is 2.5. Then, any mean score equal to or higher than 2.5 for a question indicated that the respondents perceived the question, while a mean score below 2.5 showed that the question was not perceived. All statistical analyses were performed with R software (R Development Core 2010) and SPSS 20 software (SPSS for Windows, Release 2013 Chicago: SPSS Inc.).

3. Results

3.1. Profile of the Respondents

Table **1** presents the frequencies of respondents in each class with respect to the socioeconomic and demographic variables. Most of the respondents (84.38%) were men, with 53.13% aged 30-50 years. The respondents were composed of 30 natives and 34 migrants. Up to 37% do not have completed secondary school education. The respondents' major sources of income were agriculture and the selling of NTFPS (56.25%), whereas 43.75% generated their income through other activities. The land for agriculture is mainly acquired by inheritance (46.88%), loan (31.25%), and only a few by gift (21.87%).

Table 1: Profile of the respondents.

Variables		Frequency	Percentage (%)
Gender	Male Female	54 10	84.38 15.62
Age	[20-30[[30-50[>50	14 34 16	21.88 53.13 25.00
Education	Illiterate Primary school Secondary school Adulte education	9 24 2 5	14.06 37.5 3.13 7.81
Residence statut	Native Migrant	30 34	46.88 53.12
Source of income	ASP AGR	36 28	56.25 43.75
Acquisition of land	Inheritance Loan Gift	30 20 14	46.88 31.25 21.87
Size of farm (ha)	[1-2] [2-4] [4-6] >6	10 35 14 5	15.63 54.68 21.88 7.81

Note: ASP: selling of NTFPs cash crop and livestock; AGR: small trades.

Table 2: Summary of the species composition and structural characteristics of trees≥ 5 cm dbh for each type of land tenure in agroforestry parklands of Tiogo, Burkina Faso (mean±SE).

Land Tenure	Non-Landowner	Landowner
Sample plots	34	30
Stem density per hectare	141±21a	107±26a
Families (number)	19±1[a]	16±4[a]
Genera (number)	32±2a	34±6a
Species (number)	44±1a	48±8a
Average dbh (cm)	26,4±1,60a	29,28±0,18a
Basal area m^2/ha	5,63±0,84a	6,12±1,47a

Means with similar letter doesn't vary significantly (P< 0.05) based on Tukey's HSD test. **Abbreviation:** dbh=diameter at breast height.

3.2. Vegetation Composition and Species Diversity in Agroforestry Parklands

In total, 49 woody species belonging to 19 families and 38 genera were encountered during the inventories at all farms. Land and tree tenure did not influence the composition of woody vegetation in terms of numbers of families, genera, and species or the average dbh of mature trees. For individuals ≥ 5 cm dbh, the number of species was higher in the non-landowners' farms than landowners' farms (Table **2**). The species with the highest importance values in the non-landowners' farms were *Vitellaria paradoxa*, *Parkia biglobosa*, *Piliostigma reticulatum*, *Piliostigma thonningii* and *Dicrostachys glomerata*, which together accounted for 192% of the total importance value. *V. paradoxa*, *D. glomerata*, *Lannea microcarpa* and *P. thonningii* were the most abundant species in the landowners' farms (Table **3**). In both types of land tenures, Leguminosae, Combretaceae, and Anacardiaceae were taxonomically diverse, and the Leguminosae and Sapotaceae had the highest FIV owing to the high stem density (Table **3**). In non-landowners' farms, Leguminosae was the species-rich family (14 species), followed by Combretaceae (6 species) and Anacardiaceae (4 species). Also, Leguminosae (9 species) and Combretaceae (5 species) were the species-rich families in landowners' farms.

Table 3: The five most abundant species in each type of land tenure in agroforestry parklands according to decreasing order of the importance value index (IVI).

Land Tenure	Species	Relative Dominance (%)	Relative Density (%)	Relative Frequency (%)	IVI (%)
Non-landowner	*Vitellaria paradoxa*	47,93	7,72	4,44	60,09
	Parkia biglobosa	31,21	1,27	4,23	36,7
	Piliostigma reticulatum	2,47	6,44	27,55	36,46
	Piliostigma thonningii	2,85	6,86	20,7	30,42
	Dicrostachys glomerata	0,57	20,72	7,04	28,33
	Total	85,03	43,01	63,96	192
	Remains	14,97	56,99	36,04	108
Landowner	*Vitellaria paradoxa*	15,99	5,85	1	42,97
	Dicrostachys glomerata	0,36	25,88	5,2	31,44
	Lannea microcarpa	17,34	5,85	0,46	23,65
	Parkia biglobosa	20,05	0,32	2,4	22,77
	Piliostigma thonningii	1,11	14,56	6,4	22,06
	Total	54,85	52,46	15,46	142,89
	Remains	45,15	47,54	84,54	157,11

IVI: Importance Value Index.

3.3. Structure of Vegetation in Agroforestry Parklands

A total of 5243 individuals were recorded in all farms, of which 95.27% were individuals with dbh <5cm (considered here as an understory). Excluding these saplings or seedlings, stem density was highest in non-landowners farms (Table **2**). The average diameter and basal area were the highest in the landowners farms compared with the non-landowners farms. The diameter class distribution of tress in all farms produced a reverse "J" shaped curve (Figure **2**), indicating that the young individuals dominated woody vegetation in the agroforestry parklands. Most individuals, 68% in the non-landowners' farms and 61% in landowners' farms, were in the two first dbh class. Two individuals of *V. paradoxa* and one individual of *P. biglobosa* in non-landowners' farms and one individual of *Ficus platyphylla* and *P. biglobosa* reached >60 cm dbh. The height class distribution of trees in both the farms produced a negative exponential curve (Figure **2**). Most of the individuals had the height range from the top two classes. The species having higher diameters also have the increased height in encountered species.

