Scientific Research Publishing

American Journal of Plant Sciences, 2023, 14, 1343-1359
https://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

Characterization of Woody Vegetation in Different Land Uses in the Commune of Coubalan (Bignona Department, Senegal)

Francis Artur Gomez, Ismaïla Coly*, Arfang Ousmane Kémo Goudiaby, Mohamed Ndao

Agroforestry and Ecology Laboratory (LAFE), Department of Agroforestry, Assane Seck University, Ziguinchor, Senegal
Email: *icoly@univ-zig.sn

How to cite this paper: Gomez, F.A., Coly, I., Goudiaby, A.O.K. and Ndao, M. (2023) Characterization of Woody Vegetation in Different Land Uses in the Commune of Coubalan (Bignona Department, Senegal). *American Journal of Plant Sciences*, **14**, 1343-1359.
https://doi.org/10.4236/ajps.2023.1411091

Received: September 9, 2023
Accepted: November 21, 2023
Published: November 24, 2023

Abstract

Woody vegetation provides a number of ecosystem services, including soil protection, carbon sequestration and oxygen production. Despite its important role in maintaining ecological balance, woody vegetation is currently undergoing continuous degradation due to climatic hazards and anthropogenic actions. As a result, it is essential to gather information for the sustainable and rational management of woody formations. It is with this in mind that this study aims to contribute to a better understanding of the state of woody vegetation in the different land-use types in Basse Casamance. To this end, stratified random sampling of woody vegetation was carried out in the different land-use types (fields, fallow land and forests) of the Coubalan commune. The sampling unit for fields and fallows was a 2500 m^2 plot, and for forests was a 900 m^2 plot. A total of 53 species, divided into 48 genera belonging to 22 families, were inventoried in the commune. Structural parameters were higher in the forest, with 1321.3 ± 635.8 individuals/ha, 13.09 ± 0.1 m^2 and 79.25% ± 21.08% respectively for observed density, basal area and cover rate. As for dendrometric parameters, they are higher in the fields, with 20.4 ± 13.6 cm and 7.4 ± 3.8 m respectively for trunk diameter and woody height. Fallow land is characterized by species with low dendrometric parameters. These results provide a useful database for rational management of the various land-use types in the commune of Coubalan.

Keywords

Lower Casamance, Forest, Fallow Field, Woody Vegetation

1. Introduction

Woody formations are of vital importance, as they contribute to food security and improved living conditions for millions of people worldwide [1], as well as helping to mitigate the effects of global warming. Between 2015 and 2020, global forest area accounted for 31% of total land area, or 4.06 billion hectares [2]. However, a large proportion of forests are lost through conversion to agricultural land [3] [4] [5]. According to the [6], in tropical and subtropical areas, the main causes of deforestation are large-scale commercial agriculture (responsible for around 40% of deforestation) and local subsistence agriculture (33%). In fact, according to the same source, we are witnessing a major loss of forest land to other land uses (agricultural, industrial, housing, etc.). Added to this is the loss of forest area due to fires, such as the recent fires in the Amazon rainforest and Australia (186,000 km^2) [7]. Moreover, estimates point to a potential increase in the area burned annually of 120% - 270% by 2090, above the 2000-2010 average [2]. Furthermore, according to analyses published in the PNAS (Proceedings of the National Academy of Sciences), global warming is accelerating the loss of biodiversity [8]. As a result, the protection of woody formations through the implementation of rational management strategies is imperative to conserve terrestrial biodiversity and contribute to mitigating the effects of climate change. To achieve this, it is essential to assess the current state of woodland formations. This study is a contribution to a better understanding of the current state of woody vegetation in the different land-use systems of Lower Casamance.

2. Materials and Methods

2.1. Study Area

The study was carried out in Lower Casamance, more precisely in the commune of Coubalan, located south of the Tenghory arrondissement, in the Bignona Department of the Ziguinchor region (**Figure 1**). The climate here is coastal South Sudanian, with two seasons: dry and rainy [9]. Average monthly temperatures range from 21.5˚C to 35˚C between 1990 and 2016 [9]. Average annual rainfall over the 1980-2018 series is 1302.04 mm [10]. The Tenghory district is characterized by a predominance of tropical ferruginous and ferralitic soils [11] cited by [10] and [12]. Lower Casamance boasts the densest forests in Senegal, with trees reaching heights of 15 to 20 meters. There are mangrove areas as well as dense dry forests composed mainly of evergreen species [13] [14] cited by [12] and [15].

2.2. Floristic Inventory and Dendrometric Measurements

Random stratified sampling was carried out for the different land-use types in all 13 villages of the commune of Coubalan. The sampling unit for fields and fallows is a square plot of 50 m × 50 m, *i.e.* a survey area of 2500 m^2 as recommended by [16] for the study of woody vegetation in agroforestry systems. As for forests, plots measuring 30 m × 30 m were set up, *i.e.* an area of 900 m^2 [17] [18] [19]. The plots were, therefore, installed randomly according to land use as follows: 20 plots at field level, 8 plots at fallow level and 12 plots at forest level.

