

# Characteristics of the Flora and Woody Vegetation of Agroforestry Parks in the District of Kataba 1 (Bignona, Lower Casamance)

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## Abstract

Like several Sahelian countries, Senegal is facing a strong degradation of woody and arable resources. This is due to the development of certain inappropriate agricultural practices. To mitigate this situation, the populations tend to preserve and maintain certain woody species of interest in the fields, thus constituting agroforestry parks. Thus, the objective of this study was to contribute to a better understanding of the characteristics of woody vegetation in agroforestry parks in the department of Bignona. To this end, a plot of 2500 m<sup>2</sup> (50 m × 50 m) was installed in the fields of each farmer selected in a sample of 99 farm managers distributed in the three communes (Djinaky, Kataba1 and Kafountine) of the Kataba1 district, for a total of 99 plots installed. A total of seventy-three (73) species divided into fifty-five (55) genera and twenty-eight (27) botanical families were inventoried. In the agroforestry parks of the Kataba 1 district, the density of woody vegetation is 56.12 individuals/ha, the cover rate is 27.9% and the basal area is 5.9 m<sup>2</sup>/ha. The vertical structure of the woody vegetation is characterized by a predominance of individuals between 2 and 4 m in height (48.07%). As for the horizontal structure, it is characterized by a predominance of individuals of diameter between 5 and 20 cm (39.19%). These results obtained will serve as a source of information for better management of these agroforestry parks by the populations.

## Keywords

Agroforestry Parks, Flora, Woody Vegetation, Kataba 1

## 1. Introduction

In the semi-arid and sub-humid zones of West Africa, farmers have been im-

plementing a traditional land use system known as “agroforestry parks” for generations [1]. It is characterized by the deliberate maintenance of trees scattered on cultivated land or on recent fallow land [2] [3]. These trees are an integral part of the system and provide food, fuel, fodder, medicinal substances, building materials and marketable products. In addition to these services, these trees also contribute to the maintenance of soil fertility, water conservation and environmental protection. Through species selection, farmers have deliberately adapted tree production to their specific needs on their land [1].

The natural region of Casamance, in Senegal, has the greatest diversity of wood resources in the country [4]. These ecosystems generate very important foreign exchange and environmental services, thus contributing to cultural and socio-economic development worldwide. Indeed, according to [5], forestry remains a factor of economic development and contributes to 2.7% of the GDP in ten major tropical producing countries. However, these important ecosystems are now threatened by climatic hazards and strong anthropic pressure. The latter results in the uncontrolled exploitation of certain species of interest such as those producing quality timber. These species are often exploited fraudulently without any respect for management principles [6]. Indeed, species such as *Pterocarpus erinaceus* are currently threatened in all forest areas and agroforestry parks in the Sahelo-Sudanian and Sudanian zone [7]. Therefore, an assessment of the current status of these ecosystems appears to be imperative. It is in this perspective that this study proposes to establish the floristic and structural characteristics of the woody vegetation of these agrarian systems. The aim of this study is to establish the floristic and structural characteristics of the woody vegetation of these agrarian systems in order to have a database for more rational management of these ecosystems.

## 2. Material and Methods

### 2.1. Presentation of the Study Area

The district of Katabal belongs to the department of Bignona and the region of Ziguinchor. It consists of four communes, three of which are rural (Kafountine, Djinaky and Kataba 1) and one urban (Diouloulou). It is bordered to the east by the Sindian district, to the south by the Oussouye department and the Tendouck district, to the west by the Atlantic Ocean and to the north by the Gambia (Figure 1).

From a climatic standpoint, the Katabal district belongs to the Lower Casamance climatic zone, which has a coastal South Sudanese type of climate marked by the existence of two seasons: a dry season and a rainy season. The lower Casamance is characterized by rainfall that is higher than 1000 mm everywhere [8]. The average annual rainfall over the 1980-2018 series is 1302.04 mm (Figure 2) [9].

The nature of the soils in Lower Casamance is a function of the toposequence [10]. Three types of soil are encountered: hydro morphic soils exploited for rice

