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SOMMAIRE

Characteristics of woody species diversity based on the type of agroforestry parkland bordering the Kuinima classified forest in Western Burkina Faso

Francis NOUFE[1,2*], Joséphine YAMEOGO[2], Paulin OUOBA[1]

Short title: Woody species diversity and management units

Abstract

In Burkina Faso, the conservation of woody species in agroforestry parklands is a major concern. The aim of this study was to characterize the diversity and health status of woody species according to the management units bordering the Kuinima classified forest. A systematic inventory of woody species in 84 square plots of 2,500 m2 each, spread over four types of management units: hut fields, bush fields, village fields and lowlands. The Shannon-Weaver diversity index (H') and rarity index (IR) were determined. The results show a total of 47 woody species belonging to 22 families and 45 genera. The bush and village fields had the highest number of species recorded. The Shannon-Weaver diversity index was very low in the lowlands with H'=1.96 bits compared to that of the bush fields with H'=2.10 bits. A large number of species with RI ≥ 80%, and therefore considered rare, were recorded in the bush fields (31 species) and village fields (28 species). Regeneration concerned 44 species and was dominated by *Vitellaria paradoxa* Gaertn.f (36.8%). In addition, more than 50% of the species, with the exception of those in the hutches, had been attacked by parasites, mainly *Tapinanthus*. These results are a reference for monitoring the dynamics of agroforestry parklands.

Keywords : Agroforestry parkland, Floristic diversity, Regeneration, Health status, Kuinima

Caractéristiques de la diversité des espèces ligneuses en fonction du type de parc agroforestier en bordure de la forêt classée de Kuinima à l'Ouest du Burkina Faso

Résumé

Au Burkina Faso, la conservation des ligneux dans les parcs agroforestiers est une préoccupation majeure. Cette étude visait à caractériser la diversité et l'état sanitaire des ligneux en fonction des unités de gestion en bordure de la forêt classée de Kuinima. Ainsi, un inventaire systématique des ligneux a été fait dans 84 placettes carrées de 2500 m^2 chacune, réparties dans des champs de case, brousse, village et bas-fonds. Les indices de diversité de Shannon-Weaver (H') et de rareté (IR) ont été déterminés. Les résultats montrent un

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total de 47 espèces ligneuses recensés appartenant à 22 familles et 45 genres. Les champs de brousse et de village comportent le plus grand nombre d'espèces. L'indice de diversité de Shannon-Weaver était très faible au niveau des bas-fond avec H'=1,96 bits comparativement à celui des champs de brousse avec H'=2,10 bits. Un grand nombre d'espèces considérées comme rares avec RI ≥ 80%, ont été recensées sur les champs de brousse (31 espèces) et de village (28 espèces). La régénération concernait 44 espèces et était dominée par *Vitellaria paradoxa* Gaertn.f (36,8%). Aussi, 50% des espèces, exceptées celles des champs de case, ont subi des attaques parasitaires, principalement de *Tapinanthus*. Ces résultats sont une référence pour le suivi de la dynamique des parcs agroforestiers.

Mots-clés : Parc agroforestier, Diversité floristique, Régénération, Etat sanitaire, Kuinima

Introduction

The conservation and sustainable use of plant biodiversity is a major concern at the centre of scientific debates and international conventions regarding the future of our planet (CISSE, 2021). The issues of climate change and biodiversity loss are crucial for the arid regions of Africa (BURKE et *al*., 2009). The effects of these two phenomena have been impacting considerably on the development efforts of african countries, and consequently on the livelihoods of rural people who depend on agroforestry resources (CISSE et *al*., 2018).

In Burkina Faso, the degradation phenomenon appeared as such that it is increasingly necessary to find inexpensive and adapted control methods for small-scale producers being the most representative group of the agricultural sector. Thus, for finding solutions to address degradation issues, farmers have adopted agroforestry systems as an alternative to the loss of plant resources. In some agricultural fields, the number of trees per hectare has been imposed in order to improve the biodiversity of woody plant species. This tree-crop cohabitation has inspired a number of researchers. For that, several studies focused on the tree-crop interactions (PALLO, 2001, YAMEOGO et *al*., 2004, YELEMOU et *al*., 2013), practices related to the tree conservation in agroforestry parklands (LARWANOU et *al*, 2010) and the factors affecting the woody plant biodiversity in agroforestry parklands (ABEGG et *al*., 2006a). The composition of the woody plant species preserved in the fields could be influenced by the type of management units. Few studies considered this factor. However, in a context of climate change, gathering details on the dynamics of woody plant species in management units would be a major contribution to biodiversity conservation, food security and the adaptation of production systems (PALM et *al*., 2014, SEGHIERI and HARMAND, 2019). This was why this study focused on the dynamics of woody species biodiversity in agroforestry parklands. Therefore, it was to characterize the diversity and health status of the woody plant species based on the type of management unit. The specific objectives were to inventory the woody plant species and regenerations preserved in the management units, and to examine the health status of the woody stands in these agroforestry parklands.

I. Material and methods

1.1. The site of study

The classified forest of Kuinima (FKC) is located in the western part of Burkina Faso in the Houet province (Bobo-Dioulasso) between latitudes 11°03 and 11°7 North and 04°19 and 04°36 West. It covers a surface area of 2,150 ha (YAMEOGO, 2008). The study was carried out in the agroforestry parklands which were surrounded by four (04) villages bordering this forest, namely (Figure 1): Dingasso in South-West of the FCK, Farakoba located in the West, Kuinima in the North and Kouakoualé in the South-East (OUEDRAOGO et *al.*, 2011).

According to THIOMBIANO et *al*. (2010a), the climate in this area is South Sudanian, with an alternating rainy season (May to October) and dry season (November to April). The average rainfall between 727 and 1079 mm from 2012 to 2021. The average monthly temperatures ranged from 22.4°C to 33.70°C, with an annual average of 27.97°C. Most of the soils are of the tropical ferruginous type. The FCK belongs to the Southern Sudanian phytogeographical zone and its vegetation is a mosaic of forest comprising gallery forest, open forest, plantations, wooded savannah, trees and shrubs.