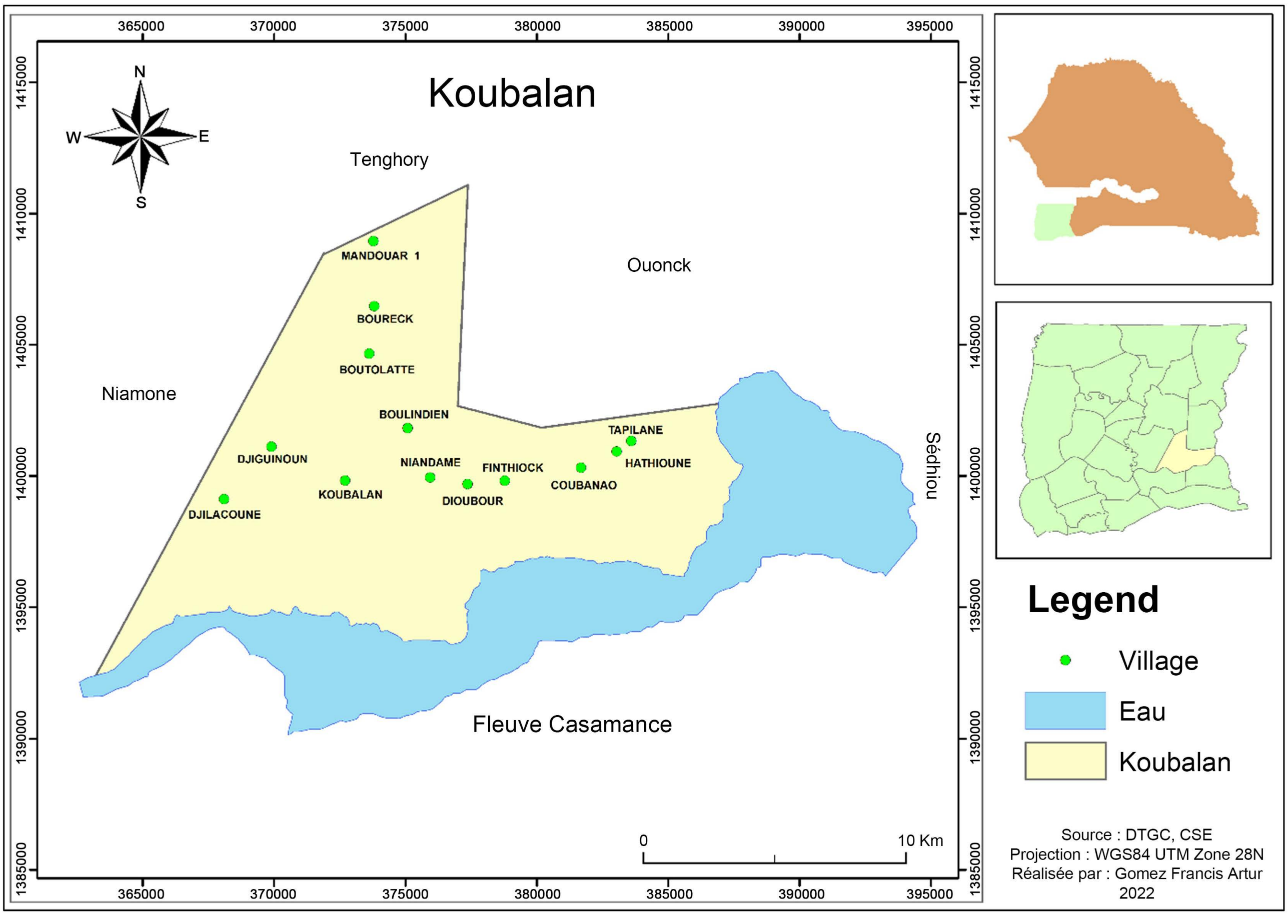

Figure 1. Study area location map.

In each survey, all species were inventoried and the dendrometric parameters of each individual were measured. Total height was measured using a suntoo dendrometer, trunk diameter at breast height using a forestry compass, and cross diameter of the crown (East-West and North-South direction) using a metric tape.

Young trees were counted to assess regeneration. Woody species with a diameter of less than 5 cm at 1.30 m are considered to be regenerating [20]. Individuals of the Arecaceae family with stipes less than 1.30 m high are considered part of the regeneration [21] cited by [22].

2.3. Statistical Processing

The data obtained was entered and the tables and graphs were produced using Excel. XLSTAT Version 2014 software was used to perform the Analysis of Variance (ANOVA), followed by the Newman-Keuls test of comparison of means at the 5% significance level to determine the different groups. A Principal Component Analysis (PCA) was performed to establish the discriminating characteristics of the different land-use patterns.

Various formulas were used to calculate vegetation parameters, including:

Specific frequency

The frequency of occurrence provides information on the distribution of a species in a stand.

It can be expressed as an absolute value or as a percentage. In percentage terms, it is calculated using the following formula:

$$F = Nri/Nr \times 100$$

F = frequency of presence expressed as a percentage (%); *Nri* = number of surveys where species *i* is present; *Nr* = total number of surveys.

Species richness

This is assessed on the basis of total species richness, which is the total number of species present in the stand considered in a given ecosystem [23].

Density

This is the number of individuals per unit area. It is expressed in number of individuals/ha. Observed or actual density is obtained by dividing the total number of individuals in the sample (*N*) by the surface area sampled (*S*).

$$D = N/S$$

D = density (ind/ha); *N* = total number of individuals in the stand; *S* = sample area sample area (ha).

Basal area

This is the surface area occupied by the tree at the base of its trunk. It is expressed in square meters per hectare, and is calculated as follows:

$$St = \left(\sum \pi \left(d1.30/2\right)^2\right)/S$$

St = basal area; *d*1.30 = trunk diameter in m at 1.30 m from the ground; *S* = sample area (ha).

Woody cover

This is the surface area of the tree crown projected vertically onto the ground. It is expressed in square meters per hectare. Woody cover is calculated using the following formula:

$$C = \left(\sum \pi \left(dmh/2\right)^2\right)/S$$

C = woody cover; *dmh* = average crown diameter in m; *S* = sample area (ha).

Shannon weaver index (*H'*)

Consider both abundance and species richness, and is used to assess the distribution of individuals according to species. It ranges from 0 to 4.5. The index is minimum when all individuals belong to the same species. It is maximum when each individual represents a distinct species [24]. It can be expressed in bits and its formula is:

$$H' = -\sum pi.\log 2\, pi$$

Pi = relative abundance of each species.

Evenness index (*E*)

Provide information on the distribution of species abundance in the stand. According to [25], the regularity index is a more rigorous term of comparison. It ranges from 0 to 1. It tends towards 0 when all individuals correspond to a single species. It tends towards 1 when each species is represented by the same number of individuals [23] cited by [26]. This index is given by the following formula:

$$E = H'/H_{\max}$$

H': Shannon Weaver Index; $H_{\max} = \log2(S)$.

Importance Value Index (*IVI*)

This is a synthetic, quantified expression of the importance of a species in a stand. To assess specific preponderance in tropical forests, this index is often used [27] cited by [28]. For better interpretation, the IVI has been expressed as a percentage (%) and is defined as the arithmetic mean, for species *i*, of relative density (*Dr*), relative frequency (*Fr*) and relative dominance (*Domr*).

$$\text{IVI} = \left(Dr + Fr + Domr\right)/3$$

$Dr = (Ni/N) \times 100$ (Dr = relative density (%); Ni = sample size of species i; N = total sample size).

$Fr = (Fi/\text{F}) \times 100$ (Fr = relative frequency (%); Fi = frequency of presence of species i (%); F sum of frequencies of all species in the sample).

$Domr = (Sti/St) \times 100$ ($Domr$ = relative dominance (%); Sti = basal area occupied by species i; St = total basal area of species in sample).

Stand regeneration rate

IL is given by the percentage ratio between the total number of seedlings and the total number of trees in the stand.

SRR = (Total number of seedlings)/(Total number of trees in stand) × 100.

3. Results

3.1. Floristic Composition

The woody flora surveyed in the commune of Coubalan enabled us to identify 53 species, divided into 48 genera belonging to 22 botanical families.

In the fields, 37 species in 34 genera and 17 families were identified; in the fallow land, 28 species in 27 genera and 15 families were identified; and in the forests, 43 species in 41 genera and 19 botanical families were identified (**Table 1**).

Table 1. Floristic composition of woody vegetation by Land Use Patterns (LUPs).