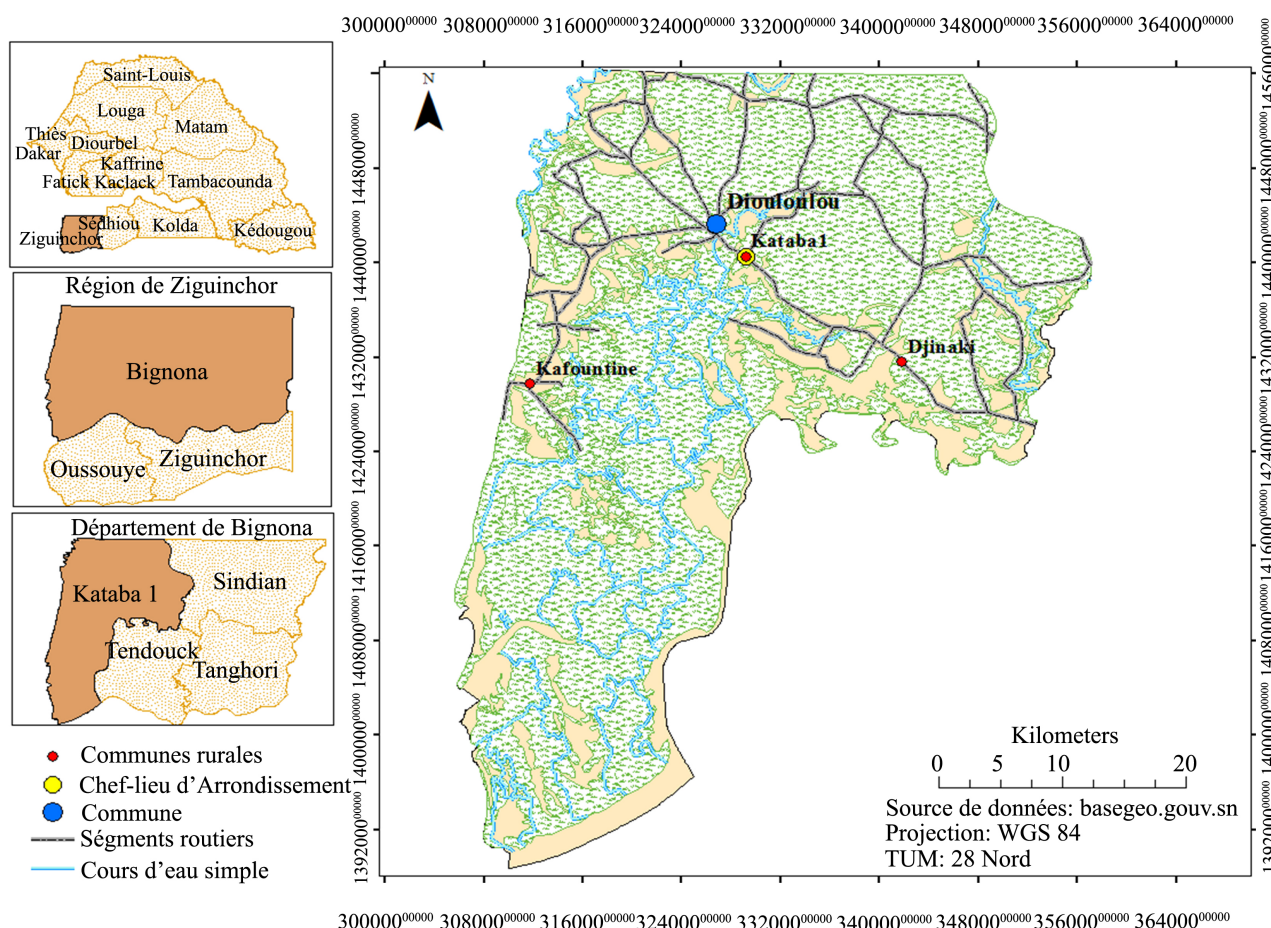


Figure 1. Location map of the Kataba1 district.

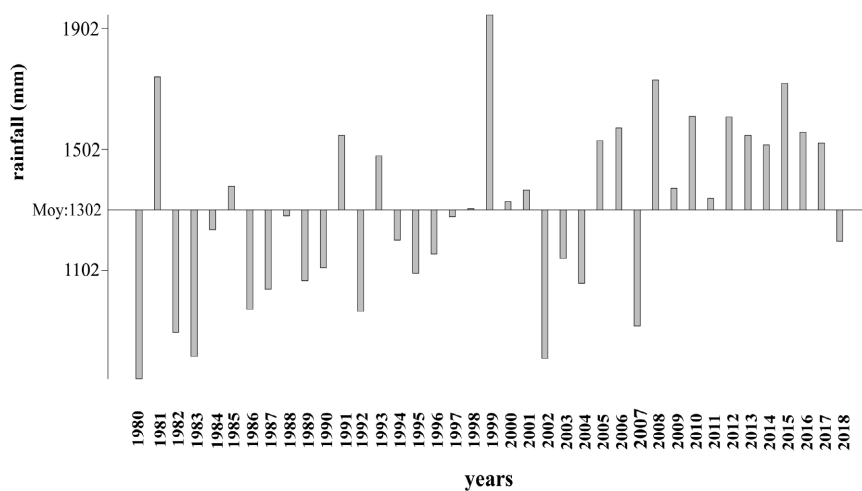


Figure 2. Variation in mean annual rainfall (mm) for the 1988-2018 series recorded at the meteorological station in the Ziguinchor region [9].

and market gardening; acid sulfate soils in the lower part of the basin, tropical ferruginous soils and ferralitic soils exploited for rainfed crops on the plateaus and terraces forming the watersheds [11].

## 2.2. Vegetation Surveys

Stratified sampling was carried out in the agroforestry parks of Kataba1 district, taking the three municipalities of the district as strata (Table 1). The criterion for choosing villages was based on geographic distribution in order to ensure a good network in each municipality. The selection criterion for farmers is whether they have a cultivated field.

Thus, 99 plots are distributed among the municipalities in proportion to their number of farms, with one plot per farm manager. The survey area is 2500 m<sup>2</sup> as recommended by [12] for the study of woody vegetation in agroforestry systems.

In each plot, all species were inventoried and dendrometric measurements were made for each individual that reached the pre-count diameter (5 cm).

The dendrometric parameters measured are:

- Trunk diameter at breast height (DBH) using a forestry compass;
- The circumference of the trunk using a metric tape for individuals with a large trunk;
- Tree height using a suntoo dendrometer;
- The cross-sectional diameter of the crown (East-West and North-South) using a metric tape.

Also, an exhaustive count of all young individuals, with a diameter less than 5 cm was carried out to evaluate the regeneration.

## 2.3. Data Processing

The data from the vegetation surveys were entered into an EXCEL spreadsheet. The latter was used to perform the calculations and to develop graphs and tables. XLSTAT Version 2014 was used for the multivariate treatments, in particular the Principal Component Analysis (PCA).

A number of formulas were used to assess diversity and to calculate vegetation structure parameters.

Species richness is the total number of species in a given stand in a given ecosystem [13].