Table 4: The four most important families in each type of land tenure in agroforestry parklands according to in decreasing order of family importance value (FIV).

Land Tenure	Families	Genera	Species	Density (N/ha)	FIV
Non-landowner	Leguminosae	7	14	220	67,13
	Sapotaceae	1	1	14	57,97
	Combretaceae	2	6	40	20,02
	Anacardiaceae	2	4	6	16,36
Landowner	Leguminosae	9	9	339	54,54
	Sapotaceae	1	1	27	38,06
	Combretaceae	5	5	57	22,25
	Moraceae	1	1	1	19,37

FIV: Family Importance Value.

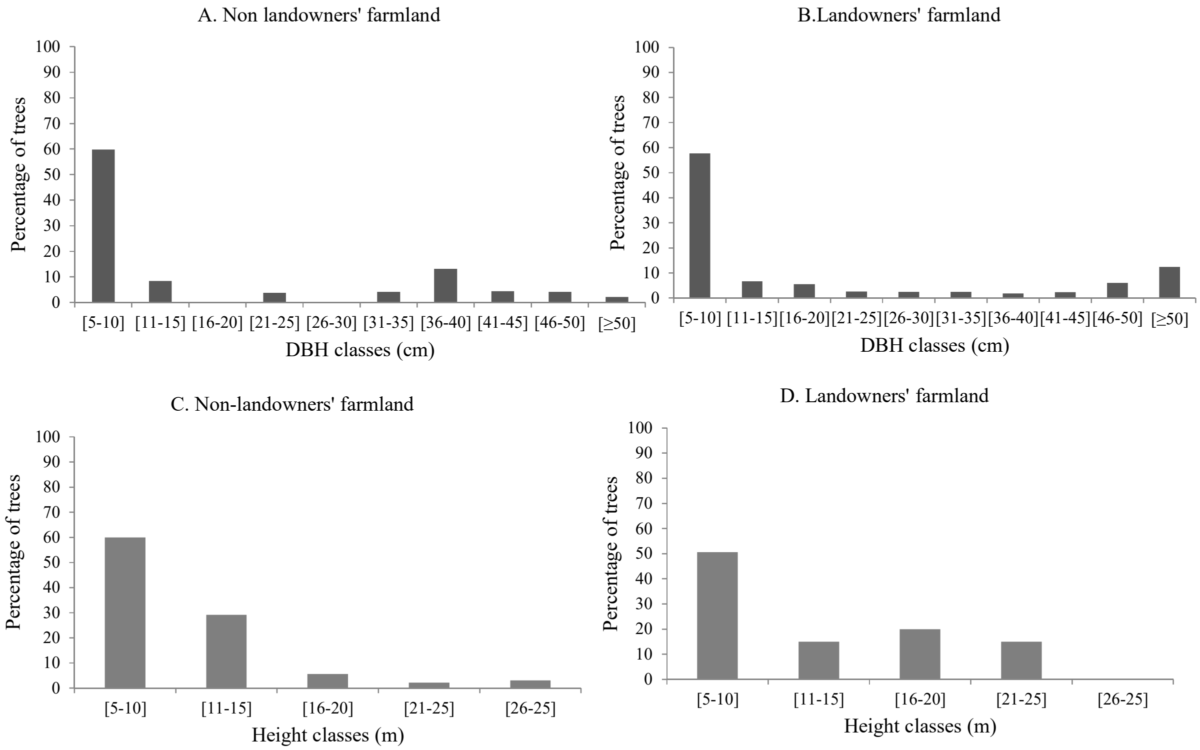

Figure 2: Diameter and height class distribution of individuals ≥ 5 cm dbh in two types of land tenure in agroforestry parklands in Burkina Faso.

3.4. Seedling and Distribution Pattern in Agroforestry Parklands

The number of recruited seedlings decreased significantly in non-landowners farms than landowners farms ($P<0.05$). Woody regeneration was the highest in landowners farms (197±21 small individuals/ha) than non-landowners farms (89±12 small individuals/ha). Spatial distributions of seedlings of each species at the type of land tenure were obtained from the calculated standardized Morisita's index (Ip), which ranged from -0.5 to 1, showing that certain species had a random dispersion (Ip=0), clumped dispersion (Ip>0) or uniform dispersion (Ip<0). For the non-landowners' farms, all species had Ip values ranged from 0.2 to 1, indicating that these species had a random dispersion. In landowners' farms many species had a clumped dispersion, and few species had a uniform dispersion (*P. biglobosa, Sclerocarya birrea, Terminalia laxiflora* and *V. paradoxa*) and random dispersion (*Gardenia erubescens, Grewia mollis, L. acida, L. microcarpa, L. velutina, Mangifera indica, Pteleopsus suberosa,* and *Tamarindus indica*) (Table **5**).

3.5. Species Diversity in Agroforestry Parklands

To allow a comparison of diversity between the type of land tenure, several diversity measures were computed (Table **6**). The total number of individuals (N) was the highest in the non-landowner's farms than landowners' farms, and it is not the same in richness species. In terms of numerical species richness, defined as the number of species per specified number of individuals (S/N), the landowners' farms had the highest value (0.44).