Families	Genera	Species	C	J	F
Anacardiaceae	*Anacardium*	*Anacardium occidentale* L.	+	+	+
	Lannea	*Lannea acida* A. Rich.	+	+	+
	Mangifera	*Mangifera indica* L.	+	−	−
	Spondias	*Spondias mombin* L.	−	−	+
Annonaceae	*Annona*	*Annona senegalensis* Pers.	+	+	+
	Uvaria	*Uvaria chamae* P. Beauv.	+	+	+
Apocynaceae	*Holarrhena*	*Holarrhena floribunda* var. *tomentella* H. Huber	+	−	+
	Landolphia	*Landolphia heudelotii* A. DC.	−	−	+
	Saba	*Saba senegalensis* (A. DC.) Pichon	−	−	+
	Voacanga	*Voacanga africana* Stapf.	−	−	+

Continued

Arecaceae	*Borassus*	*Borassus akeassii* Bayton, Ouédr. & Guinko	+	+	−
	Elaeis	*Elaeis guineensis* var. *microsperma* Welw.	+	+	+
Bignoniaceae	*Newbouldia*	*Newbouldia laevis* (P. Beauv.) Seem. ex Bureau	−	+	+
Bombacaceae	*Adansonia*	*Adansonia digitata* L.	+	−	−
	Bombax	*Bombax costatum* Pellegr. & Vuill.	+	−	+
	Ceiba	*Ceiba pentandra* (L.) Gaertn.	−	+	−
Caesalpiniaceae	*Cassia*	*Cassia sieberiana* DC.	+	+	+
	Daniellia	*Daniellia oliveri* (Rolfe) Hutch. & Dalziel	+	+	+
	Detarium	*Detarium microcarpum* Guill. & Perr.	+	−	+
	Dialium	*Dialium guineense* Willd.	−	−	+
	Peltophorum	*Peltophorum pterocarpum* (DC.) K. Heyne	−	−	+
	Piliostigma	*Piliostigma reticulatum* (DC.) Hochst.	+	−	+
		Piliostigma thonningii (Schumach.) Milne-Redh.	+	+	+
Chrysobalanaceae	*Neocarya*	*Neocarya macrophylla* (Sabine) Prance	+	+	−
Combretaceae	*Combretum*	*Combretum aculeatum* Vent.	+	−	−
		Combretum micranthum G. Don	+	+	+
		Combretum nioroense Aubrév. ex Keay	−	−	+
		Combretum indicum (L.) DeFilipps	−	+	−
	Guiera	*Guiera senegalensis* J.F. Gmel.	+	+	+
	Terminalia	*Terminalia macroptera* Guill. & Perr.	+	+	+
Fabaceae	*Albizia*	*Albizia lebbeck* var. *australis* Burtt Davy	−	+	+
	Erythrina	*Erythrina senegalensis* DC.	+	−	+
	Pterocarpus	*Pterocarpus erinaceus* Poir.	+	−	+
Icacinaceae	*Icacina*	*Icacina oliviformis* (Poir.) J. Raynal var. *oliviformis*	+	−	−
Meliaceae	*Azadirachta*	*Azadirachta indica* A. Juss.	+	+	+
	Khaya	*Khaya senegalensis* (Desr.) A. Juss.	+	+	+
Mimosaceae	*Acacia*	*Acacia ataxacantha* DC.	+	+	+
	Dichrostachys	*Dichrostachys cinerea* var. *argillicola*	+	+	+
	Faidherbia	*Faidherbia albida* (Delile) A. Chev.	+	+	+
	Parkia	*Parkia biglobosa* (Jacq.) R. Br. ex G. Don	+	+	+
	Prosopis	*Prosopis africana* (Guill. & Perr.) Taub.	+	+	+
Moraceae	*Antiaris*	*Antiaris toxicaria* var. *africana* Scott-Elliot ex A. Chev.	+	−	+
	Ficus	*Ficus sycomorus* L.	+	+	−
		Ficus sur Forssk.	−	−	+
Polygalaceae	*Securidaca*	*Securidaca longipedunculata* var. *parvifolia* Oliv.	−	−	+
Rubiaceae	*Nauclea*	*Nauclea latifolia* Sm.	−	−	+
Rutaceae	*Citrus*	*Citrus limon* (L.) Burm. f.	+	−	+
	Zanthoxylum	*Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler	−	−	+
Sapindaceae	*Allophylus*	*Allophylus africanus* var. *griseotomentosus* (Gilg) Verdc.	−	+	+
Simaroubaceae	*Quassia*	*Quassia undulata* (Guill. & Perr.) D. Dietr.	+	+	+
Sterculiaceae	*Cola*	*Cola lateritia* var. *maclaudi* (A. Chev.) Brenan & Keay	+	+	+
Ulmaceae	*Celtis*	*Celtis toka* (Forssk.) Hepper & J.R.I. Wood	+	−	−
		Celtis integrifolia Lam.	+	−	−
Verbenaceae	*Vitex*	*Vitex madiensis* Oliv. subsp. madiensis	−	−	+

3.2. Most Abundant Species

The species with the highest relative abundances in the fields of the Coubalan commune are *Icacina oliviformis* (53.77%), *Guiera senegalensis* (5.43%), *Terminalia macroptera* (2.99%), *Acacia ataxacantha* (1.96%) and *Cassia sieberiana* (1.46%).

In fallow land, the most abundant species is *Guiera senegalensis* with a relative abundance of 79.58%. It is followed by *Cassia sieberiana* (5.01%), *Azadiracta indica* (4.55%), *Combretum micranthum* (4.36%) and *Terminalia macroptera* (1.65%).

In forests, the most abundant species are *Guiera senegalensis* (21.12%), *Combretum micranthum* (20.57%), *Terminalia macroptera* (18.18%), *Combretum nioroense* (14.96%) and *Cassia sieberiana* (3.88%) (**Figure 2**).

3.3. Structural and Dendrometric Parameters of the Woody Stand

With regard to structural parameters, analysis of variance revealed a significant difference in observed density ($P < 0.0001$), cover ratio ($P < 0.0001$) and basal area ($P = 0.003$) between the different land-use types.

In fact, forest density (1321.3 ± 635.8 ind/ha) is statistically higher than that of the other land uses, which show no significant difference between them. Forest density is almost four times that of fallow land (335.5 ± 297.4 ind/ha) and more than thirty-four times that of fields (38.6 ± 26.7 ind/ha) (**Table 2**).

As with density, forest cover was statistically higher (79.25 ± 21.08%) than other land uses, which showed no significant difference between them. Woody vegetation cover in the forest is thus 7 times higher than in the fields (11.373%) and more than 5 times higher than in the fallow land (14.731%).

As for basal area, as for density and cover rate, it is significantly greater in forests (13.09 ± 0.1 m^2/ha) compared to fallow (1.18 ± 0.013 m^2/ha) and fields (2.32 ± 0.024 m^2/ha) (**Table 2**).