Frequency analysis is a method of assessing the distribution of species across surveys. The frequency ( $F$ ) provides information on the distribution of a species

**Table 1.** Number of villages and farms by commune and in the sample.

Municipalities	Sample			
	Number of villages	Number of farms	Number of villages	Number of farms
Djinaky	25	201	3	5
Kataba 1	35	2596	7	30
Kafontaine	17	5755	5	64
<b>Total</b>	<b>77</b>	<b>8552</b>	<b>15</b>	<b>99</b>

in a stand. It is estimated in percent (%). It is calculated as follows:

$$F = \frac{N_{ri}}{N_r} \times 100.$$

$F$  = frequency of occurrence,  $N_{ri}$  = number of surveys where species  $i$  is found,  $N_r$  = total number of surveys.

The density is the number of individuals per unit area. It is expressed in number of individuals per hectare. The observed density ( $D_{ob}$ ) is obtained by dividing the total number of individuals in the sample ( $N$ ) by the sampled area ( $S$ ).

$$D_{ob} = \frac{N}{S}.$$

The woody cover ( $C$ ), is the surface covered by the projection of the tree crown in relation to the ground. It is expressed in square meters per hectare ( $m^2/ha$ ) and is calculated as follows:

$$C = \sum \pi \left[ \frac{d_{mh}}{2} \right]^2 / S_E.$$

$C$  = woody cover;  $d_{mh}$  = average crown diameter in m;  $S_E$  = area of the sample considered in ha.

Basal area (BA) is the area of the tree evaluated at the base of the tree trunk. It is expressed in square meters per hectare ( $m^2/ha$ ) and is obtained by the following formula:

$$S_t = \sum \pi \left[ \frac{d_{1,3}}{2} \right]^2 / S_E.$$

$d_{1,3}$  = diameter (m) at breast height,  $S_E$  = sample area in hectares.

The Shannon-Weaver diversity index [14] provides information on the magnitude of the number of abundant species in a given environment. It is expressed in bits.

It is given by the following formula:

$$H' = -\sum p_i \log_2 p_i.$$

$p_i$  = relative abundance of each species.  $\log_2$  = logarithm calculated with base 2.

$p_i = N_i/N$ , where  $N_i$  = the number of species  $i$ ;  $N$  = total number of species.

The evenness index ( $E$ ) provides information on the distribution of species abundances in the stand. According to [15], the regularity index appears to be a more rigorous comparison term. It is between 0 and 1. It tends towards 0 when all the individuals correspond to a single species. It is calculated as follows:

$$E = \frac{H'}{H_{\max}}.$$

$H_{\max} = \log_2 s$  avec  $s$  = effectif total des espèces.

### 3. Results

#### 3.1. Floristic Composition

The woody flora of the agroforestry parks of Kataba1 district is rich in seven-

ty-three (73) species distributed in fifty-five (55) genera and twenty-eight (28) botanical families. The most represented families are: *Fabaceae* (18.66%), *Moraceae* (8%) and *Anacardiaceae*, *Caesalpinaceae* and *Rutaceae* with each a proportion of 6.66%. These five (5) families alone represent 33.32% of the species inventoried (**Table 2**).

Of these 73 species, the municipality of Katabal recorded 23 species divided into 23 genera elonging to 12 families. In the commune of Djinaky, 52 species were recorded. These are divided into 41 genera belonging to 19 families. As for the commune of Kafountine, it recorded 63 species divided into 48 genera and 25 families (**Table 2**).

### 3.2. Frequency Analysis

The analysis of the table below shows that in the Katabal district the most frequent woody species in agroforestry parks are: *Borassus akeassii* (42.42%), *Mangifera indica* (40.40%), and *Citrus sinensis* (39.39%). The lowest frequency is observed in *Azelia africana*, *Albizia zigya*, *Allophullus africanus* with a frequency of presence of 1.01% each.

At the municipality level, it appears that *Mangifera indica*, *Combretum micranthum*, and *Parkia biglobosa* are the most frequent species in the municipality of Djinaky with frequencies of presence of 80%, 80%, and 60% respectively.

In the municipality of Katabal, the most frequent species are *Parkia biglobosa* (60%), *Borassus akeassii* (50%) and *Pterocarpus erinaceus* (46.67%).

In the commune of Kafountine, *Piliostigma thonninguii*, *Elaeis guineensis*, and *Citrus sinensis* are the most frequent species with respective frequencies of presence of 50%, 45.31%, and 42.19% (**Table 3**).

### 3.3. Structural Characteristics of Woody Vegetation in Agroforestry Parks

The average cover rate of agroforestry parks in the Katabal district is 27.9%. It is higher in the municipality of Djinaky (28.49%) and lower in that of Kafountine (13.10%) (**Table 4**).

The basal area is 5.6 m<sup>2</sup>/ha in the parks of the district. It is higher in the parks of the municipality of Djinaky (5.48 m<sup>2</sup>/ha) and lower in those of the municipality of Kafountine (2.82%) (**Table 4**).

As for density, it is 56.12 individuals/ha at the scale of the parks of the district and is higher in the parks of the municipality of Katabal with 64 individuals/ha and lower in those of the municipality of Djinaky (19.2 plants/ha).

Specific diversity is highest in the parks of the municipality of Djinaky with a Shannon index of 3.38 bits and a Pielou index of 0.77. The lowest diversity is noted in the parks of the commune of Kafountine with a Shannon index of 2.74 bits and a Pielou index of 0.53 (**Table 4**).