According to Margalef's index of species richness, representing an intermediate mathematical measure between S/N and S, and Menhinick's index that is a variance of Margalef's index showed that the landowner's farms were the most diverse. According to Pielou's index of equitability, McIntosch's index, and Shannon's measure of evenness, the non-land owners and landowner's farms did not differ significantly and had the same values for these indexes of diversity. The reciprocal of Simpson's concentration index ($1/\lambda$), which specifies the inverse of the probability that any two individuals draw randomly from an infinitely large community belonging to different species would be identical, showed the landowner's farms had the most diverse and the non-landowners farms the least diverse. Fisher's diversity index, the most stringent and widely recommended measure of diversity,

Table 5: Spatial distribution of seedlings population of each type of land tenure in agroforestry parkland.

Species	Type of Land Tenure	
	Non-landowner	Landowner
Diospyros mespiliformis	Clumped	Clumped
Detarium microcarpum	Clumped	Clumped
Entada africana		Clumped
Feretia apodanthera	Clumped	Clumped
Gardenia aqualla	Clumped	Random
Gardenia ternifolia	Clumped	Clumped
Gardenia triacantha	-	Clumped
Gardenia erubescens	-	Random
Grewia mollis	Clumped	Random
Guiera senegalensis	Clumped	Clumped
Heeria insignis	-	Random
Holarrhena florinbunda	Clumped	Random
Vitellaria paradoxa	Clumped	Clumped
Lannea acida	-	Random
Lannea microcarpa	Clumped	Random
Lonchocarpus laxiflorus	-	-
Lannea velutina	Clumped	Random
Mangifera indica	-	Random
Mayetenus senegalensis	Clumped	Clumped
Parkia biglobosa	-	Uniform
Piliostigma reticulatum	Clumped	Clumped
Piliostigma thonningii	Clumped	Clumped
Prosopis africana	Clumped	Clumped
Pteleopsus suberosa	Clumped	Random
Pterocarpus erinaceus	Clumped	Clumped
Saba senegalensis	Clumped	Clumped
Sclerocarya birrea	Clumped	Uniform
Securinega virosa	Clumped	Clumped
Sterospermum kunthianum	-	Clumped
Terminalia avicennioides	Clumped	Clumped
Tamarindus indica	Clumped	Random
Terminalia laxiflora	Clumped	Uniform
Terminalia macroptera	Clumped	Clumped
Vitellaria paradoxa	Clumped	Uniform
Ximenia americana	Clumped	Uniform
Ziziphus mucronata	Clumped	Clumped

-signify that the species were not recorded during inventories.

Table 6: Diversity measure for trees ≥ 5 cm dbh in each type of land tenure in agroforestry parklands of the Sudanian zone, Burkina Faso.

Diversity Measures	Type of Land Tenure	
	Non-Landowner	Landowner
Number of individuals recorded, N,	141±21a	108±26a
Total number of species recorded, S	44±1a	48±8a
Rate of species increase per individual enumerated, S/N	0.31±0.05a	0.44±0.30a
Margalef's index of species richness, D_{Mg}=(S-1)/lnN	8,61±0,40a	9,94±1,14a
Menhinick's index, DMn=S/√N	3,68±0,33a	4,58±0,19a
Pielou's index of equitability, E=H/lnS	0,68±0,07a	0,68±0,03a
McIntosch's index	0,67±0,05a	0,68±0,00a
Shannon's measure of eveness, J'=H'/lnS	0,31±0,03a	0,31±0,01a
Shannon-Wiener index, H'=-$\sum p_i \log_2 p_i$	1,145±0,13a	1,18±0,007a
The reciprocal of Simpson's index, 1/λ=$\sum n_i (n_i\text{-}1)/N_i (N_i\text{-}1)$	0,085±0,09a	0,11±0,007a
Fisher index of diversity &= N(1-x)/x, x is the log series parameter	0,76±0,11a	0,58±0,14a

also indicated the non-landowners farms as the most diverse and the landowner's farms as the least diverse. As a whole, most diversity measures showed that the landowners' farms were most diverse than the non-landowners farms. When comparing species similarity between vegetation patches in agroforestry parklands in Tiogo, we found that landowner's farms and non-landowners farms were more similar (Appendix **A**). These similarities varied from 61% to 75%, according to Jaccard's index and Morisita's index, respectively,

3.6. Main Reasons and Factors Affecting the Conservation of Trees on Farms

The main reasons to incorporate the trees on the farms were more linked to their multipurpose roles (Appendix **B**). These important roles were food for humans (92%), forage for livestock (85%), soil fertility and protection against diverse forms of erosion (80%), medicine (72%), needs for charcoal and fuelwood (65%), rituals (60%), and absence of certain species in the forest (55%). The respondents did not highly perceive the reasons for shade and biodiversity conservation with a percentage below 50% (Figure **3**). Other factors influenced the conservation of trees on farms: lack of funds ($\bar{x}$=2.97, SD=1.01), lack of skill and silvicultural knowledge ($\bar{x}$=2.93, SD=0.94), scarcity of land ($\bar{x}$=2.65, SD=1.03), lack of germplasm ($\bar{x}$=2.58, SD=0.98) and land and tree tenure ($\bar{x}$=2.50, SD=0.94) (Table **7**).

Table 7: Factors influencing plantation and conservation of trees on farms.

Factors	Mean ($\bar{x}$)	Standard Deviation
Lack of fund	2,97*	1,01
Lack of skill and silvicultural knowledges	2,93*	0,94
Land area	2,65*	1,03
Lack of germplasm	2,58*	0,98
Land and tree tenure	2,50*	0,94
Plant diseases and competition to nutrients	2,32	0,85
Culturales and traditional contraints	2,21	1,03

* Significativity.