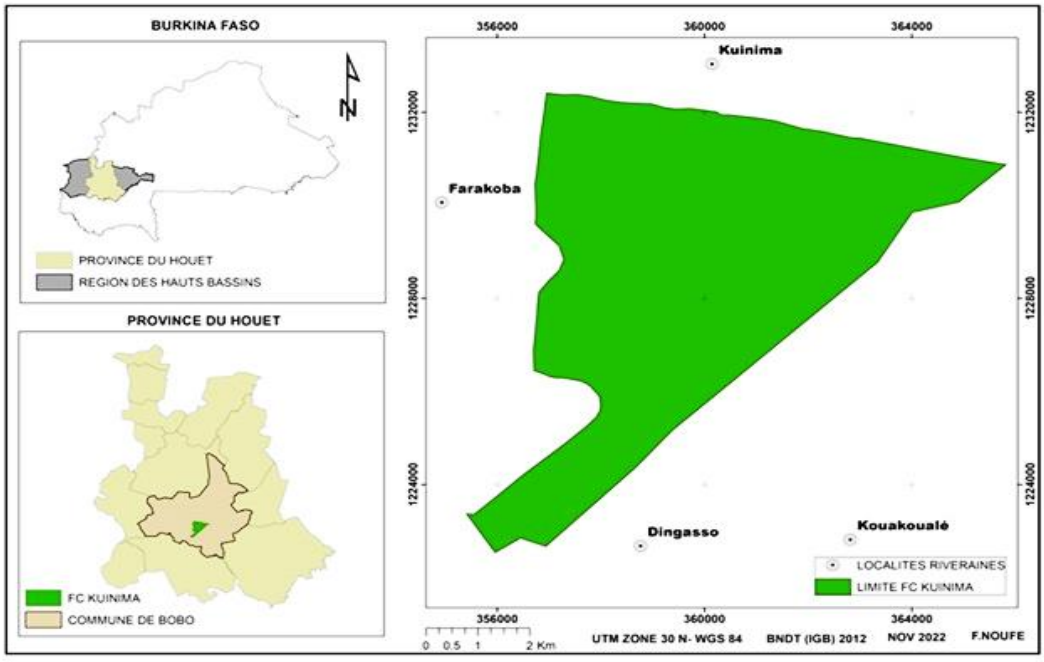


Figure 1: Map of Kuinima classified forest with surrounding villages

1.2. Floristic inventories

The inventory consisted of setting up 2,500 m² square plots (50 m x 50 m) in the agroforestry parklands. The types of agroforestry parkland are management units, including hut fields (HF) near houses, village fields (VF) near homes within the village, bush fields (BF) outside the village and lowfonds (L). A total of 84 plots, as shown in Table I, were delimited and woody plant species were systematically counted. In each plot, dendrometric measurements were performed on individuals with a diameter height (DBH) ≥5 cm. Individuals having a diameter less than 5 cm in diameter were included in the regeneration.

Table I: Number and surface area of plots surveyed in the management

N^{O}	Village	Lowfonds	Bush fields	Village fields	Hut fields	TOTAL
1	Dingasso	3	5	6	7	21
2	Farako-Ba	3	7	5	7	22
3	Kouakoualé	3	6	6	7	22
4	Kuinima	3	7	4	5	19
Number of plots		**12**	**25**	**21**	**26**	**84**
Total area (ha)		**2.5**	**6.25**	**5.25**	**6.5**	**20.5**

1.3. Health status

The health status of the inventoried woody plants surveyed was assessed by visual observation (TAFOKOU et *al*., 2010 ; YAMEOGO et *al*., 2020a). Three levels of classification were then used: (1) Healthy individuals: these are individuals with no apparent defects, (2) Attacked individuals: these are individuals with parasites and/or other signs that could affect their health conditions. Attacked individuals were identified by observing the presence of insects on the organs and under the crowns of the inventoried individuals, rodent tracks, perforated leaves, etc. (3) Cut individuals: these are individuals showing signs due to human action (pruning, skinning, accentuated signs of fire). This classification was inspired by NACOULMA et *al*. (2011) and YAMEOGO et *al*. (2020b).

1.4. Data analysis

The list of inventoried plant species in the management units of the surrounding villages of FCK was drawn up using the flora identification method of ARBONNIER (2009). For the floristic composition, the nomenclature of LEBRUN et STORK (1991) was used. The following biodiversity parameters were calculated based on the collected data :

- **Rarity Index (RI)**

The Rarity Index was allowed to assess the availability of plant species used by the population in the FCK. This index reflects the frequency at which the plant was observed in the FCK. It was calculated by considering the following equation :

$$\boldsymbol{RI = \left(1 - \frac{n_i}{N}\right) \times 100}$$

ni = number of records in which species i was present and N = total number of records. The established thresholds of TRAORE et *al*. (2011a) on Sudanian plant were used for data interpretation: RI< 60%, for very frequent species in plant formations, 60 ≤ RI< 80% for moderately frequent species and RI ≥80% for so-called rare species.

- **Species richness**

Species richness was determined based on all records carried out in each management unit. This index enabled us to assess the species richness of each unit.

- **Specific diversity**

The specific diversity of the woody stands was assessed by calculating the following indices for each site.

- The Shannon-Weaver diversity index (H) is expressed by the following formula

The Shannon-Weaver diversity index (H') measures the order (or disorder) of a system. It takes into account the relative abundance of species and is defined by :

$$\boldsymbol{H' = \sum_{i=1}^{s} Pi\, ln\, Pi}$$

S is the species richness, pi is the relative abundance of species i. This index generally varies from 0 to 5 bits. It is low when H' is less than 2.5 bits ; medium if H' is between 2.5 and less than 4 ; high when H' is greater than or equal to 4 bits (BARMO et *al*., 2019).

- The Piélou Equitability Index (E) measure the relative abundance of the different species that make up the richness of an area. The higher it is, the more species number of species involved in the it is expressed by :

$$\boldsymbol{E = \frac{H'}{ln\, S}}$$

H' is the Shannon-Weaver diversity index, lnS is the theoretical value of the maximum diversity that can be achieved in each environment environment; it corresponds to a state of equal distribution distribution of all individuals among all the species in the environment. This index varies from 0 to 1. Is low for E < 0.6; medium for E in the range 0.6 to 0.70; high for E ≥ 0.8 (BARMO et *al*., 2019).