### 3.4. Regeneration Rate of Agroforestry Parks

The regeneration rate of woody vegetation in the agroforestry parks of the

**Table 2.** Floristic composition of agroforestry parks in the Kataba1 district.

Families	genera	Species	Municipalities and district			
			Dji.	Kat.1	Kaf.	Kat.1 District
Anacardiaceae	<i>Anacardium</i>	<i>Anacardium occidentale</i> L.	+	+	+	+
	<i>Lannea</i>	<i>Lannea acida</i> A. Rich.	+	+	+	+
	<i>Lannea</i>	<i>Lannea velutina</i> A. Rich.	-	-	+	+
	<i>Mangifera</i>	<i>Mangifera indica</i> L.	+	+	+	+
	<i>Spondias</i>	<i>Spondias mombin</i> L.	-	-	+	+
Annonaceae	<i>Annona</i>	<i>Annona glauca</i> Schumach. & Thonn.	-	+	+	+
	<i>Annona</i>	<i>Annona senegalensis</i> Pers.	+	+	+	+
	<i>Annona</i>	<i>Annona squamosa</i> L.	-	-	+	+
	<i>Uvaria</i>	<i>Uvaria chamea</i> L.	+	+	-	+
Apocynaceae	<i>Calotropis</i>	<i>Calotropis procræ</i> (Aiton) W. T. Aiton	-	+	+	+
	<i>Holarrhena</i>	<i>Holarrhena floribunda</i> L.	+	+	-	+
	<i>Landolphia</i>	<i>Landolphia heudelotii</i> A. DC.	-	+	+	+
	<i>Saba</i>	<i>Saba senegalensis</i> (A. DC.) Pichon	-	+	+	+
Arecaceae	<i>Cocus</i>	<i>Cocus nucifera</i> L.	-	-	+	+
	<i>Borassus</i>	<i>Borassus akeassii</i> Bayton. Ouéd. & Guinko.	+	+	+	+
	<i>Elaeis</i>	<i>Elaeis guineensis</i> Jacq.	+	+	+	+
Asclepiadaceae	<i>Calotropis</i>	<i>Calotropis procræ</i> (Aiton) W.T.Aiton	-	+	+	+
Bignoniaceae	<i>Newbouldia</i>	<i>Newbouldia laevis</i> (P. Beauv.) Seem	-	+	+	+
Bombacaceae	<i>Adonsonia</i>	<i>Adonsonia digitata</i> L.	-	-	+	+
	<i>Bombax</i>	<i>Bombax aquaticum</i> (Aubl.) K. Schum.	-	+	+	+
Caesalpinaceae	<i>Detarium</i>	<i>Detarium guineensis</i> Willd.	+	+	+	+
	<i>Detarium</i>	<i>Detarium senegalensis</i> Gmel.	-	+	+	+
	<i>Dialium</i>	<i>Dialium guineensis</i> Willd.	-	+	-	+
	<i>Piliostigma</i>	<i>Piliostigma reticulata</i> (Schumach.) Milne-Redh	-	+	+	+
	<i>Piliostigma</i>	<i>Piliostigma thonninguii</i> (Schumach.) Milne-Redh.	+	+	+	+
Caricaceae	<i>Carica</i>	<i>Carica papaya</i> L.	-	-	+	+
Chrysobalanaceae	<i>Ceiba</i>	<i>Ceiba pentandra</i> (L.) Gaertn.	-	-	+	+
	<i>Neocaria</i>	<i>Neocarya macrophylla</i> (Sabine) Prance	-	-	+	+
Combretaceae		<i>Combretum glutinosum</i> Perr. Ex DC.	-	+	+	+
	<i>Combretum</i>	<i>Combretum micranthum</i> G. Don	+	+	+	+
		<i>Combretum paniculatum</i>	-	-	+	+
	<i>Guiera</i>	<i>Guiera senegalensis</i> J. F. Gmel	-	+	+	+
	<i>Terminalia</i>	<i>Terminalia macroptera</i> Guill. & Perr.	+	+	+	+