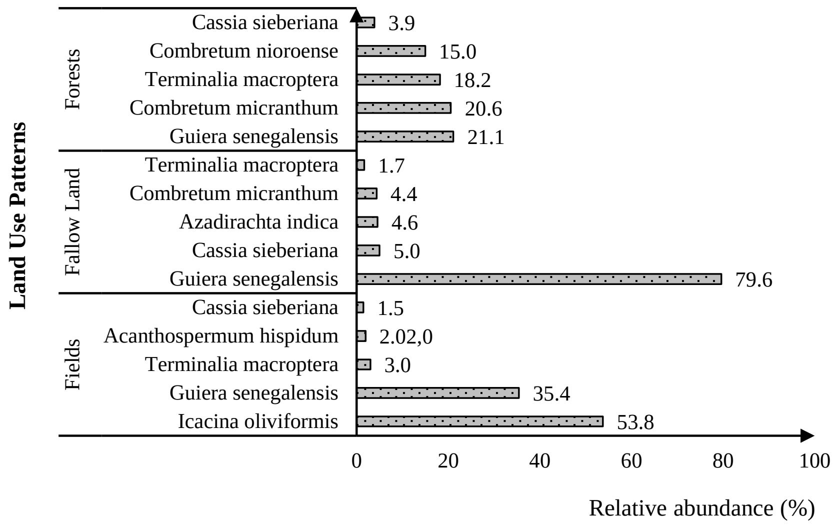

Figure 2. Most abundant species in the different land use patterns.

Table 2. Variation in structural and dendrometric parameters of the woody stand according to the land use patterns.

Land use patterns	Density (ind/ha)	Vegetation cover rate (%)	Basal area (m^2/ha)	Trunk diameter (cm)	Height (m)
Fields	38.6 ± 26.7^b	11.373 ± 5.92^b	2.32 ± 0.024^b	20.4 ± 13.6^a	7.4 ± 3.8^a
Fallow land	335.5 ± 297.4^b	14.731 ± 4.52^b	1.18 ± 0.013^b	3.4 ± 2.1^c	3.05 ± 0.9^c
Forests	1321.3 ± 635.8^a	79.25 ± 21.08^a	13.09 ± 0.1^a	5.4 ± 3.8^b	4.2 ± 1.7^b
P-value	<0.0001	<0.0001	0.003	<0.0001	<0.0001

Legend: ind/ha: individual per hectare. In the same column, values accompanied by the same letters are not significantly different.

In terms of dendrometric parameters, statistical analysis revealed a highly significant difference in woody diameter and height ($P < 0.0001$) between the different land-use types (Table 2).

Average trunk diameter and average woody height are highest in fields, with values of 20.4 cm and 7.4 m respectively, followed by forests, with average trunk diameter of 5.4 cm and average height of 4.2 m. The lowest values for dendrometric parameters were recorded in fallow land, with 3.4 cm and 3.05 m respectively for average trunk diameter and average woody height (Table 2).

3.4. Woody Stand Species Diversity

Analysis of Table 3 shows that the Shannon Weaver index (H') is highest in forests (3.34 bits), followed by fallow land (1.73 bits) and fields (1.37). As for the regularity index (E), it is higher in forests (0.62) and lower in fallow land (0.28).

It thus appears that specific diversity is higher in forests and lower in fallow land.

3.5. Regeneration Rate

The regeneration rate of the woody stand in the Coubalan commune is 96.11%. This rate varies from one type of land use to another. Fallow land has the highest regeneration rate at 98.49%, followed by fields at 98.32% and forests at 87.51% (Figure 3).

3.6. Ecological Importance of Species

The species with the highest Importance Value Indices (IVIs) in the different land-use types are shown in Table 4.

In the fields, the 5 species with the highest Importance Value Indices are *Icacina oliviformis* (18.74%), *Guiera senegalensis* (15.89%), *Faidherbia albida* (12.71%), *Anacardium occidentale* (7.02) and *Parkia biglobosa* (6.63%).

In fallow land, the 5 most ecologically important species are *Guiera senegalensis* (31.83%), *Faidherbia albida* (16.39%), *Azadirachta indica* (9.90%), *Cassia sieberiana* (5.29%) and *Parkia biglobosa* (4.24%).

Table 3. Variation in stand specific diversity indices according to land use patterns.

Land use patterns	*H'* (bits)	*E*
Fields	1.37	0.33
Fallow land	1.73	0.28
Forests	3.34	0.62

Legend: *H'*: Shannon index; *E*: Regularity index.

Table 4. Species with the highest Importance Value Indices (IVIs) according to land use patterns.

LUP	Species	*Dr* (%)	*Fr* (%)	*Domr* (%)	IVI (%)
Fields	*Icacina oliviformis*	53.77	2.44	0.00	18.74
	Guiera senegalensis	35.43	12.20	0.04	15.89
	Faidherbia albida	0.75	11.38	25.99	12.71
	Anacardium occidentale	0.92	8.13	12.02	7.02
	Parkia biglobosa	0.28	7.32	12.30	6.63
Fallow land	*Guiera senegalensis*	10.14	79.58	5.78	31.83
	Faidherbia albida	8.70	0.51	39.96	16.39
	Azadirachta indica	8.70	4.55	16.44	9.90
	Cassia sieberiana	8.70	5.01	2.17	5.29
	Parkia biglobosa	2.90	0.05	9.78	4.24
Forests	*Combretum micranthum*	5.66	20.57	13.22	13.15
	Guiera senegalensis	6.29	21.12	1.15	9.52
	Terminalia macroptera	5.03	18.18	4.52	9.24
	Khaya senegalensis	3.77	0.33	20.00	8.04
	Cola lateritia	0.63	0.11	18.31	6.35

Legend: *Dr*: Relative density; *Fr*: Relative frequency; *Domr*: Relative dominance.

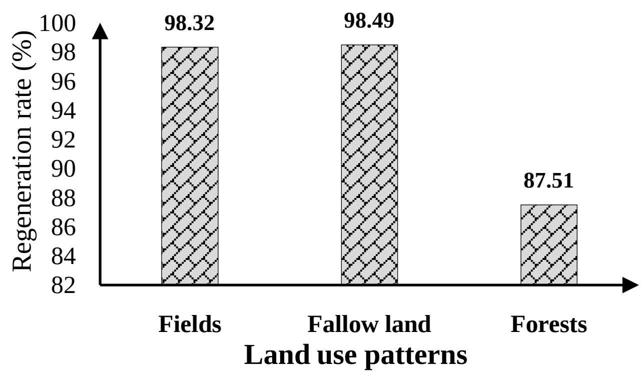

Figure 3. Regeneration rate of woody vegetation according to land-use patterns.

The 5 most ecologically important forest species are *Combretum micranthum* (13.15%), *Guiera senegalensis* (9.52%), *Terminalia macroptera* (9.24%), *Khaya senegalensis* (8.04%) and *Cola lateritia* (6.35%) (**Table 4**).

3.7. Demographic Structure of the Woody Stand

Horizontal structure

Analysis of Figure 4 shows that in the fields of the Coubalan commune, the woody stand is characterized by a predominance of individuals in the [5 - 15] diameter class. This class alone accounts for 40.12% of the stand. It is followed by the [15 - 25] and [35 - 45] classes, comprising 26.54% and 12.35% of the stand respectively.

In terms of fallow land, the [5 - 15] diameter class is still the best represented, accounting for 72.13% of the stand. This is followed by the [15 - 25] and [25 - 35] classes, which account for 14.75% and 6.56% respectively.