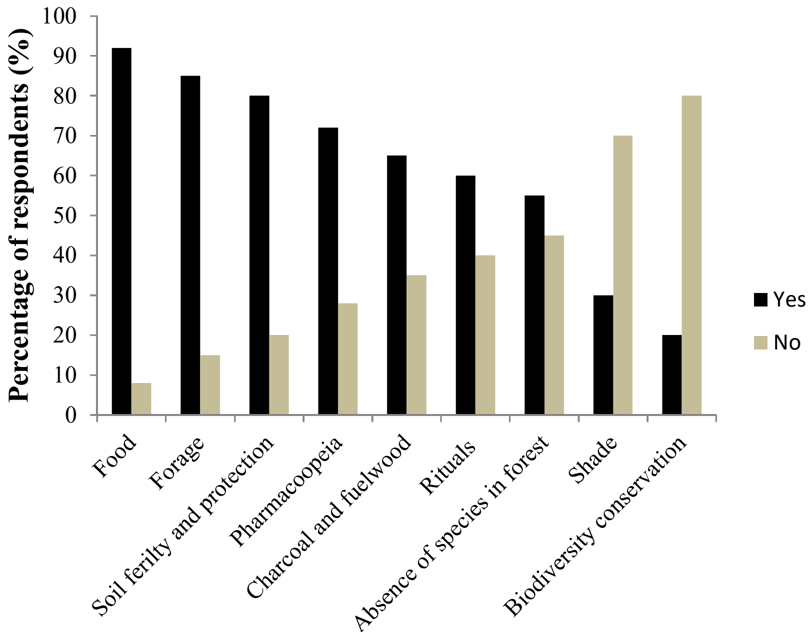

Figure 3: Reasons motivating the conservation of trees on farms.

4. Discussion

Agroforestry parkland systems maintain a significant level of woody species richness, which may contribute to biodiversity conservation at the national, regional, or even international level [19]. The numbers of families, genera and species reported in the present study account for nearly one-third of the native woody species found in the savanna woodlands of Burkina Faso. Lebrun [20] reported that the woody flora (trees, small shrubs, and climbers) at the country level includes 55 families, 214 genera, and 376 species (with 96 exotic species). This relatively high species richness could be attributed to habitat heterogeneity (patchiness), which has increased the tree diversity of woodlands and savannas in Africa [15, 21]. Also, the high species richness in agroforestry parklands in Tiogo may be due to perceptions of local communities on the advantages and many economic benefits and opportunities of conservation of trees in farms. The species richness was high in landowners' farms than the non-landowners' farms. According to Vodouhê *et al*. [19], the highest species richness observed in inherited land from their parents (landowners' land) is due to the land tenure system.

The most common families in each type of land tenure were Leguminosae, Sapotaceae, Combretaceae, Anacardiaceae, and Moraceae. According to Fontès and Guinko [22] and Sawadogo [23], these families are a pattern common in most savanna-woodland mosaics in Africa and typical of the northern Sudanian Zone in Burkina Faso. The predominance families in traditional agroforestry parkland systems of Benin were Leguminosae and Anacardiaceae [19].

The agroforestry parklands are dominated by Vitellaria paradoxa, Parkia biglobosa, Lannea microcarpa, Piliostigma reticulatum, Piliostigma thonningii and Dichrostachys glomerata that are considered as the main multipurpose species used for human food, medicine, forage for livestock, soil fertilization or reclamation, marketable products for rural households. This result is consistent with the findings of Bayala *et al*. [24], Vodouhê *et al*. [19], and Raebild *et al*. [25] in traditional agroforestry parkland systems in West Africa (Burkina Faso and Benin), who found that the most frequent species were V.paradoxa, P. biglobosa , L. microcarpa, Adansonia digitata, and Piliostigma spp. V. paradoxa, P. biglobosa, L. microcarpa generated food and the additional income to resource households, especially during the dry season when people are facing food shortage problems. This confirms that agroforestry systems play important roles for household well-being (increase livelihood security, poverty reduction) and incentives forest conservation and sustainable use. This indirectly provides important environmental services such as soil enrichment and erosion prevention, watershed protection, rehabilitation of degraded land, and reducing the environmental risks associated with high climatic variability in the region, carbon sequestration, and opportunities for payments for environmental services, i.e., Reducing Emissions from Deforestation and Forest Degradation (REDD+) program advocated by the United Nations.

In addition, our findings corroborated the previous studies that found that "useful" trees are saved in farmlands for their properties and importance in the daily needs of livelihood [26-28, 14]. Consequently, the phytodiversity of agroforestry parkland was dominated by these useful tree species [29, 30]. From an ecological point of view, the abundance of certain beneficial species is probably due to their adaptability to site conditions and disturbances during labor for annual crops, or the intensification of cultivation maintains ecological niches for the establishment of these species. However, *P. reticulatum* and *P. thonningii*, usually found in fallows with sandy to clay soil, had large numbers of seedlings and adults, supporting the hypothesis of endozoochorus [31] or the hydrochorus seed dispersal in savanna woodlands [32].

The stem density per hectare found in the agroforestry parkland in this study was higher compared to the findings of Vodouhê *et al*. [19] in traditional parklands of Benin. Also, with regard to stem density, a large number of individuals with dbh< 5 cm corresponding to young individuals (seedling populations) were found in non-landowners' farms and landowners farms, indicating the high regeneration potential of trees. These results are consistent with the findings of Raebild *et al*. [7], Raebild *et al*. [25], and Akinbisoye *et al*. [33], who reported that borrowed fields contain as many trees as fields cultivated by the landowners and the shrub and sapling densities were significantly high in agroforestry systems. Most woody savanna species regenerate by coppicing and root suckering after disturbances such as fire and wood cutting that frequently occur each year in these ecosystems [34]. Species such as *Entada africana*, *D.microcarpum, Pteleopsus suberosa* encountered during our inventories regenerate profusely after such disturbances, according to the findings of Ky-Dembelé *et al*. [35]. The reverse "J" shape of cumulative diameter class distribution of all woody plants in each type of land tenure is an indicator of good regeneration status. Many individuals with a girth <5 cm dbh were found in each agroforestry parkland. The proportion of seedlings and saplings could therefore suffice to maintain a stable tree population.