- **Regeneration rate**

The regeneration was assessed by calculating the stand regeneration rate (SRR) according to the equation below. It is determined by the ratio between the total number of young seedlings (diameter <5 cm) and the total number species in the stand (POUPON, 1980).

$$\mathbf{SRR} = \frac{\textbf{Total number of seedlings}}{\textbf{Total nimber of trees in stand}} \mathbf{\ x\ 100}$$

According to the ROTHE (1964), this rate is used to determine the regeneration capacity of a species:

- less than 100% : regeneration difficulties,

- between 100% and 1000% : good regeneration,

- above 1000% : very good regeneration.

- **Density**

The average density (D) is obtained by dividing the total number of individuals in the management unit in question (N) by the surface area of the management unit in question (S). It is expressed as the number of individuals/ha.

$$\boldsymbol{D = \frac{N}{S}}$$

II. Results

2.1. Woody species diversity in the management unit

Analysis of the inventory data allowed to identify 47 woody species in the management units in the surrounding villages of FCK (Table II). Results showed that Bush fields and village fields had the highest number of species, with 40 and 37 respectively, out of the 47 observed species. The most common species in all management units was *Vitellaria paradoxa* Gaertn.F. It was frequent in lowfonds, hut fields, village fields and bush fields by 35.45%, 31.34%, 28.51% and 27.59% respectively. This species was followed by *Azadirachta indica* A.Juss. [cult.] was recorded with 9.72% and 9.02% respectively in the bush fields and hut fields. Next, *Detarium microcarpum* Guill. & Perr (9.18% in village fields) and *Tamarindus indica* L with 9.09% in lowfonds were recorded. Species such as *Citrus limon* (0.43%) and *Moringa oleifera* (0.43%) were found only in the hut fields. Spiny woody species (*Ziziphus mauritiana* Land and *Dichrostachys cinerea* L.Wight & Arn.) were only found in bush fields. The analysis also revealed a total of 22 families. The family with the largest number of species were Fabaceae with 10 species and Anacardiaceae with 6 species.

Table II : List of species found in the different management units in order of priority and their frequency

Rank	Lowfonds (%)	Bush fields (%)	Village fields (%)	Hut fields (%)
1	*Vitellaria paradoxa (35.45)*	*Vitellaria paradoxa (27.59)*	*Vitellaria paradoxa (28.51)*	*Vitellaria paradoxa (31.34)*
2	*Tamarindus indica (9.09)*	*Azadirachta indica (9.72)*	*Detarium microcarpum (9.18)*	*Azadirachta indica (9.02)*
3	*Detarium microcarpum (6.36)*	*Tamarindus indica (8.47)*	*Parkia biglobosa (9.18)*	*Terminalia avicennoides (7.73)*
4	*Parkia biglobosa (6.36)*	*Parkia biglobosa (7.84)*	*Azadirachta indica (8.22)*	*Parkia biglobosa (7.73)*
5	*Mangifera indica (4.54)*	*Adansonia digitata (5.33)*	*Terminalia avicennoides (4.84)*	*Tamarindus indica (5.58)*
6	*Terminalia avicennoides (4.54)*	*Detarium microcarpum (5.02)*	*Tamarindus indica (3.87)*	*Burkea africana (3.87)*
7	*Azadirachta indica (4.54)*	*Mangifera indica (4.08)*	*Adansonia digitata (3.39)*	*Daniellia oliveri (3.87)*
8	*Khaya senegalensis (3.63)*	*Terminalia avicennoides (3.45)*	*Daniellia oliveri (2.9)*	*Detarium microcarpum 3.87)*
9	*Borassus akeassii (2.72)*	*Anacardium occidentale (2.51)*	*Eucalyptus camaldulensis (2.9)*	*Adansonia digitata (3.44)*
10	*Bombax costatum (2.72)*	*Khaya senegalensis (2.5)*	*Anacardium occidentale (2.42)*	*Senna siamea (3.01)*
11	*Anacardium occidentale (1.81)*	*Eucalyptus camaldulensis (2.51)*	*Annona senegalensis (1.94)*	*Anacardium occidentale (2.58)*
12	*Daniellia oliveri (1.81)*	*Burkea africana (2.2)*	*Khaya senegalensis (1.94)*	*Annona senegalensis (2.15)*
13	*Gmelina arborea (1.81)*	*Daniellia oliveri (2.2)*	*Saba senegalensis (1.45)*	*Faidherbia albida (2.15)*

14	*Adansonia digitata (1.81)*	*Diospyros mespiliformis (1.89)*	*Elaeis guineensis (1.45)*	*Mangifera indica (1.72)*
15	*Ficus sycomorus (1.81)*	*Annona senegalensis (1.57)*	*Senna siamea (1.45)*	*Eucalyptus camaldulensis (1.72)*
16	*Eucalyptus camaldulensis (1.81)*	*Ficus sycomorus (1.57)*	*Piliostigma thonningii (1.45)*	*Borassus akeassii (1.29)*
17	*Sclerocarya birrea (0.9)*	*Senna siamea (1.26)*	*Tectona grandis (1.45)*	*Ceiba pentandra (1.29)*
18	*Annona senegalensis (0.9)*	*Sclerocarya birrea (0.95)*	*Ceiba pentandra (1.45)*	*Lannea microcarpa (0.86)*
19	*Hyphaena thebaica (0.9)*	*Gmelina arborea (0.95)*	*Ficus sycomorus (1.45)*	*Maranthes polyandra (0.86)*
20	*Guiera senegalensis (0.9)*	*Lannea microcarpa (0.63)*	*Mangifera indica (0.97)*	*Isoberlinia doka (0.86)*
21	*Diospyros mespiliformis (0.9)*	*Pteleopsis suberosa (0.63)*	*Faidherbia albida (0.97)*	*Piliostigma thonningii (0.86)*
22	*Burkea africana (0.9)*	*Isoberlinia doka (0.63)*	*Gardenia erubescens (0.97)*	*Khaya senegalensis (0.86)*
23	*Pterocarpus erinaceus (0.9)*	*Prosopis africana (0.63)*	*Balanites aegyptiaca (0.97)*	*Sclerocarya birrea (0.43)*
24	*Lophira lanceolata (0.9)*	*Tectona grandis (0.63)*	*Maranthes polyandra (0.49)*	*Elaeis guineensis (0.43)*
25	*Lannea microcarpa (0.9)*	*Trichelia emetica (0.63)*	*Sclerocarya birrea (0.49)*	*Guiera senegalensis (0.43)*
26	*Sterculia setigera (0.9)*	*Lannea acida (0.32)*	*Borassus akeassii (0.49)*	*Diospyros mespiliformis (0.43)*
27	-	*Borassus akeassii (0.32)*	*Guiera senegalensis (0.49)*	*Tectona grandis (0.43)*
28	-	*Elaeis guineensis (0.32)*	*Pteleopsis suberosa (0.49)*	*Bombax costatum (0.43)*