As for the forest, like the two previous land-use types, its stand is dominated by individuals belonging to the [5 - 15] diameter class, with 80.9% of the woody stand. This class is followed by [15 - 25], [25 - 35] and [35 - 45] with 8.8% and 5.9% of the stand respectively.

The woody stand structure in forests and fallow land is L-shaped, while that in fields is exponential and decreasing. These structures are all characteristic of a young, balanced stand, reflecting good regeneration of the stand, with recruitment of young individuals towards the intermediate classes being greater in the fields.

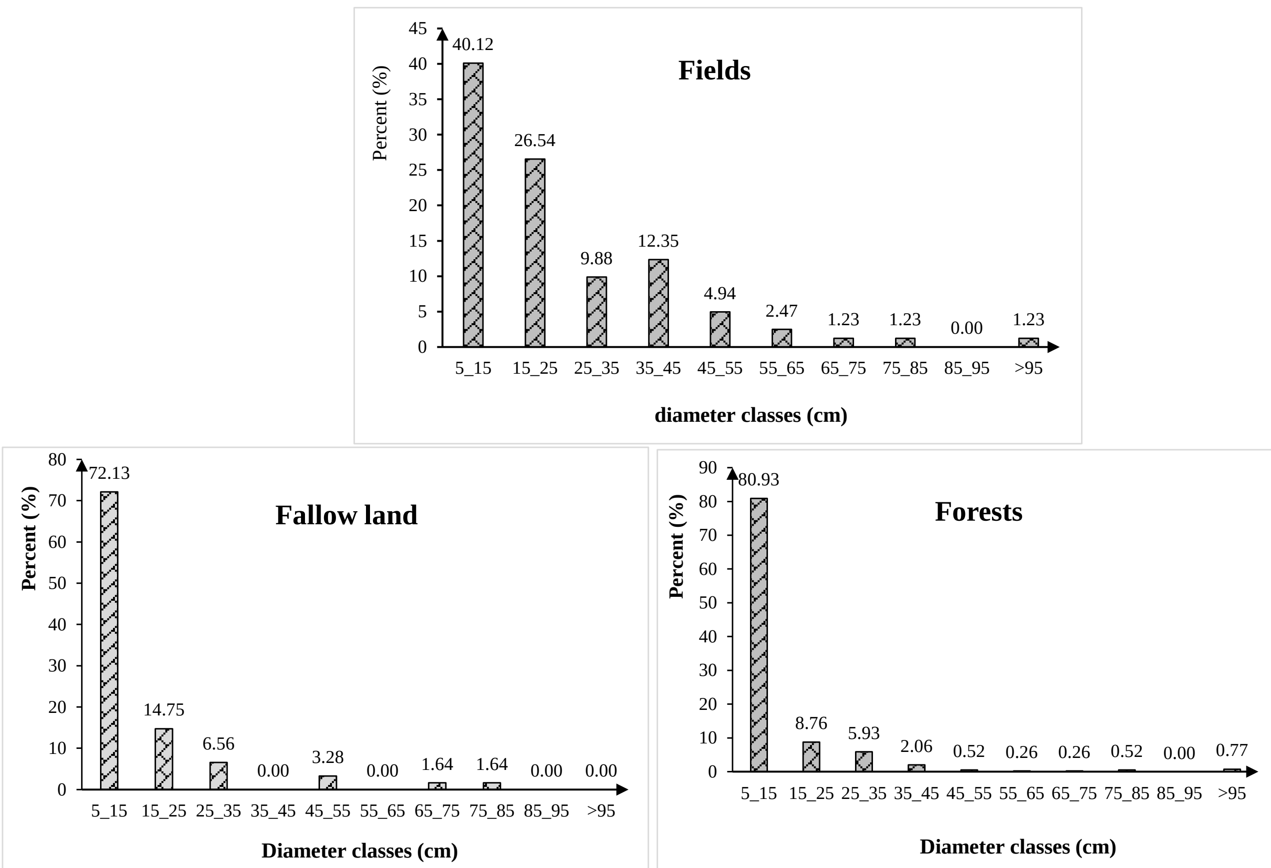

Figure 4. Distribution of woody stand individuals by diameter classes according to different land-use patterns.

Vertical structure

In the woody stand of the different land-use types in the Coubalan commune, the [2 - 4] height class is the most represented, with 27.0%, 89.61% and 58.28% of individuals in fields, fallows and forests respectively (**Figure 5**). This class is followed by the 4-6m height class, with 17.71%, 7.23% and 27.58% of individuals in fields, fallows and forests respectively (**Figure 5**).

As with the horizontal structure, the vertical structure is characteristic of a young, balanced stand.

3.8. Discriminating Characteristics of Different Land-Use Types

Figure 6, obtained from the Principal Component Analysis (PCA) performed on the basis of the matrix of three land-use types and six woody vegetation parameters, shows the discriminating characteristics of each land-use type. We thus distinguish:

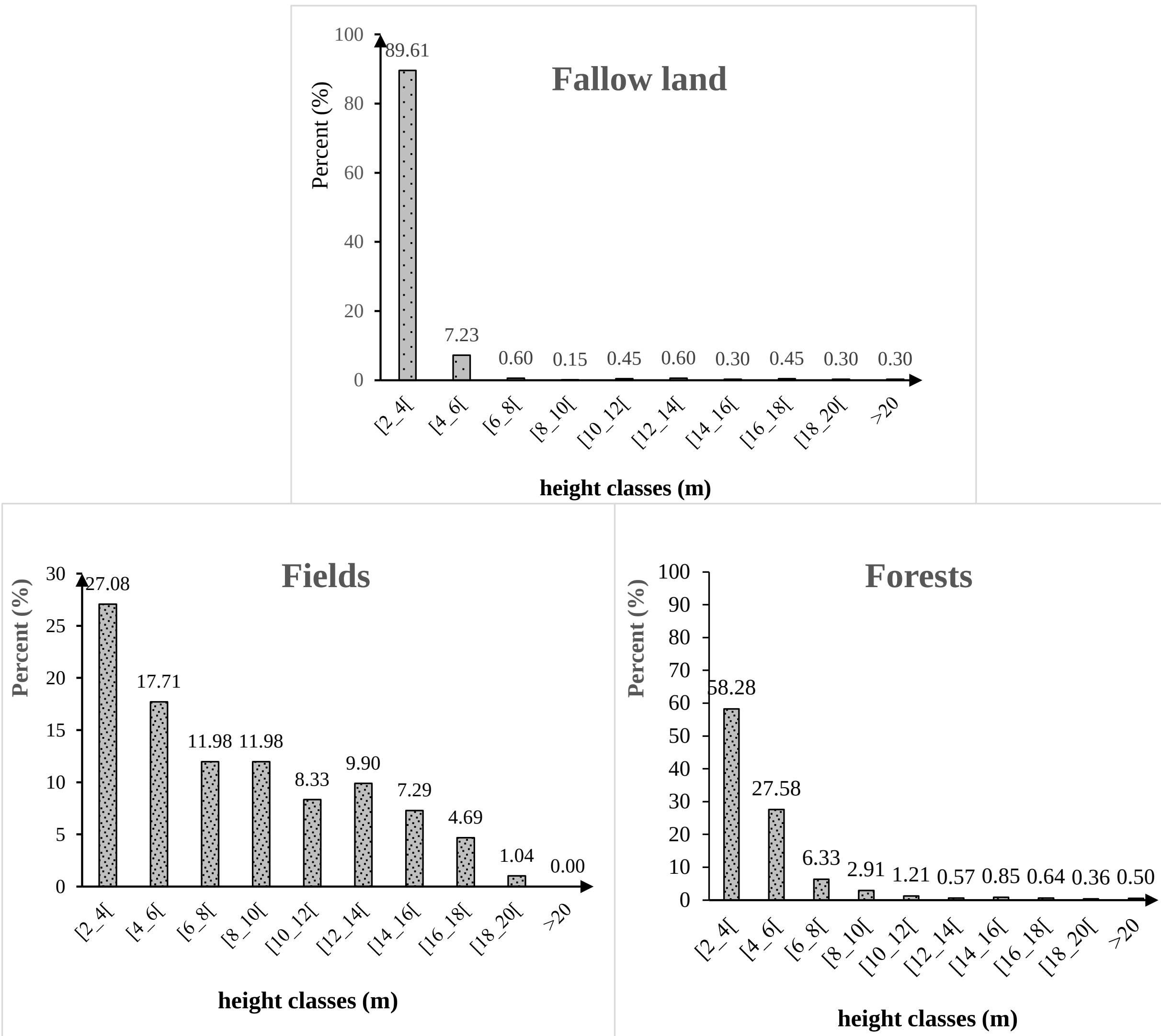

Figure 5. Distribution of woody stand individuals by height classes according to different land-use patterns.

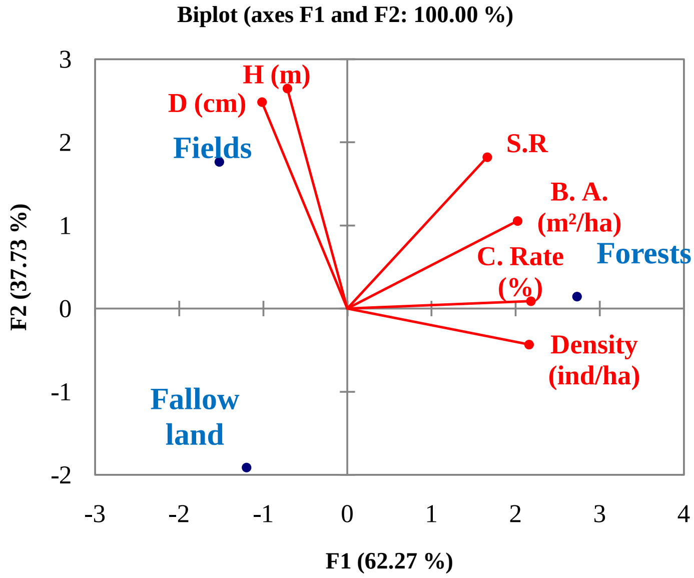

Figure 6. Types of land use based on woody vegetation characteristics. Legend: *D*: trunk diameter; *H* = height; SR: species richness; B.A.: basal area; C.R.: cover rate.

- Fields, characterized by vegetation consisting essentially of large-sized (*H*) and large-diameter (*D*) woody plants.
- Forests, characterized by high vegetation structural parameters (basal area, cover ratio and density) and high species richness.
- And fallow land, characterized by low structural parameters and low species richness.

The figure also shows that stand density is strongly correlated with woody vegetation cover rate, and woody height is strongly correlated with trunk diameter.

4. Discussion

The results of this study revealed the presence of 53 species, divided into 48 genera belonging to 22 botanical families in the commune of Coubalan. These results differ from those of [12], who found 64 woody species in 53 genera and 20 botanical families in agroforestry parks in the Tenghory district, and from those of [26], who found 69 woody species in 58 genera belonging to 23 families in traditional Elaeis guineensis agroforestry parks in Lower Casamance. Of the 22 families inventoried in this study, the most represented in the Coubalan commune are *Combretaceae* (37.42%), followed by *Icacinaceae* (29.86%) and *Fabaceae* (19.01%). These results are in line with those of [29] who state that the Mangagoulack area (Bignona Department) is dominated by the *Fabaceae* and *Combretaceae* families. The most abundant species in the Coubalan commune are *Guiera senegalensis* (42.86%), *Icacina oliviformis* (29.86%) and *Terminalia macroptera* (5.85%). These data are in line with those of [12] and [10], according to whom the most abundant species in the fields of Bignona Department are *Icacina oliviformis*, *Guiera senegalensis* and *Terminalia macroptera*.

And according to [10], this could be explained by their high regeneration capacity after cutting. These results also corroborate those of [30]-[35] according to whom in the Groundnut Basin, Combretaceae are the dominant species in the fields.

The density of woody vegetation in the fields of the Coubalan commune is 38.6 individuals/ha. These results are similar to those of [10], who found a density of 37.41 individuals/ha in agroforestry parks in the Bignona Department. However, the density in Coubalan's forests and fallows is respectively 1321.3 individuals/ha and 335.5 individuals/ha respectively. These results are higher than those obtained by [28] in the central area of the Ferlo reserve (154 individuals/ha) and those recorded by [36] in village terroirs in south-central *Ni*ger (151.09 individuals/ha).

Coverage rates in Coubalan's fields and fallows are 11.373% and 14.731% respectively. These values are close to those of [10] and [12], which respectively recorded a coverage rate of 12.71% for agroforestry parks in the Bignona Department and 13.7% for parks in the Tenghory district. The forest coverage rate is much higher, at 79.25%. This can be explained by the fact that forest areas are less anthropized.

The highest basal area was found in forests (13.09 m^2/ha), followed by fields (2.32 m^2/ha) and fallow land (1.18 m^2/ha). The results obtained for fields and fallow land are close to those of [12], who obtained a basal area of 3.3 m^2/ha for parks in the Tenghory district. These results could be explained by the fact that farmers tend to reduce the space occupied by woody species in order to increase the area under cultivation [37].

Overall, with the exception of basal area, the other structural parameters (density and cover ratio) are lower in the field. This reflects a higher level of anthropization in this type of land use.

Specific diversity is higher in forests, with a Shannon Weaver index of 3.34 bits, which could be explained by the rarity of wood cutting in forest zones. Indeed, according to [38], this high diversity may be linked to the fact that these forests do not appear to have undergone any major disturbance, as also shown by the Piélou Equitability value (0.62).

The regeneration rate of the woody stand in the Coubalan commune is 96.11%. This result is close to those of [12] and [39], who respectively obtained a regeneration rate of 95.8% in the Tenghory arrondissement and 88.19% in the Tendouck arrondissement agroforestry parks. According to [10], this could be explained by the high regeneration capacity of *Guiera senegalensis*, the dominant species in fields and fallow lands.