However, the transition from seedlings to young saplings or higher size classes is a critical survival step of the recruitment stage where saplings are sensitive to frequent fire, browsing, drought, and livestock trampling, which induce seedling shoot die-back and compromise the successful transition from seedling to trees [35-41]. Thus, this transition often takes a long time, depending on many biotic and abiotic factors such as variation of rainfall, the availability of nutrients, the space and hydric stress, degeneration of young saplings, the substrate of seed germination, the anthropogenic pressures etc. [42-45, 37]. Also, factors such as grazing, fire, and labor influence biodiversity in agroforestry parkland by favoring preferred species and affecting tree size seriously.

Most diversity measures showed that the landowners' farms were most diverse than the non-landowners' farms. According to Shannon's and Simpson's diversity indices, woody populations in landowner's' farms were more diverse than non-landowner's' farms. This is most likely related to the relatively large numbers of abundant species found in the inventories plots at these farms [37]. Shannon's diversity index is usually found to fall between 1.5 and 3.5 and is rarely above 5.0 [17]. The values found during inventories are in an acceptable range, i.e., ranged below 1.5 and 3.5. Simpson's index describes the evenness of the distribution of individuals among species at different types of land tenure as low. This is due to the difference in the importance value index (IVI) of the species on the type of land tenure [37]. Analyses of variance of the entire woody vegetation of agroforestry parklands revealed no significant differences in terms of all computed indexes, basal area, or species richness. These findings corroborated with the results of [14], who found no major differences according to diversity indices such as Shannon index and Evenness index between native and migrant farmers' fields except for species richness. However, the obtained basal areas in this study are lower than those reported by De Wolf [46], who found average basal areas up to 15 m^2/ha in the Soudano-Guinean climatic zone in Senegal. The high value of average basal areas may be due to high precipitation and denser tree vegetation than our study.

The average diameter and total basal area of trees ≥ 5 cm dbh were the largest in landowners farms, which could be related to the land tenure effect where the landowners have no right to benefit from the advantages of trees in borrowed lands. Most indices showed that landowner's farms are more diverse than non-landowners farms. These findings may be explained by the fact in many cases, it is prohibited to non-landowners to plant trees in borrowed lands because planting is considered as an appropriation form of land. Most seedling species have a clumped dispersion. This distribution pattern probably reflects the dominance of clonal propagation in the study area and is the survival strategy of woody plants after disturbances events [35, 37]. The similarity in species composition between landowners' farms and non-landowners farms was generally high, indicating the least diversity between both types of land tenure. These similarities are probably due to the same site conditions.

However, the reasons that motivated farmers to plant and conserve trees on farmland were linked to their utilities and rareness in the forest. This is consistent with the findings of Vodouhê *et al*. [19], who found that people are more favorable to conserve in their fields the species that they perceive less available in the wild. In sub-Saharan Africa, trees are preserved on farmland because of the numerous benefits derived from them (food, commercialization of tree fruits, use of tree shade during farms activities and species contribution to soil fertility improvement, fuelwood, construction, medicine, climatic amelioration, and boundary markers [47, 48]. Murniati *et al*. [49] added that in the area where timber is the main product harvested from the forest (as the case of our context in Tiogo State forest), farmers expressed a strong interest in growing high-quality timber in their mixed gardens to ensure a future timber supply. The factors such as lack of funds, lack of skill and silvicultural knowledge, land area, lack of germplasm, land and tree tenure that were found as factors influencing and conservation of trees on farms are consistent with previous studies [50-53, 27].

Concluding Remarks

This study aimed to explore the species composition, structure, and diversity of woody species at agroforestry parklands according to land tenure. It reveals that the agroforestry parkland in Tiogo and the surrounding area has a large number of woody species, which is related to habitat heterogeneity and the real attention of farmers in the adoption of agroforestry systems. The results indicate that woody vegetation attributes decrease in landowners' farms. In each type of land tenure, the number of seedlings was disproportionately higher compared to adult trees, which could lead to higher recruitment of adults if measures are taken to improve the regeneration of woody species. Land tenure affected the biodiversity of agroforestry parkland. Land and tree tenure reforms may be the efficient solution to promote more active participation of non-landowner in agroforestry programs. Thus, when the local rights to use trees by non-landowners are flexible, they must be introduced and protected species in order to restore agricultural land and also diversify their productions. These findings highlight the important role of agroforestry parklands to maintain woody species richness and diversity and convert farmlands to biodiversity stock. The governments should pay more attention to development agencies, and ONGs should encourage the adoption of agroforestry practices by helping the local populations resolve the constraints that demotivate the improvement and promotion of agroforestry systems.

References

[1] Aeez IO, Onyem MC. Conflicts of land tenure and tree tenure on land use and management among agro-based households in Nigeria. Int J Advance Agric Res 2013; 53-61.

[2] Agrawal A, Ostrom E. Collective action, proverty rights and devolution of forest and protected area management. Research paper. 1999. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.298.6479, Accessed: January 23, 2018.

[3] Ndayambaje JD, Heijman WJM, Mohren M. Farm woodlots in rural Rwanda: purposes and determinants. Agrofor Syst 2013; 87: 797-814. https://doi.org/10.1007/s10457-013-9597-x

[4] Grolleau A. Contribution à l'étude de la multiplication végétative par greffage du karité (Vitellaria paradoxa Gaertn. f. =Butyrospermum paradoxum Hepper). Bois For et Trop 1989; 222: 238-240.