29	-	*Cordia mixa (0.32)*	*Burkea africana (0.49)*	*Moringa oleifera (0.43)*
30	-	*Combretum fragans (0.32)*	*Isoberlinia doka (0.49)*	*Citrus limon (0.43)*
31	-	*Guiera senegalensis (0.32)*	*Pterocarpus erinaceus (0.49)*	-
32	-	*Faidherbia albida (0.32)*	*Gmelina arborea (0.49)*	-
33	-	*Pterocarpus erinaceus (0.32)*	*Bombax costatum (0.49)*	-
34	-	*Bombax costatum (0.32)*	*Sterculia setigera (0.49)*	-
35	-	*Ceiba pentandra (0.32)*	*Trichelia emetica (0.49)*	-
36	-	*Sterculia setigera (0.32)*	*Lophira lanceolata (0.49)*	-
37	-	*Securidaca longepedunculata (0.32)*	*Securidaca longepedunculata (0.49)*	-
38	-	*Ziziphus mauritiana (0.32)*	.	-
39	-	*Gardenia erubescens (0.32)*	.	-
40	-	*Dichrostachys cinerea (0.32)*	.	-
	n=26	**n=40**	**n=37**	**n=30**

n*=number of species. Numbers in brackets indicate frequencies.*

2.2. Origins of woody plants in the management units

The management units around the FCK were characterized by fairly high proportions of plants originating from Assisted Natural Regeneration (ANR). These proportions were found to be 75% in the bush fields, 62% in the lowfonds and 52% in the village fields. Only the species in the hut fields were mostly from plantations and seedlings, with 52% and 28% of individuals respectively (Figure 2).

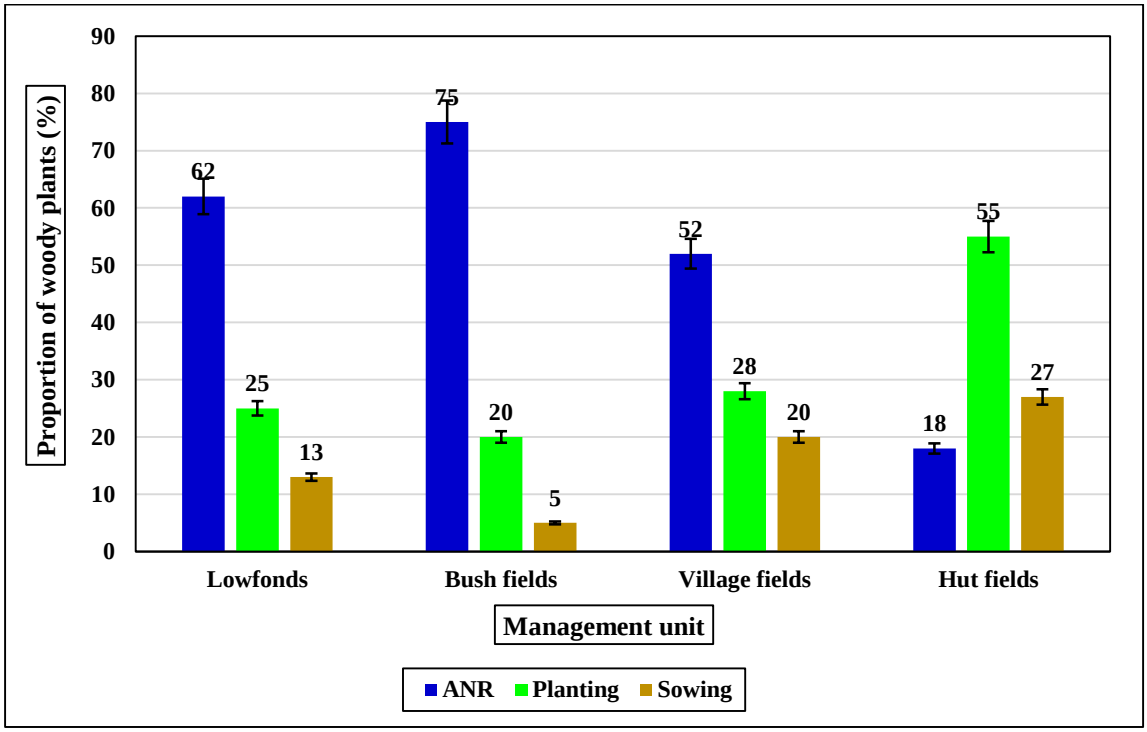


Figure 2: Origin of woody vegetation in the management units

2.3. Densities of woody species in the management units

In a surface area of 20.5 ha, 339 individuals were inventoried in the management units, with an average of 17 individuals/ha (Table III). With regards to the density of individuals, it varied from one management unit to another. It was found to be remarkably higher in the bush fields with 23 individuals/ha than in the village and hut fields which were 19 and 11 individuals/ha, respectively. The density was relatively low in the lowfonds, with only 8 individuals/ha.

Table III : Woody plants density in the management units

Management units	Total individuals	Inventoried area (ha)	Average density (Individuals/ha)
Lowfonds	20	2.5	8±3
Bush fields	143	6.25	23±15
Village fields	102	5.25	19±9
Hut fields	74	6.5	11±7
Total	**339**	**20.5**	**17±11**

2.4. Specific diversity

- ***Diversity index***

The species richness was relatively very low for the types of management unit. There are 47 woody species.