## Continued

<i>Icacinaceae</i>	<i>Icacina</i>	<i>Icacina senegalensis</i> Juss	+	+	-	+
<i>Lamiaceae</i>	<i>Phloemis</i>	<i>Phloemis africana</i> P. Beauv.	-	-	+	+
<i>Malvaceae</i>	<i>Cola</i>	<i>Cola cordifolia</i> (Cav.) R. Br	+	+	-	+
<i>Meliaceae</i>	<i>Azadirachta</i>	<i>Azadirachta indica</i> A. Juss.	+	+	+	+
	<i>Khaya</i>	<i>Khaya senegalensis</i> (Desr.) A. Juss.	-	+	+	+
<i>Mimosaceae</i>	<i>Afzelia</i>	<i>Afzelia africana</i> Sm. & Pers.	+	-	-	+
	<i>Albizia</i>	<i>Albizia adianthifolia</i> W. Wight	-	+	+	+
	<i>Albizia</i>	<i>Albizia zygia</i> (DC.) J. F. Macbr	-	+	-	+
	<i>Cassia</i>	<i>Cassia aulo</i> DC.	-	+	-	+
	<i>Cassia</i>	<i>Cassia sieberiana</i> DC.	+	+	+	+
	<i>Cordyla</i>	<i>Cordyla pinnata</i> Lour.	-	-	+	+
	<i>Daniellia</i>	<i>Daniellia oliveri</i> (Rolfé) Hutch. & Dalziel	-	+	-	+
	<i>Dicrostachys</i>	<i>Dicrostachys cineria</i> (L.) Wight. & Arn.	+	+	+	+
	<i>Erythrina</i>	<i>Erythrina senegalensis</i> L.	-	+	+	+
	<i>Faidherbia</i>	<i>Faidherbia albida</i> (Delile) A. Chev.	+	+	+	+
<i>Moraceae</i>	<i>Parkia</i>	<i>Parkia biglobosa</i> (Jacq.) R. Br. Ex G. Don	+	+	+	+
	<i>Prosopis</i>	<i>Prosopis</i> sp	-	+	-	+
	<i>Prosopis</i>	<i>Prosopis africana</i> (Guill. & Perr.) Taub.	+	+	+	+
	<i>Pterocarpus</i>	<i>Pterocarpus erinaceus</i> Poir.	-	+	+	+
	<i>Antiaris</i>	<i>Antiaris africana</i> Engl.	-	+	+	+
<i>Moraceae</i>	<i>Ficus</i>	<i>Ficus asperifolia</i>	-	+	+	+
	<i>Ficus</i>	<i>Ficus exasperata</i> Vahl	-	-	+	+
	<i>Ficus</i>	<i>Ficus sycomorus</i> L.	-	+	+	+
	<i>Ficus</i>	sp	-	+	+	+
	<i>Ficus</i>	<i>Ficus vogeli</i> Miq.	-	-	+	+
<i>Moringaceae</i>	<i>Moringa</i>	<i>Moringa oleifera</i> Lam.	-	-	+	+
<i>Myrtaceae</i>	<i>Psidium</i>	<i>Psidium guajava</i> L.	-	+	-	+
<i>Phyllanthaceae</i>	<i>Margaritaria</i>	<i>Margaritaria discoidea</i> (Baill.) G. L. Webster	-	-	+	+
<i>Rhamnaceae</i>	<i>Ziziphus</i>	<i>Ziziphus mauritiana</i> Lam.	-	-	+	+
<i>Rubiaceae</i>	<i>Sarcocephalus</i>	<i>Sarcocephalus latifolia</i> Afzel. Ex R. Br	-	+	+	+
	<i>Sarcocephalus</i>	<i>Sarcocephalus leavis</i> Afzel. Ex R. Br	-	-	+	+
<i>Rutaceae</i>	<i>Citrus</i>	<i>Citrus lemon</i> (L.) Burm. F.	-	+	+	+
	<i>Citrus</i>	<i>Citrus reticulata</i> L.	-	+	+	+
	<i>Citrus</i>	<i>Citrus sinensis</i> (L.) Osbeck	-	+	+	+



## Continued

	Fagara	<i>Fagara senegalensis</i> (DC.) A. Chev.	-	+	+	+
	Fagara	<i>Fagara xanthoxyloides</i> Lam.	-	-	+	+
<i>Sapindaceae</i>	Allophylus	<i>Allophulus africanus</i> P. Beauv.	+	-	-	+
<i>Simaroubaceae</i>	Hannoa	<i>Hannoa undulata</i> (Guill. & Perr) Planch.	-	+	-	+
<i>Ulmaceae</i>	Celtus	<i>Celtus integrifolia</i> Lam.	+	-	+	+
<i>Verbanaceae</i>	Gmelina	<i>Gmelina arborea</i> Roxb. EX Sm.	-	+	+	+
	Vitex	<i>Vitex doniana</i> Oliv.	-	-	+	+
<b>Total 27</b>	<b>55</b>	<b>73</b>	<b>23</b>	<b>52</b>	<b>63</b>	<b>73</b>

**Legend:** Kat.1 = Kataba 1; Kaf = Kafountine; Dji = Djignaky; Kat1 District = Kataba 1 District. +: presence; -: absence.

**Table 3.** Frequency of presence (%) of inventoried species according to the municipalities and the district of Kataba 1.

Species	Municipalities			Kataba 1 District
	Djinaky	Kataba 1	Kafountine	
<i>Adansonia digitata</i> L.	0	0	3.125	2.02
<i>Azelia africana</i> Sm. & Pers.	20	0	0	1.010
<i>Albizzia adiantifolia</i> W. Wight	0	6.660	1.563	33.333
<i>Albizzia zygia</i> (DC.) J. F. Macbr.	0	3.330	0	1.010
<i>Allophullus africanus</i> P. Beauv	20	0	0	1.010
<i>Anacardium occidentale</i> L.	40	33.333	20.313	25.253
<i>Annona glauca</i> Schumach. & Thonn.	0	23.330	1.560	8.081
<i>Annona senegalensis</i> Pers.	20	23.333	15.625	18.182
<i>Annona squamosa</i> L.	0	0	6.250	4.040
<i>Antiaris africana</i> Engl.	0	3.330	1.560	2.020
<i>Azadirachta indica</i> A. Zuss	20	16.667	14.063	16.162
<i>Bombax aquaticum</i> (Aubl.) K. Schum.	0	3.330	15.600	2.020
<i>Borassus akeassii</i> Bayton, Ouédraogo & Guinko	20	50	40.625	42.424
<i>Calotropis procera</i> (Aiton) W. T. Aiton	0	3.330	23.438	16.162
<i>Carica papaya</i> L.	0	0	7.810	5.051
<i>Cassia aulo</i>	0	3.330	0	1.010
<i>Cassia sieberiana</i> DC.	40	33.333	6.250	16.162
<i>Ceiba pentandra</i> (L.) Gaertn.	0	0	1.560	1.010
<i>Celtis integrifolia</i> DC.	20	0	1.560	2.020
<i>Citrus limon</i> (L.) Burm. f	0	13.330	6.250	8.081
<i>Citrus reticulata</i> Blanco.	0	6.660	6.250	6.061
<i>Citrus sinensis</i> (L.) Osbeck	0	40	42.188	39.394