[5] Sanou L, Savadogo P, Ezebilo EE, Thiombiano A. Drivers of farmer's decisions to adopt agroforestry: Evidence from the Sudanian savanna zone, Burkina Faso. Renewable Agric Food Syst 2017; 1-18. https://doi.org/10.1017/S1742170517000369.

[6] Wunder S, Angelsen A, Belcher B. Forest, Livelihoods, and conservation: Broadening the Empirical Base. World Develop 2014. http//dx.doi.org/10.1016/j.worlddev.2014.03.007.

[7] Raebild A, Hansen HH, Dartell J, Kiléa-Ky JM, Sanou L. Ethnicity, land use and woody vegetation: a case study from south-western Burkina Faso. Agroforest Systems. 2007; 70: 157-167. DOI 10.1007/s10457-007-9043-z.

[8] Sawadogo L. Influence de facteurs anthropiques sur la dynamique de la végétation des forêts classées de Laba et de Tiogo en zone soudanienne du Burkina Faso. Thèse d'Etat. Université de Ouagadougou. 2009; 142p.

[9] Ezebilo EE, Mattsson L. Contribution of non-timber forest products to livelihoods of communities in southeast Nigeria. International Journal of Sustainable Development & World Ecology 2010; 17: 231-235. https://doi.org/10.1080/13504501003749992

[10] Fontès J, Guinko S. Carte de la végétation et de l'occupation des sols du Burkina Faso: 67.

[11] Breman H, Kessler JJ. The role of woody plants in agro-ecosystems of semi-arid regions: with an emphasis of the Sahelian countries. Advanced Series in Agricultural Sciences. 1995; 23: Springer-Verlag, Berlin. https://doi.org/10.1007/978-3-642-79207-6

[12] INSD. Résultats préliminaires du recensement général de la population et de l'habitatde 2006. In: Institut National des Statistiques et de la Démographie (INSD). Direction de la démographie, Ouagadougou. Burkina Faso. 2007

[13] Clason DL, Dormody TJ. Analyzing data measured by individual Likert-type items. J Agric Educ 1994; 35(4): 31-35. https://doi.org/10.5032/jae.1994.04031

[14] Augusseau X, Nikiéma P, Torquebiau E. Tree biodiversity, land dynamics and farmers' strategies on the agricultural frontier of southwestern Burkina Faso. Biodiversity and Conservation. 2006; 15: 613-630. https://doi.org/10.1007/s10531-005-2090-8

[15] Savadogo P, Tigabu M, Sawadogo L, Oden PC. Woody species composition, structure and diversity of vegetation patches of sudanian savanna-woodland in Burkina Faso. Bois et Forêts des Tropiques. 2007; 294 (4): 5-20.

[16] Arbonnier M. Arbres, arbustes et lianes des zones sèches d'Afrique de l'Ouest, 3e Ed.,QUAE/MNHN. 2009; 504.

[17] Magurran AE. Measuring biological diversity. Blackwell Publishing, Malden, Oxford and Victoria. 2004; 256.

[18] Krebs JC. Ecological Methodology. Addison-Wesley Educational Publishers Inc. New York, USA. 1999.

[19] Vodouhê FG, Coulibaly O, Biaou G, Sinsin B. Traditional agroforestry systems and biodiversity conservation in Benin (West Africa). Agroforest Syst 2011; 82: 1-13. https://doi.org/10.1007/s10457-011-9377-4

[20] Lebrun JP. Catalogue des plantes vasculaires du Burkina Faso. Insitut d'élévage et de medecine vétérinaire des pays tropicaux, Maison-Alfort, France, 341. Victoria. 1991; 256 p.

[21] Menaut JC, Lepage M, Abbadie L. Savannas, woodlands and dry forests in Africa. In: Seasonally dry tropical forests. Cambridge University Press, UK, USA. 1995; 64-92. https://doi.org/10.1017/CBO9780511753398.004

[22] Fontès J, Guinko S. Carte de la végétation et de l'occupation des sols du Burkina Faso. Ministère de la Coopération Française: projet campus (88 313 101), Toulouse, France. 1995; p. 67.

[23] Sawadogo L. Evaluation des potentialités pastorales d'une forêt classée soudanienne du Burkina Faso. (Cas de la forêt classée de Tiogo). Thèse Doctorat 3ème Cycle, Université de Ouagadougou, Burkina Faso. 1996.

[24] Bayala J, Ouedraogo SJ, Teklehaimanot Z. Rejuvenating indigenous trees in agroforestry parkland systems for better fruit production using crown pruning. Agroforestry Syst 2008; 72: 187-194. https://doi.org/10.1007/s10457-007-9099-9

[25] Raebild A, Hansen UB, Kambou S. Regeneration of Vitellaria paradoxa and Parkia Biglobosa. Agroforest Syst 2012; 85: 443-453. https://doi.org/10.1007/s10457-011-9397-0

[26] Boffa JM. Les parcs agroforestiers en Afrique de l'Ouest: clés de la conservation et d'une gestion durable. Unasylva. 2000; 51: 11-17.

[27] Jamala GY, Shehu HE, Yidau JJ, Joel L. Factors Influencing Adoption of Agro-Forestry among Smallholder Farmers in Toungo, Southeastern, Adamawa State, Nigeria. J Environ Scie Toxicology Food Techn 2013; 6: 66-72. https://doi.org/10.9790/2402-0666672

[28] Bayala J, Sanou J, Teklehaimanot Z, Ouedraogo SJ, Kalinganire A, Coe R. Van Noordwijk M. Advances in knowledge of processes in soil-tree-crop interactions in parkland systems in the West African Sahel: A review. Agric Ecosyst Environ 2015; 205: 25-35. https://doi.org/10.1016/j.agee.2015.02.018

[29] Boffa JM. Agroforestry Parklands in sub-Saharan Africa. FAO conservation guide 34. Food and Agriculture Organization, Rome. 1999.