The Shannon diversity index was 2.10 bits for bush fields, 2.09 bits for village fields, 2.01 bits for hut fields and 1.96 bits for lowfonds (Table IV). The Piélou equitability index is virtually identical for all management units. It was 0.60, 0.56, 0.58 and 0.59 respectively for the lowfonds, village fields, bush fields and hut fields.

Table IV : Species diversity indices in the management units

Type of management unit	Number of species	Number of family	Indices	
			Shannon diversity (Bits)	Piélou equitability
Lowfonds	**26**	**13**	**1.96**	**0.60**
Bush fields	**40**	**18**	**2.10**	**0.58**
Village fields	**37**	**16**	**2.09**	**0.56**
Hut fields	**30**	**14**	**2.01**	**0.59**

- ***Species rarity index***

Analysis of species frequency enabled us to calculate the rarity indices for the inventoried species. The interpretation was performed by using the thresholds proposed by (TRAORE et *al*., 2011b) for Sudanian plant. Results showed that only 4 species were considered frequent regardless of the management units. These species were *Vitellaria paradoxa*, *Azadirachta indica*, *Parkia biglobosa* and *Tamarindus indica*. It also highlighted that 5 species were considered to be moderately frequent regardless of the management unit (*Detarium microcarpum*, *Adansonia digitata*, *Terminalia avicennoides*, *Daniellia oliveri*, *Khaya senegalensis*). Further, the species considered rare were 31 in the bush fields, 28 in the village fields, 21 in the hut fields and 17 in the lowfonds (Table V).

Table V: Status of the species in the management units based on the rarity index.

Unit Indices and Status	Lowfonds	Bush fields	Village fields	Hut fields
RI < 60 Frequent species	*Vitellaria paradoxa, Azadirachta indica, Parkia biglobosa, Tamarindus indica* (4)	*Vitellaria paradoxa, Azadirachta indica, Parkia biglobosa, Tamarindus indica* (4)	*Vitellaria paradoxa, Azadirachta indica, Parkia biglobosa, Tamarindus indica* (4)	*Vitellaria paradoxa, Azadirachta indica, Parkia biglobosa, Tamarindus indica* (4)
60 ≤ RI < 80 Moderately frequent species	*Detarium microcarpum, Adansonia digitata, Terminalia avicennoides, Daniellia oliveri, Khaya senegalensis* (5)	*Detarium microcarpum, Adansonia digitata, Terminalia avicennoides, Daniellia oliveri, Khaya senegalensis* (5)	*Detarium microcarpum, Adansonia digitata, Terminalia avicennoides, Daniellia oliveri, Khaya senegalensis* (5)	*Detarium microcarpum, Adansonia digitata, Terminalia avicennoides, Daniellia oliveri, Khaya senegalensis* (5)
RI ≥ 80 Rare species	*Anacardium occidentale, Burkea africana, Eucalyptus camaldulensis, Ficus sycomorus,Borassus akeassii, Sclerocarya birrea, Sterculia setigera, Gmelina arborea, Guiera senegalensis, Hyphaena thebaica, Bombax costatum, Annona senegalensis, Pterocarpus erinaceus, Diospyros*	*Anacardium occidentale, Mangifera indica, Annona senegalensis, Burkea africana, Eucalyptus camaldulensis, Senna siamea, Ficus sycomorus,Borassus akeassii, Faidherbia albida, Ceiba pentandra, Bombax costatum, Isoberlinia*	*Anacardium occidentale, Magifera indica, Annona senegalensis, Burkea africana, Eucalyptus camaldulensis, Senna siamea, Ficus sycomorus,Borassus akeassii, Isoberlinia doka, Sclerocarya birrea, Tectona grandis, Elaeis guineensis, Balanites aegyptiaca, Pteleopsis suberosa, Securidaca longepedunculata, Trichelia*	*Anacardium occidentale, Mangifera indica, Annona senegalensis, Burkea africana, Eucalyptus camaldulensis, Senna siamea, Borassus akeassii, Faidherbia albida, Ceiba pentandra, Bombax costatum, Isoberlinia doka, Sclerocarya*

	mespiliformis, Mangifera indica, Lophira lanceolota, Lannea microcarpa (17)	*doka, Sclerocarya birrea, Tectona grandis, Elaeis guineensis, Dichrostachys cinerea, Gmelina arborea, Guiera senegalensis, Gardenia erubescens, Pterocarpus erinaceus, Sterculia setigera, Pteleopsis suberosa , Securidaca longepedunculata, Trichelia emetica, Diospyros mespiliformis, Prosopis africana, Lannea microcarpa, Lannea acida, Cordia mixa, Combretum fragans, Ziziphus mauritiana* (31)	*emetica, Saba senegalensis, Piliostigma thonningii, Faidherbia albida, Ceiba pentandra, Gardenia erubenscens, Maranthes polyandra, Guiera senegalensis, Pterocarpus erinaceus, Gmelina arborea, Bombax costatum, Sterculia setigera, Lophira lanceolota* (28)	*birrea, Tectona grandis, Elaeis guineensis, Diospyros mespiliformis, Piliostigma thonningii, Lannea microcarpa, Moringa oleifera, Maranthes polyandra, Guiera senegalensis, Citrus limon* (21)
Total species	**26**	**40**	**37**	**30**

2.5. Plants regeneration status in the management units

Analysis of data regarding the woody plants regeneration within the management units around the FCK showed that 44 species belonging to 43 genera and 19 families were inventoried. The regeneration was low in all management units, with plant densities being less than 22 individuals/ha (Table VI). These densities were 21.28 in bush fields with a dominance of *Daniella oliveri* (3.2 individuals/ha), 18.36 in village fields with a dominance of *Vitellaria paradoxa* (2.48 individuals/ha), 12.8 in lowfonds with a dominance of *Annona senegalensis* (2.4 individuals/ha) and 10.47 in hut fields with a dominance of *Vitellaria paradoxa* (1.7 individuals/ha).