## Continued

<i>Cocus nucifera L.</i>	0	0	1.560	1.010
<i>Cola cordifolia (Cav.) R. Br</i>	20	6.660	0	3.030
<i>Combretum glutinosom Perr. Ex DC.</i>	0	10	1.560	4.040
<i>Combretum micranthum G. Don</i>	80	23.330	6.250	13.131
<i>Combretum paniculatum</i>	0	0	1.560	0
<i>Cordyla pinnata Lour.</i>	0	0	7.813	5.051
<i>Daniellia oliveri (Rolfé) Hutch. &amp; Dalziel</i>	0	6.660	0	2.020
<i>Detarium guineensis Willd.</i>	40	6.660	3.125	6.061
<i>Detarium senegalense Gmel.</i>	0	20	1.560	7.071
<i>Dialium guineensis Willd.</i>	0	3.333	0	1.010
<i>Dichrostachys cineria L.</i>	20	23.333	17.188	19.192
<i>Elaeis guineensis Jacq.</i>	40	20	45.313	37.374
<i>Erythrina senegalense L.</i>	0	10	9.375	9.091
<i>Fagara senegalensis (DC.) A. Chev.</i>	0	6.660	4.680	5.051
<i>Fagara xanthoxyloides Lam.</i>	0	0	1.560	1.010
<i>Faidherbia albida (Del) A. Chev.</i>	20	13.333	17.188	16.162
<i>Ficus asperfolia Miq.</i>	0	10	3.120	5.051
<i>Ficus exasperata Vahl.</i>	0	0	4.688	3.030
<i>Ficus niafolocarpa (Miq.) C. C. Berg</i>	0	3.330	7.810	6.061
<i>Ficus sp Miq.</i>	0	6.660	3.120	4.040
<i>Ficus vogeli Miq.</i>	0	0	7.810	5.051
<i>Gmelina arborea Roxb. EX Sm.</i>	0	6.660	3.120	4.040
<i>Guiera senegalensis Adans. Ex Juss.</i>	0	16.667	1.560	6.061
<i>Hannoa undulata (Guill. &amp; Perr.) Planch.</i>	0	3.330	0	1.010
<i>Holarrhena africana DC.</i>	20	3.330	0	2.020
<i>Icacina senegalensis A. Juss</i>	20	40	37.500	3.374
<i>Khaya senegalensis (Ders.) A. Juss.</i>	0	6.660	3.125	4.040
<i>Landolphia heudeloti A. DC</i>	0	6.660	1.560	3.030
<i>Lannea acida A. Rich.</i>	20	6.667	1.560	3.030
<i>Lannea velutina A. Rich.</i>	0	0	1.560	1.010
<i>Mangifera indica L.</i>	80	30	42.188	40.404
<i>Margaritaria discoidea (Baill.) G. L. Webster</i>	0	0	1.560	1.010
<i>Moringa oleifera Lam.</i>	0	0	1.560	1.010
<i>Neocarya macrophylla (Sabine) Prance</i>	0	0	1.560	1.010
<i>Newbouldia laevis (P. Beauv.) Seem</i>	0	10	7.813	8.081

## Continued

<i>Parkia biglobosa</i> (Jacq.) Benth	60	50	4.680	21.212
<i>Phlomis africana</i> P. Beauv.	0	0	6.250	4.040
<i>Piliostigma reticulate</i> (Schumach.) Milne-Redh.	0	3.330	3.120	3.030
<i>Piliostigma toninguii</i> (Schumach.) Milne-Redh.	40	43.333	50	43.434
<i>Prosopis Africana</i> (Guill., Perrot et Rich.) Taub.	20	30	4.688	13.131
<i>Prosopis sp</i> (Guill., Perrot et Rich.) Taub.	0	3.330	0	1.010
<i>Psidium goyava</i> L.	0	3.333	0	1.010
<i>Pterocarpus erinaceus</i> Poir.	0	46.667	12.500	22.222
<i>Saba senegalensis</i> A.DC	0	16.667	1.560	6.061
<i>Sarcocephalus latifolia</i> Afzel. Ex R.Br	0	13.333	20.313	17.172
<i>Sarcocephalus leavis</i> Afzel. Ex R.Br	0	0	14.063	9.091
<i>Spondias mombin</i> L.	0	0	6.250	4.040
<i>Terminalia macroptera</i> Guill & Perr.	20	43.333	18.750	26.263
<i>Uvaria chamae</i> L.	20	10	0	4.040
<i>Vitex doniana</i> Oliv.	0	0	3.120	2.020
<i>Zizyphus mauritiana</i> Lam.	0	0	3.125	2.020

**Table 4.** Variation in structural parameters of woody vegetation in parks by municipality and district.

		Density (individuals/ha)	Canopy cover (%)	Basal area (m <sup>2</sup> /ha)	Shannon Diversity Index (bits)	Pielou regularity Index
Municipalities and district	Djinaky	19.2	28.49	5.48	3.38	0.77
	Kataba1	64	25.38	3.02	3.19	0.61
	Kafountine	55.31	13.10	2.82	2.74	0.53
	Arr Kataba1	56.12	27.9	5.9	3.18	0.55

Kataba1 district is relatively high at 84.17%. This rate is higher in the parks of the municipality of Djinaky (86.93%), followed by the municipality of Kataba1 (84.64%). The lowest regeneration rate is noted in the parks of the municipality of Kafountine with 83.78%.

### 3.5. Woody Vegetation Structure of Parks

#### 3.5.1. Vertical Structure

The vertical structure of the woody vegetation in the agroforestry parks of the Kataba district 1 is L-shaped. This structure is characteristic of a young stand indeed, individuals belonging to the height class [2 – 4 m[ are the most

represented (48.07%). Individuals with a height greater than 20 m are poorly represented with 0.92% of the stand (Figure 3).