[30] Lovett PN, Haq N. Diversity of the Sheanut tree (Vitellaria paradoxa C.F. Gaertn.) in Ghana. Gen Resour Crop Evol 2000; 47(3): 293-304. https://doi.org/10.1023/A:1008710331325

[31] Razanamandranto S, Tigabu M, Neya S, Odén PC. Effects of gut treatment on recovery and germinability of bovine and ovine ingested seeds of four woody species from the Sudanian savanna in West Africa. Flora. 2004; 119: 389-397. https://doi.org/10.1078/0367-2530-00167

[32] Savadogo P, Tigabu M, Sawadogo L, Oden PC. Woody species composition structure and diversity of vegetation patches of a Sudanian savanna in Burkina Faso. Bois et Forêts des Tropiques 2007; 294 (4): 5-20.

[33] Akinbisoye OS, Oke SO, Adebola SI, Mokwenye AI. Influence of Taungya Agroforestry System on Diversity of Native Woody Species and Soil Physico-Chemical Properties in Nigeria. Int J Scientific Res Publications 2014; 4: 1-15.

[34] Sawadogo L, Nygard R, Pallo F. Effects of livestock and prescribed fire on coppice growth after selective cutting of Sudanian savannah in Burkina Faso. Ann For Scie 2002; 59: 185-195. https://doi.org/10.1051/forest:2002005

[35] Ky-Dembelé C, Tigabu M, Bayala J, Ouedraogo SJ, Oden PC. The relative importance of different regeneration mechanisms in a selectively cut savanna-woodland in Burkina Faso, West Africa. For Ecol Manage 2007; 28-38. https://doi.org/10.1016/j.foreco.2007.01.091

[36] Ouedraogo A, Thiombiano A, Hahn-Hadjali K, Guinko S. Diagnostic de l'etat de degradation des peuplements de quatre especes ligneuses en zone soudanienne du Burkina Faso. Secheresse. 2006; 17: 485-491.

[37] Tabuti JRS, Mugula BB. The ethnobotany and ecological status of Albizia coriaria Welw. ex Oliv. in Budondo Subcounty, eastern Uganda. Afr J Ecol 2007; 45: 126-129. https://doi.org/10.1111/j.1365-2028.2007.00869.x

[38] Bognounou F, Thiombiano A, Savadogo P, Boussim JI, Oden PC, Guinko S. Woody vegetation structure and composition at four sites along a latitudinal gradient in Western Burkina Faso. Bois For Trop 2009; 300: 30-44. https://doi.org/10.19182/bft2009.300.a20412

[39] Gnoumou A, Bognounou F, Hahn K, Thiombiano A. A comparison of Guibourtia copallifera Benn. stands in South West Burkina Faso-community structure and regeneration. J Forest Res 2011; 23: 29-38. https://doi.org/10.1007/s11676-012-0224-x

[40] Ouédraogo A, Glèlè RK, Thiombiano A, Andersen A. Population structure of the widespread species, Anogeissus leiocarpa (DC.) Guill. & Perr. across the climatic gradient in West Africa semi-arid area. South Afr J Bot 2013; 88: 286-295. https://doi.org/10.1016/j.sajb.2013.07.029

[41] Lankoandé B, Ouédraogo A, Boussim IJ, Lykke AM. Natural stands diversity and population structure of Lophira lanceolata Tiegh. ex Keay, a local oil tree species in Burkina Faso, West Africa. Agroforest Syst 2016; 91: 85-96. https://doi.org/10.1007/s10457-016-9913-3

[42] Scholes RJ, Walker BH. An African Savanna: Synthesis of the Nylsvley Study Cambridge University Press, Cambridge. 1993; 306p. https://doi.org/10.1017/CBO9780511565472

[43] Eliapenda S. Plant Ecological Studies Related to Restoration of a degraded Ecosystem in Central Tanzania. Acta Universitatis Upsaliensis:40. 2000.

[44] Kozlowski TT. Physiological ecology of natural regeneration of harvested and disturbed forest stands : implications for forest management. For Ecol Manage 2002; 158: 195-221. https://doi.org/10.1016/S0378-1127(00)00712-X

[45] Sagar R, AS R, Singh JS. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. For Ecol Manage 2003; 154: 61-71. https://doi.org/10.1016/S0378-1127(03)00235-4

[46] De Wolf J. Species composition and structure of the woody vegetation of the middle Casamance region (Senegal). For Ecol Manage 1998; 111: 249-264. https://doi.org/10.1016/S0378-1127(98)00347-8

[47] Lamien N, Sidibé A, Bayala J. Use and commercialization of non-timber forest products in western Burkina Faso. In: Leakey RRB, Temu AB, Melnyk M (eds) Domestication and commercialization of non-timber forest products in agroforestry systems. FAO, Non-wood For Prod, Rome, 1996; 9: 51-63.