The horizontal and vertical structures of the different land uses in the Coubalan commune are of the "L" type, synonymous with a young, balanced stand with good regeneration capacity for woody vegetation. Indeed, according to [40], the L-shaped structure of populations indicates good regeneration of the species. These results are not in phase with those of [20], who found a predominance of large-diameter individuals (diameter ≥ 50 cm) in anthropogenic *Parkia biglobosa* and *Piliostigma reticulatum* savannas in Burkina Faso.

The typology of woody vegetation in the different land use patterns shows that the Champs are characterized by vegetation consisting essentially of large-sized (H) and large-diameter (D) woody plants. According to [41], this could be explained by the fact that the lower the tree density, the greater the increase in height and thickness. This is in line with our results, since fields have the lowest density. Finally, forests are characterized by high vegetation structural parameters and high species richness. According to [12], these high structural parameters can be explained by the low level of human intervention in forests.

5. Conclusions

Following this study, 53 species in 48 genera belonging to 22 families were inventoried. The study revealed that basal area, density and cover rate are higher in forests. The lowest values of these parameters were observed in fields for density and cover rate, and in fallow land for basal area. Dendrometric parameters are higher in the field and lower in the fallow.

These results constitute a useful source of information for the implementation of rational and sustainable management strategies for woody formations in Lower Casamance. These strategies will be based on reforestation and the protection of endangered species in different land-use patterns. It would, therefore, be interesting to repeat this study in the other agroecological sub-zones of Casamance.

Acknowledgements

We would like to thank the people of the Coubalan commune for their cooperation during our fieldwork. We would also like to thank the students Mapathé DIENG, Bamba SECK and Khar NDIAYE for their participation in our field activities.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] FAO (Food and Agriculture Organization) (2020) La FAO présente l'analyse la plus complète des ressources forestières sous une forme novatrice. L'actualité mondiale un regard humain. https://news.un.org/fr/story/2020/07/1073501

[2] FAO (Food and Agriculture Organization) (2021) Évaluation des ressources forestières mondiales 2020. Rapport Principal, FAO, Rome. https://doi.org/10.4060/ca9825fr

[3] Banoin, M. and Guengant, J.P. (1998) Les systèmes agraires traditionnels nigériens dans l'impasse face à la démographie. In: Christian, F. and Roger, P., Eds., *Jachère et Systèmes Agraires*, Faculté d'Agronomie, Dakar, 1-14.

[4] Nkarnleu, G.B., Kamajou, E. and Gockowski, J. (2000) La pratique de la jachère en Afrique tropicale: Caractérisation comparée au Nigeria et au Cameroun. *Proceedings of the International Seminary*, Dakar, 13-16 April 1999, 1-5.

[5] Maiga O. (2000) Facteurs socio-démographiques explicatifs de la crise des jachères en zone soudanienne nord au Mali. In: Christian, F. and Roger, P., Eds., *La Jachère en Afrique Tropicale*: *Rôles*, *Aménagement*, *Alternatives*: 1. *Actes du Séminaire International*, *Dakar*, 13-16 *Avril* 1999, John Libbey Eurotext, Paris, 52-58.

[6] FAO (Food and Agriculture Organization) (2016) State of the World's Forests 2016. Forests and Agriculture: Land Use Challenges and Opportunities. FAO, Rome, 138 p.

[7] Noble, F. (2020) Government Set to Revise Total Number of Hectares Destroyed during Bushfire Season to 17 Million. https://www.9news.com.au/national/australian-bushfires-17-million-hectares-burnt more-than-previously-thought/b8249781-5c86-4167-b191-b9f628bdd164

[8] Arneth, A., Shin, Y., Leadley, P., Rondinini, C., Bukvareva, E., Kolb, M., Midgley, G.F., Oberdorff, T., Palomo, I. and Saito, O. (2020) Post-2020 Biodiversity Targets Need to Embrace Climate Change. *Proceedings of the National Academy of Sciences*, **117**, 30882-3089. https://doi.org/10.1073/pnas.2009584117

[9] Sagna, P. (2005) Dynamique du Climat et son évolution récente dans la partie Ouest de l'Afrique occidentale. Master's Thesis, Université Cheikh Anta Diop de Dakar, Dakar.

[10] Coly, I. (2021) Caractérisation de la flore et de la végétation ligneuse et influence de Pterocarpus erinaceus poir. et Parkia biglobosa (Jacq.) R. Br ex G. D sur les rendements de l'arachide (Arachis hypogaea L.) dans les parcs agroforestiers du département de Bignona (Basse Casamance, Sénégal). Master's Thesis, Université Cheikh Anta Diop de Dakar, Dakar.

[11] Charreau, C. and Fauck, R. (1967) Les sols au Sénégal. *Etudes Sénégalaise*, **9**, 115-154.

[12] Badji, A. (2019) Caractérisation de la flore et de la végétation ligneuses des parcs agroforestiers et importance de l'espèce *Parkia biglobosa* (Jacq.) R. Br. ex G. Don dans les exploitations agricoles de l'arrondissement de Tenghory (Bignona, Basse Casamance). Master's Thesis, Université Assane Seck de Ziguinchor, Ziguinchor.

[13] Aubreville, A. (1950) Flore forestière soudano-guinéenne. A.O.F.-Cameroun-A.E.F. Société d'Éditions Géographiques, Maritimes et Colonials, Paris.

[14] Goudiaby, M. (2013) Les parcs agroforestiers en Basse Casamance: Contribution de *Parkia biglobosa* (néré) à la réduction des risques de pauvreté des ménages de la communauté rurale de Mangangoulack, au Sénégal. Master's Thesis, Université de Laval, Québec.

[15] Gueye, S. (2000) Étude sur les ressources forestières et les plantations du Sénégal, période de 1992-1999. Food and Agriculture Organization, Rome.

[16] Thiombiano, A., Glélé, K.R., Bayen, P., Boussim, J.I. and Mahamane, A. (2016) Méthodes et dispositifs d'inventaires forestiers en Afrique de l'Ouest: État des lieux et propositions pour une harmonisation. *Annales des Sciences Agronomiques*, **20**, 15-31.