Kataba1 and Kafountine municipalities have vertical “L” structures characteristic of a young stand with a predominance of individuals between 2 and 4 m in height. This height class includes 49.34 and 48.4% of the individuals in the stand in Kafountine and Kataba1 municipalities respectively. Individuals with a height greater than 20 m are very poorly represented with 0.59% and 11% in Kafountine and Kataba1 municipalities respectively. In the district of Djinaky, individuals with a height of between 14 and 16 m are the most represented (39.13%). Individuals in the [2 – 4 m[, [6 – 8 m[ and [12 – 14 m[ height classes are poorly represented with 4.35% of individuals each (Figure 3).

### 3.5.2. Horizontal Structure

In the agroforestry parks of the district, individuals with a diameter between 5 and 20 cm are the most represented (39.19%). This class is followed by the one with a diameter between 20 and 35 cm (36.60%). Individuals with a diameter > 110 cm are the least represented with only 0.49% of the individuals in the stand (Figure 4).

In the parks of the municipality of Djinaky, we note a dominance of individuals in the [25 – 45 cm[ class (34.78%). The least represented individuals are those with diameters between 95 and 110 cm and those with diameters greater than 110 cm. These classes each contain 4.35% of the individuals in the stand.

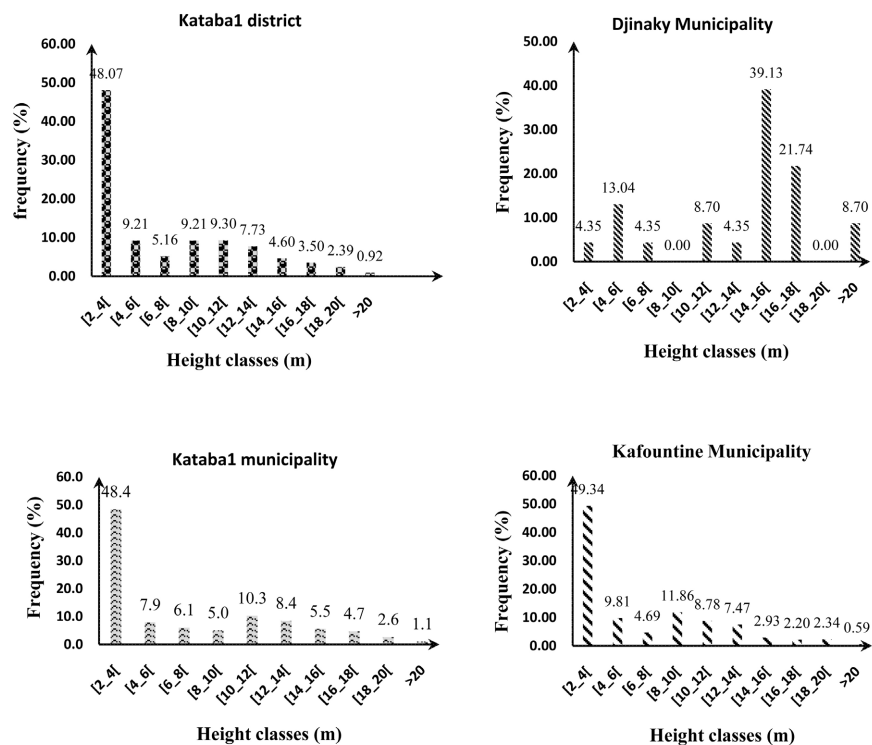
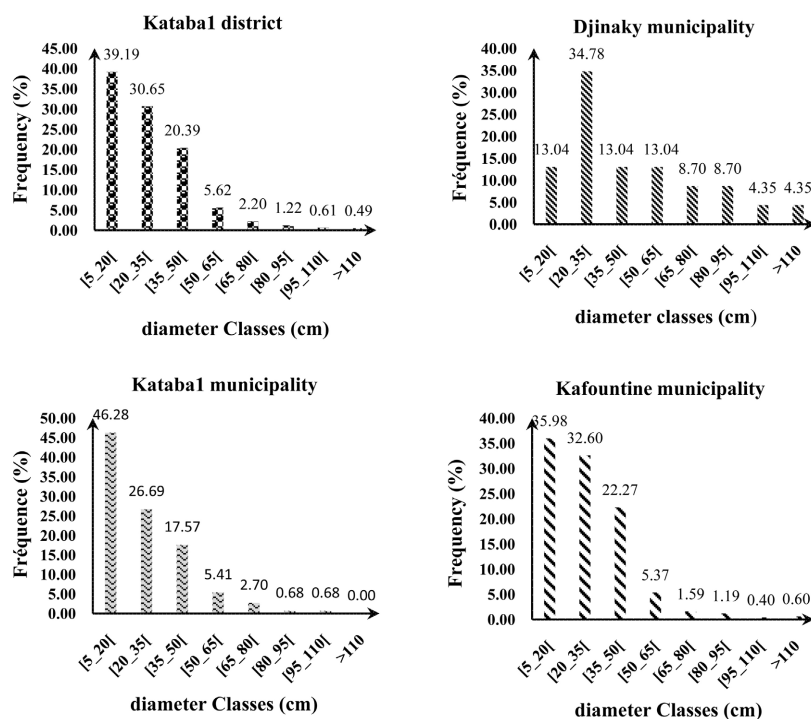


Figure 3. Distribution of individuals in the woody stand of agroforestry parks by height classes according to the municipalities and Kataba1 district.



**Figure 4.** Distribution of individuals in the woody stand of agroforestry parks by diameter classes according to the municipalities and Katabal district.