Tables VI : Regeneration density in the management units

Unit Rank	Lowfonds (Individuals/ha)	Bush fields (Individuals/ha)	Village fields (Individuals/ha)	Hut fields (Individuals/ha)
1	*Annona senegalensis (2.4)*	*Daniellia oliveri (3.2)*	*Vitellaria paradoxa (2.48)*	*Vitellaria paradoxa (1.7)*
2	*Detarium microcarpum (2)*	*Detarium microcarpum (2.4)*	*Daniellia oliveri (1.91)*	*Detarium microcarpum (0.93)*
3	*Vitellaria paradoxa (2)*	*Annona senegalensis (2.24)*	*Detarium microcarpum (1.72)*	*Adansonia digitata (0.77)*
4	*Gardenia erubescens (1.6)*	*Piliostigma thonningii (1.92)*	*Piliostigma thonningii (1.53)*	*Azadirachta indica (0.77)*
5	*Pterocarpus erinaceus (1.2)*	*Azadirachta indica (1.76)*	*Azadirachta indica (1.34)*	*Parkia biglobosa (0.77)*
6	*Parkia biglobosa (0.8)*	*Vitellaria paradoxa (1.6)*	*Annona senegalensis (1.15)*	*Tamarindus indica (0.77)*
7	*Piliostigma thonningii (0.8)*	*Guiera senegalensis (1.44)*	*Gmelina arborea (1.15)*	*Daniellia oliveri (0.62)*
8	*Adansonia digitata (0.4)*	*Lophira lanceolota (1.28)*	*Guiera senegalensis (1.15)*	*Anacardium occidentale (0.47)*
9	*Borassus akeassii (0.4)*	*Khaya senegalensis (0.8)*	*Burkea africana (0.96)*	*Guiera senegalensis (0.47)*
10	*Burkea africana (0.4)*	*Senna siamea (0.64)*	*Khaya senegalensis (0.96)*	*Mangifera indica (0.47)*

Unit Rank	Lowfonds (Individuals/ha)	Bush fields (Individuals/ha)	Village fields (Individuals/ha)	Hut fields (Individuals/ha)
11	*Daniellia oliveri (0.4)*	*Pterocarpus erinaceus (0.64)*	*Lophira lanceolota (0.77)*	*Piliostigma thonningii (0.47)*
12	*Ficus sycomorus (0.4)*	*Burkea africana (0.48)*	*Parkia biglobosa (0.77)*	*Annona senegalensis (0.31)*
13		*Gardenia erubescens (0.48)*	*Adansonia digitata (0.58)*	*Bombax costatum (0.31)*
14		*Parkia biglobosa (0.48)*	*Pterocarpus erinaceus (0.58)*	*Senna siamea (0.31)*
15		*Terminalia avicennoides (0.48)*	*Gardenia erubescens (0.39)*	*Eucalyptus camaldulensis (0.31)*
16		*Diospyros mespiliformis (0.32)*	*Mangifera indica (0.39)*	*Khaya senegalensis (0.31)*
17		*Gmelina arborea (0.32)*	*Tamarindus indica (0.39)*	*Citrus limon (0.31)*
18		*Securidaca longipedunculata (0.32)*	*Anacardium occidentale (0.2)*	*Moringa olifera (0.31)*
19		*Tamarindus indica (0.32)*	*Borassus akeassii (0.2)*	*Gmelina arborea (0.16)*
20		*Borassus akeassii (0.16)*	*Senna siamea (0.2)*	
21			*Terminalia avicennoides (0.2)*	
	n=12	**n=20**	**n=21**	**n=19**
	d=12.8	**d=21.28**	**d=18.86**	**d=10.47**

***n** : number of species in the management unit; **d**: species density in the management unit. Numbers in brackets indicate woody species densities*

The regeneration rate was almost similar among species in the management units. However, in all management units, the rate was below 50% (Table VII). With regards to the fields, the regeneration rate was 49.26% in village fields, 48.19% in bush fields, 47.86% in hut fields and 46.38% in lowfonds. The species having high regeneration rate were *Daniellia oliveri* (3.2% in the bush fields), *Vitellaria paradoxa* (2.48% and 1.7% respectively in the village and hut fields) and *Annona senegalensis* (2.4% in the lowfonds).

Tables VII : Species regeneration status rates in the management units

Unit / Rank	Lowfonds (%)	Bush fields (%)	Village fields (%)	Hut fields (%)
1	*Annona senegalensis (8.7)*	*Daniellia oliveri (7.25)*	*Vitellaria paradoxa (6.47)*	*Vitellaria paradoxa (7.75)*
2	*Detarium microcarpum (7.25)*	*Detarium microcarpum (5.44)*	*Daniellia oliveri (4.98)*	*Detarium microcarpum (4.23)*
3	*Vitellaria paradoxa (7.25)*	*Annona senegalensis (5.08)*	*Detarium microcarpum (4.48)*	*Adansonia digitata (3.53)*
4	*Gardenia erubescens (5.8)*	*Piliostigma thonningii (4.35)*	*Piliostigma thonningii (3.99)*	*Azadirachta indica (3.53)*
5	*Pterocarpus erinaceus (4.35)*	*Azadirachta indica (3.99)*	*Azadirachta indica (3.49)*	*Parkia biglobosa (3.53)*
6	*Parkia biglobosa (2.9)*	*Vitellaria paradoxa (3.63)*	*Annona senegalensis (2.99)*	*Tamarindus indica (3.53)*
7	*Piliostigma thonningii (2.9)*	*Guiera senegalensis (3.27)*	*Gmelina arborea (2.99)*	*Daniellia oliveri (2.82)*
8	*Adansonia digitata (1.45)*	*Lophira lanceolota (2.9)*	*Guiera senegalensis (2.99)*	*Anacardium occidentale (2.12)*
9	*Borassus akeassii (1.45)*	*Khaya senegalensis (1.82)*	*Burkea africana (2.49)*	*Guiera senegalensis (2.12)*
10	*Burkea africana (1.45)*	*Senna siamea (1.45)*	*Khaya senegalensis (2.49)*	*Mangifera indica (2.12)*