[17] Houeto, G., Glele Kakaï, R., Salako, K.V., Assogbadjo, A., Fandohan, B., Sinsin, B. and Palm, R. (2013) Effect of Inventory Plot Patterns in the Floristic Analysis of Tropical Woodland and Dense Forest. *African Journal of Ecology*, **52**, 257-264. https://doi.org/10.1111/aje.12112

[18] Salako, V.K., Glèlè Kakaï, R., Assogbadjo, A.E., Fandohan, B., Houinato, M. and Palm, R. (2013) Efficiency of Inventory Plots Patterns in the Quantitative Analysis of Vegetation: Case Study of Tropical Woodland and Dense Forest in Benin. *Southern Forests*, **75**, 137-143. https://doi.org/10.2989/20702620.2013.816232

[19] Glèlè Kakaï, R., Salako, V.K. and Lykke, A.M. (2016) Techniques d'échantillonnage

en étude de végétation. Annales des Sciences Agronomiques 20—Spécial Projet Undesert-UE: 1-13.
https://www.researchgate.net/publication/301210821_Techniques_d'%C3%A9chantillonnage_en_%C3%A9tude_de_v%C3%A9g%C3%A9tation

[20] Ouedraogo, O., Thiombiano, A., Hahn-Hadjali, K. and Guinko, S. (2008) Diversité et structure des groupements ligneux du parc national d'Arly (Est du Burkina Faso). *Flora et Vegetatio Sudano-Sambesica*, **11**, 5-16. https://doi.org/10.21248/fvss.11.2

[21] Poupon, H. (1980) Structure et dynamique de la strate lineuse dune steppe sahélienne au nord du Sénégal. ORSTOM, Paris.

[22] Sagna, B., Ngom, D., Camara, B., Sambou, A., Diedhiou, M.A.A., Goudiaby, M., Mane, A.S. and Le Coq, Y. (2019) Ecological Characterization of *Elaeis guineensis* Jacq. Agroforestry Parklands in the Cacheu Region (Guinea Bissau). *American Journal of Agriculture and Forestry*, **7**, 321-329. https://doi.org/10.11648/j.ajaf.20190706.22

[23] Ramade, F. (2003) Eléments d'Écologie: Écologie fondamentale. 3ème Édition, Dunod, Paris.

[24] Frontier, S. and Pichod-Viale, D. (1995) Écosystèmes: Structure, Fonctionnement, Évolution. Dunod, Ile-de-France.

[25] Devineau, J.L., Leordier, C. and Vattoux, R. (1984) Evolution de la diversité spécifique du peuplement ligneux dans une succession pré-forestière de colonisation d'une savane protégée des feux (Lamto, Côte d'Ivoire). *Conservatoire et Jardin Botanique de Genève*, **39**, 103-133.

[26] Ngom, D., Camara, B., Gomis, Z.D. and Sagna, B. (2018) Cortège floristique, paramètres structuraux et indicateurs d'anthropisation des parcs agroforestiers à *Elaeis guineensis* Jacq en Basse Casamance, Sénégal. *Journal of Animal and Plant Sciences*, **36**, 5919-5932.

[27] Mori, S., Boom, B., De Carvalino, A. and Dos Santos, T. (1983) Southern Bahia Moist Forest. *The Botanical Review*, **49**, 155-232. https://doi.org/10.1007/BF02861011

[28] Ngom, D., Fall, T., Sarr, O., Diatta, S. and Akpo, L.E. (2013) Caractéristiques écologiques du peuplement ligneux de la réserve de biosphère du Ferlo (Nord Sénégal). *Journal of Applied Biosciences*, **65**, 5008-5023.
https://doi.org/10.4314/jab.v65i0.89644

[29] Diatta, E.A., Sambou, B., Diop, F.N. and Diatta, M. (2021) Caractérisation du parc agroforestier à *Parkia biglobosa* (Jacq.) R. Br. Ex G. Don en Basse Casamance (Sénégal). Vertigo—La revue électronique en sciences de l'environnement.
http://journals.openedition.org/vertigo/28668
https://doi.org/10.4000/vertigo.28668

[30] Charahabil, M.M., Lo, M., Bassène, E. and Akpo, L.E. (2008) Caractéristiques de la flore et végétation ligneuse des forêts communautaires de la zone soudano-sahélienne au Sénégal. *Journal des Sciences et Technologies*, **6**, 72-85.

[31] Sarr, O., Diatta, S., Gueye, M., Ndiaye, P.M., Guisse, A. and Akpo, L.E. (2013) Importance des ligneux fourragers dans un système agropastoral au Sénégal (Afrique de l'Ouest). *Revue de Medecine Veterinaire*, **164**, 2-8.

[32] Sarr, O., Ngom, D., Bakhoum, A. and Akpo, L.E. (2013) Dynamique du peuplement ligneux 136 dans un parcours agrosylvopastoral du Sénégal. *La Revue Électronique en Sciences de l'Environnement*, **13**, 2-16. https://doi.org/10.4000/vertigo.14067

[33] Bakhoum, C., Ndour, B. and Akpo, L.E. (2013) Diversity of Woodlands in the Groundnut Basin of Kaffrine, Senegal. *Journal of Applied Biosciences*, **63**, 4674-4688.
https://doi.org/10.4314/jab.v63i1.87243

[34] Badji, M., Sanogo, D. and Akpo, L.E. (2014) Dynamique de la végétation ligneuse

des espaces sylvo-pastoraux villageois mis en défens dans le Sud du Bassin arachidier au Sénégal. *Bois et Forêt des Tropiques*, **319**, 44-52. https://doi.org/10.19182/bft2014.319.a20551

[35] Ba, M.F. (2015) Les bois raméaux fragmentés (BRF) de *Guiera senegalensis* J. F. Gmel et de *Piliostigma reticulatum* (DC) Hochst dans la fertilisation des sols du bassin arachidier du Sénégal. Master's Thesis, Université Cheikh Anta Diop de Dakar, Dakar.

[36] Issoufou, B., Yameogo, J.T., Abdou, L., Adam, T. and Mahamane, A. (2019) Caractéristiques écologiques du peuplement ligneux issu de la régénération naturelle assistée (RNA) dans les régions de Maradi et Zinder, Niger. *Journal of Animal and Plant Sciences*, **39**, 6454-6467.

[37] Boffa, J.M.J. (1995) Productivity and Management of Agroforestry Parklands in the Sudan Zone of Burkina Faso, West Africa. Master's Thesis, Purdue University, West Lafayette.

[38] Tiokeng, B., Mapongmetsem, P.M., Nguetsop, V. and Walter Ndam Tacham, W.N. (2015) Biodiversité floristique et régénération naturelle sur les Hautes Terre de Lebialem (Ouest Cameroun). *International Journal of Biological and Chemical Sciences*, **9**, 56-68. https://doi.org/10.4314/ijbcs.v9i1.6

[39] Diatta, T.C. (2019) Caractérisation de la flore et de la végétation ligneuses des parcs agroforestiers et importance de l'espèce *Parkia biglobosa* (Jacq.) R.Br. Ex G. Don dans les exploitations agricoles de l'arrondissement de Tendouck (Bignona, Basse Casamance). Master's Thesis, Université Assane Seck de Ziguinchor, Ziguinchor.

[40] Bationo, B.A., Ouedraogo, S.J. and Guinko, S. (2001) Longévité des graines et contraintes à la survie des plantules de *Afzelia africana* Sm. dans la forêt classée de Nazinon (Burkina Faso). *Annales des Sciences Forestières*, **58**, 69-75. https://doi.org/10.1051/forest:2001107

[41] Husson, J. (2019) Croissance des arbres et sa variabilité dans les forêts denses humides d'Afrique Centrale—Etude au nord de la République du Congo. Master's Thesis, Université de Montpellier, Montpellier.