[48] Teklehaimanot Z. Exploiting the potential of indigenous agroforestry trees: Parkia and Vitellaria paradoxa in sub-Saharan Africa. Agrofor Syst 2004; 61: 207-220. https://doi.org/10.1007/978-94-017-2424-1_15

[49] Murniati D, Garrity P, Gintings A. The contribution of agroforestry systems to reducing farmers' dependence on the resources of adjacent national parks: a case study from Sumatra, Indonesia. Agrofor Syst 2001; 52: 171-184. https://doi.org/10.1023/A:1012047602192

[50] Buyinza M, Ntakimanyire A. Rotational woodlot technology in Kigorobya sub-county, Hoima District, Uganda. Bot Res J 2008; 1: 36-42. https://doi.org/10.17348/era.6.0.107-115

[51] Kabwe G, Bigsby H, Cullen R. Factors influencing adoption of agroforestry among smallholder farmers in Zambia. New Zealand Agric Resour Econom Soc 2009; 15.

[52] Nyoka BI, Mng'omba SA, Akinnifesi FK, Ajayi OC, Sileshi G, Jamnadass R. Agroforestry Tree Seed Production and Supply Systems in Malawi." Small Scale For J 2011; https://doi.org/10.1007/s11842-011-9159-x

[53] Mwase W, Sefasi A, Njoloma J, Nyoka BI, Manduwa D, Nyaika J. Factor Affecting Adoption of Agroforestry and Evergreen Agriculture in Southern Africa. Environ Nat Resour Res 2015; 5(2):148-157. https://doi.org/10.5539/enrr.v5n2p148

Appendix A: **Similarity in species composition (individuals with≥ 5 cm dbh) between type of land tenure in Tiogo agroforestry parklands**

Indices	Type of land tenure	Landowner	Non-landowner
Jaccard's	Landowners	1	
	Non-landowners	0,61	1
Morisita's	Landowners	1	
	Non-landowners	0,75	1

Appendix B: **Species recorded during the inventoried in the agroforestry parkland and their main uses given by the respondents**

Species	Family	Species Origin	Main Uses
Acacia dudgeoni	Leguminosae	Local	Forage
Acacia macrostachya	Leguminosae	Local	Forage
Acacia senegal	Leguminosae	Local	Forage
Acacia seyal	Leguminosae	Local	Forage
Acacia sieberiana	Leguminosae	Local	Forage
Adansonia digitata	Bombacaceae	Local	Food
Annona senegalensis	Annonaceae	Local	Food, Forage
Anogeissus leiocarpa	Combretaceae	Local	Forage
Azadirachta indica	Meliaceae	Local	Food
Balanites aegyptiaca	Balanitaceae	Local	Food, Forage
Bridelia ferruginea	Euphorbiaceae	Local	Construction
Burkea africana	Leguminosae	Local	Construction
Bombax costatum	Bombacaceae	Local	Food
Capparis sepiaria	Capparaceae	Local	Medecine
Cassia sieberiana	Leguminosae	Local	Fuelwood
Combretum glutinosum	Combretaceae	Local	Fuelwood
Combretum molle	Combretaceae	Local	Fuelwood
Combretum nigricans	Combretaceae	Local	Fuelwood
Crossopteryx febrifuga	Rubiaceae	Local	Medecine
Detarium microcarpum	Leguminosae	Local	Food, Fuelwood
Dicrostachys cinerea	Leguminosae	Local	Forage, Construction
Dicrostachys glomerata	Leguminosae	Local	Forage
Diospyros mespiliformis	Ebenaceae	Local	Food, Ritual
Eucalyptus camaldulensis	Myrtaceae	Exotic	Construction, Medecine
Entada africana	Leguminosae	Local	Fuelwood
Faidherbia albida	Leguminosae	Local	Soil fertility, Forage
Feretia apodanthera	Rubiaceae	Local	Medecine
Ficus platyphylla	Moraceae	Local	Medecine

(**Appendix B) contd….**

Species	Family	Species Origin	Main Uses
Gardenia ternifolia	Rubiaceae	Local	Food, Ritual
Gmelina arborea	Lamiaceae	Exotic	Fuelwood
Grewia bicolor	Tiliaceae	Local	Forage
Grewia mole	Tiliaceae	Local	Forage
Guiera senegalensis	Combretaceae	Local	Ritual
Khaya senegalensis	Meliaceae	Local	Fuelwood, Forage,
Lannea acida	Anacardiaceae	Local	Fuelwood
Lannea microcarpa	Anacardiaceae	Local	Food
Lannea velutina	Anacardiaceae	Local	Fuelwood
Mangifera indica	Anacardiaceae	Exotic	Food
Maytenus senegalensis	Celastraceae	Local	Soil fertility
Mitragyna inermis	Rubiaceae	Local	Forage, Medecine
Parkia biglobosa	Leguminosae	Local	Food
Piliostigma reticulatum	Caesalpiniaceae	Local	Forage, Soil fertility
Piliostigma thonningii	Caesalpiniaceae	Local	Forage, Soil fertility
Prosopis africana	Leguminosae	Local	Soil fertility, Forage, Fuelwood
Pteleopsis suberosa	Combretaceae	Local	Fuelwood
Pterocarpus erinaceus	Fabaceae	Local	Forage, Fuelwood
Saba senegalensis	Apocynaceae	Local	Food
Sclerocarya birrea	Anacardiaceae	Local	Food, Forage, Fuelwood
Securidaca longipedunculata	Polygalaceae	Local	Medecine
Sterculia setigera	Sterculiaceae	Local	Fuelwood
Tamarindus indica	Caesalpiniaceae	Local	Food
Terminalia laxiflora	Combretaceae	Local	Fuelwood
Terminalia macroptera	Combretaceae	Local	Fuelwood
Vitellaria paradoxa	Sapotaceae	Local	Food
Vitex doniana	Verbenaceae	Local	Food
Ximenia americana	Olacaceae	Local	Food, Forage
Ziziphus mauritiana	Rhamnaceae	Local	Food, Forage
Ziziphus mucronata	Rhamnaceae	Local	Construction