11	*Daniellia oliveri (1.45)*	*Pterocarpus erinaceus (1.45)*	*Lophira lanceolota (2)*	*Piliostigma thonningii (2.12)*
12	*Ficus sycomorus (1.45)*	*Burkea africana (1.09)*	*Parkia biglobosa (2)*	*Annona senegalensis (1.41)*
13		*Gardenia erubescens (1.09)*	*Adansonia digitata (1.5)*	*Bombax costatum (1.41)*
14		*Parkia biglobosa (1.09)*	*Pterocarpus erinaceus (1.5)*	*Senna siamea (1.41)*
15		*Terminalia avicennoides (1.09)*	*Gardenia erubescens (1)*	*Eucalyptus camaldulensis (1.41)*
16		*Diospyros mespiliformis (0.73)*	*Mangifera indica (1)*	*Khaya senegalensis (1.41)*
17		*Gmelina arborea (0.73)*	*Tamarindus indica (1)*	*Citrus limon (1.41)*
18		*Securidaca longipedunculata (0.73)*	*Anacardium occidentale (0.5)*	*Moringa olifera (1.41)*
19		*Tamarindus indica (0.73)*	*Borassus akeassii (0.5)*	*Gmelina arborea (0.71)*
20		*Borassus akeassii (0.37)*	*Senna siamea (0.5)*	
21			*Terminalia avicennoides (0.5*	
	n=12	**n=20**	**n=21**	**n=19**
	SRR=46.38	**SRR=48.19**	**SRR=49.26**	**SRR=47.89**

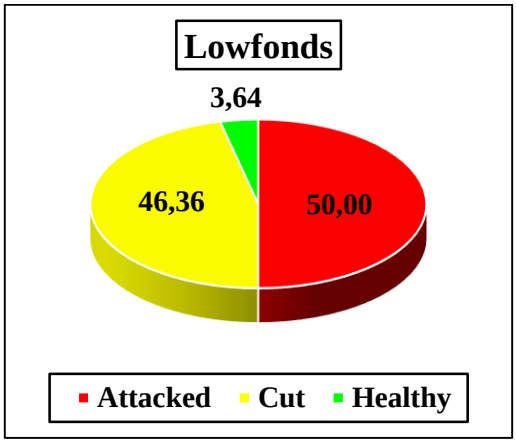
***n** : number of species in the management unit, **SRR**: species regeneration rate in the management units. Numbers in brackets indicate regeneration rates*

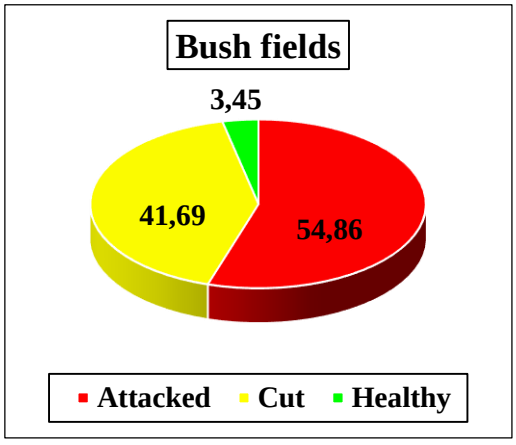
2.6. Health status of the woody plants in agroforestry parklands

Analysis of the health conditions of trees in the FCK management units showed that more than 50% of species, except those in the hut fields, were under parasites attack (Figure 3). These attacks were caused by termites (Photo 1), particularly *Odontotermes erraticus*, ants and mainly Loranthaceae. In the hut fields, 50% of the trees were cut (Photo 2), while in the other three units, the rate was over 40%. These cuts trees can be identified by observing the signs of machete use on the trunks and branches of the trees. No more than 5% of trees in any management unit were found to be healthy. These trees had no apparent defects.

Photo 1. Termite attack

Photo 2. Wood cutting





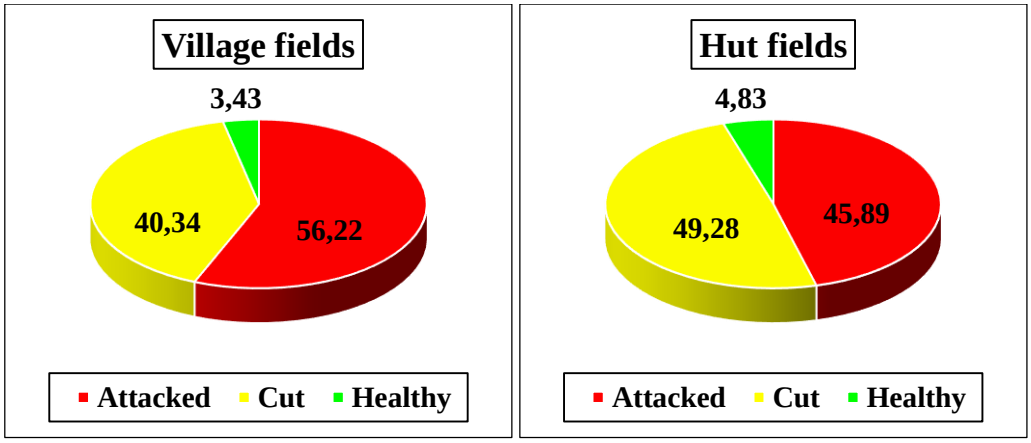


Figure 3 : Health status of the woody plants in agroforestry parklands around the FCK

III. Discussion

3.1. Floristic diversity in agroforestry parklands

Analysis of the richness species in the four management units around the FCK showed 47 species with belonging to 22 families for all four management units. This species richness remains low and was almost the same for all families. This can be explained by the fact that in agricultural areas, farmers only preserve species with huge socio-economic interest. According to ABEGG et *al* (2006b), species which can contribute to the satisfying food needs are the most favored; thus, others species are systematically cleared as a result of the observed low species richness in agroforestry parklands. This preference for certain species by famers because of the goods and services it provide may influence the composition of woody species in the parklands. In this study, the species richness in the agroforestry parklands around FCK was quite higher than that obtained by MOUROU et al (2016), who recorded 37 woody species in agroforestry parklands of Dan Saga terroir (Niger). However, our results were almost similar to those obtained by OUSMANE et *al*. (2017) who recorded 46 species belonging to 22 families and 38 genera in the Guidan Roumdji area in central Niger. This variation in the composition of woody plants within the parklands is due to the differences related to the study areas and the local population needs as demonstrated by BAGGNIAN et *al*. (2014). For these authors, the composition and structure of woody vegetation varies considerably from one locality to another depending on environmental factors and anthropogenic disturbances. Despite these factors, enormous efforts have been made by producers to maintain the biodiversity of woody plants in agroforestry parklands. However, the cultivation land use was commonly considered as one of the causes of major disturbance to vegetation (TRAORE et *al*. 2011c; Bayala et *al*, 2014, BOUKO et *al*., 2007). Nevertheless, species such as *Vitellaria*

paradoxa and *Parkia biblobosa* were considerably common in most agroforestry parklands in western Burkina Faso (OUOBA et *al*., 2018). For MBAIYETOM et *al*. (2021), their presence could be linked to the favourable environmental conditions and because of their socio-economic importance (YAOVI et *al*, 2021). In addition, apart from these emblematic species, some famers do not hesitate to introduce certain exotic species in their agricultural fields. This was the case for *Anacardium occidentale* being introduced and considered to be a species of economic interest in the western part of Burkina Faso.

The distribution of agroforestry parks following the origin of the woody species indicates that most of these species, except those from the hut fields, derived from Assisted Natural Regeneration (ANR). This practice simply consists of selecting and protecting young seedlings, then allowing plants to grow in their natural biotope without addition of exogenous plants. These results were justified by the fact that when a new park is created, farmers tend to save and maintain the woody species. This corroborated with results of LARWANOU et *al*. (2010) and BAGGNIAN et *al*. (2014). According to these authors, this behavior of farmers seems to be related to various reasons of which the main ones were the supply of firewood, the production of edible fruits, the pharmacopoeia and the palatability of the species.

The values of the Shannon diversity indices in the management units around FCK were relatively close, as it was for Piélou equitability indices. This showed that the four studied agroforestry parks are in the same geographical area, with almost the same land area. These values, regardless of the agroforestry park type, were below 2.5 bits, highlighting that the woody plant biodiversity was low in the management units around the FCK. The dominance of certain species such as *Vitellaria paradoxa* Gaertn.f compared to other recorded species could explain this low value of the various indices.

Our results were in line with those of YAMEOGO et *al*. (2005) who observed the same tendency in agroforestry parklands in Vipalogo terroir (Burkina Faso). They noted a low diversity index due to the high number of *Vitellaria paradoxa* Gaertn.f species, which dominated all other species. This was because the important socio-cultural, economic, medicinal, food and agroforestry characteristics of this species (BAYALA et *al*., 2006, GNANGLE et *al*., 2009).

With regards to species rarity, it was shown that out of the 47 recorded species, only 4 species had a RI< 60%, and therefore were considered frequent (*Vitellaria paradoxa* Gaertn.f, *Azadirachta indica* A. Juss. [cult.], *Parkia biglobosa* (Jacq.) Benth, *Tamarindus indica* L), 5 were moderately frequent (60 ≤ IR< 80%) and 38 species were rare (IR ≥80%). In fact, the need for additional agricultural lands in order to increase production would be the main reason for farmers to systematically clear certain areas, leading to the disappearance of certain species (BOUKO et *al*., 2007) which are considered to be less

useful. This practice considerably affects the growth and flourishing of certain species, which disappear over time.

3.2. Regeneration status in agroforestry parklands

Analysis of woody plants regeneration in the agroforestry parks around the FCK showed that 44 species organized into 43 genera and 19 families were found. Regeneration was low regardless of the management units. This indicated the difficulty of regenerating individuals. According to THIOMBIANO et *al*. (2010b), poor regeneration in agroforestry parks appeared as a result of agricultural practices. In the management units around the FCK, regeneration was dominated by by *Vitellaria paradoxa* Gaertn.f in the village and hut fields because local people tend to intentionally keep the adult reproductive plants which allowed the natural regeneration in these areas (LOVETT et HAQ, 2000). This was also the case for species such as *Azadirachta indica* A. Juss. [cult.] and *Parkia biglobosa* (Jacq.) Benth which, apart being monitored by RNA, were also planted in the fields. However, the seedlings are often vulnerable to degradation factors. OUEDRAOGO et *al*. (2006) found that in the Sudanian zone of Burkina Faso, the main degradation factors were fire, drought and animal grazing.

3.3. Analysis of health status

Analysis of the plants health conditions revealed that more than 50% of the inventoried woody individuals, except those in the hut fields, were attacked by parasites, mainly *Tapinanthus* and certain insects (termites, ants and caterpillars). The identified species of termite was *Odontotermes erraticus*, which would be less dangerous for woody species. It is known to attack much more crops than other plants, showing its presence in the management units. In fact, after harvests and due to the presence of crop residues on the soil, this species grows and attacks the trunks of woody species such as *Vitellaria paradoxa* Gaertn.f, *Azadirachta indica* A. Juss. [cult.], *Parkia biglobosa* (Jacq.) Benth and *Mangifera indica*. Caterpillars are most frequently observed on the leaves of *Vitellaria paradoxa* Gaertn.f, while ants on *Mangifera indica* and *Azadirachta indica* A. Juss. [cult.]. *Tapinanthus* grows on *Vitellaria paradoxa* Gaertn.f and *Tamarindus indica* L. These results showed the fairly high level of infestation in the management units. This could be as a result of agricultural practices within these management units, which create favorable conditions for the spread of parasites. In addition to humans, TAFOKOU et *al*. (2010) showed that birds and pollinators are the main vectors for parasites spreading through host trees.

Conclusion

This study allowed to characterize the woody component of agroforestry parks by considering different types of fields. Thus, the composition of woody species was different from one park to another and above all was a function of the farmers choice which depends on certain specific needs. For food reasons (leaves and fruits), famers would prefer species such as *Moringa oleifera* and *Citrus limon* in the hut fields, whereas thorny woody species (*Ziziphus mauritiana* and *Dichrostachys cinerea*) are systematically cleared in these fields as well as in the village fields. These species were only recorded in bush fields. This study highlighted that density of woody plants was low in both lowfonds and hut fields as a result of the need for space for crop cultivation and building houses. Although species richness was low, it was found that agroforestry parks help to generally conserve biodiversity and particularly a number of plant species (*Vitellaria paradoxa, Parkia biglobosa*). However, the observed low plants regeneration rate and parasite pressure in the parks raise questions about the renewal and survival of woody species in agroforestry parks. It would be important to continue this study in the other phytogeographical zones of Burkina Faso in order to lay the foundations for more sustainable management of these important ecosystems, and to raise farmers' awareness of the need for more rational management of agroforestry parklands.

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