As for the parks in the Katabal municipality, they are characterized by a predominance of individuals with diameters between 5 and 20 cm with 48.28% of the individuals. On the other hand, individuals belonging to the [80 – 95 cm[ and [95 – 110 cm[ diameter classes are the least represented with 0.68% for each of the classes.

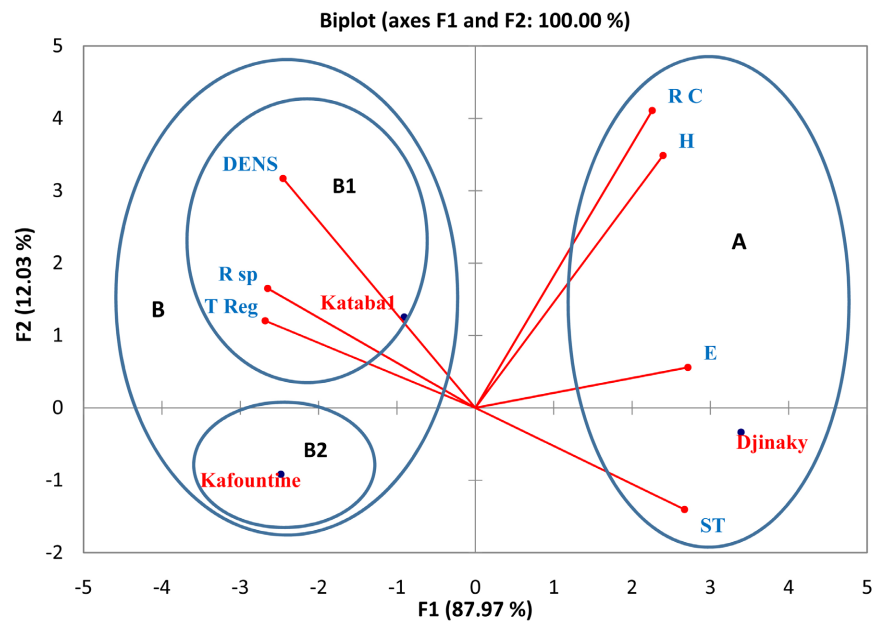
The structure of the woody stand in the parks of the municipality of Kafountine reveals a predominance of individuals in the [5 – 20 cm[ diameter class with 35.98% of individuals. Individuals with diameters between 95 and 110 cm are the least represented (0.40%).

### 3.6. Typology of the Parks According to the Municipalities

It appears from the analysis of the figure below that the F1 and F2 axes explain 100% of the variation in the parameters studied. The Principal Component Analysis (PCA) allowed us to distinguish two major groups of parks based on the floristic and structural characteristics of the woody vegetation:

Group A agroforestry parks, found in the municipality of Djinaky, characterized by high cover, basal area and diversity;

Group B agroforestry parks, located on the negative abscissa side, are made up of two subgroups. Subgroup B1 represents the parks of the Katabal municipality, characterized by a high density, specific richness and regeneration rate but with a low basal area. The B2 subgroup represents the parks of the municipality of Kafountine, which are characterized by a low cover rate and low specific diversity (Figure 5).



**Figure 5.** Characteristics of agroforestry parks in the Kataba 1 district. Legend: T R = canopy cover; Dens = density; S T = basal area; T Reg = regeneration rate; rich sp = species richness.

#### 4. Discussion

The objective of this study was to characterize the woody vegetation of the agroforestry parks in the Kataba1 district. The study showed that the flora of the parks in the Kataba1 district is rich in seventy-five (73) species divided into fifty-five (55) genera and twenty-eight (27) botanical families. The most represented family is the *Fabaceae*. These results are close to those of [16] who found 54 species, 43 genera and 24 families at the level of agroforestry parks in the island terroir of Mar Fafaco, Senegal. They are different from [17] who inventoried seven (7) plant species in the city of Nukus. Agroforestry parks in the Kataba1 district are very diverse with a Shannon index (H) equal to 3.18 bits. This result is close to that of [10] who found at the level of agroforestry parks with *Elaeis guineensis* in Lower Casamance, Shannon indices of 3.27 bits, 4.12 bits and 2.92 bits respectively in Carouante, Kabiline and Kaguitte.

The most frequent woody species in the agroforestry parks of the kataba1 district are *Borassus akeassii* (42.42%), *Mangifera indica* (40.40%), and *Citrus sinensis* (39.39%). The predominance of these species can be explained by the fact that in this area, orange and mango orchards are used as crop fields by farmers at the same time. These results are consistent with those of [18] who state that some species are maintained in the fields by farmers for socio-economic reasons.

The results for the cover rate (27.9%), basal area (5.9 m<sup>2</sup>/ha) and density (56.12 ind/ha) are different from those of [19] who found a basal area equal to 10.57 m<sup>2</sup>/ha and a density of 169.4 stems/ha in natural formations in the Sudanian zone in Benin. This difference could be explained for pedoclimatic reasons.

These results are also different from those of [20] Yameogo *et al.* who recorded a density 8.25 individuals/ha in Vipalogo agroforestry parks in Burkina Faso in 2014.

The regeneration rate of woody vegetation in the agroforestry parks of Katabal district is relatively high at 84.17%. These results are close to those of [21], who found a rate of 88.19% in the woody stands of the agroforestry parks in Tendouck district. This can be explained according to [22] by the protection and maintenance of certain woody species in the fields and particularly those with socio-economic interest. These results are different from those recorded by [23] Diatta *et al.* who found a regeneration of 1 individual/ha at Keur Samba DIA in the groundnut basin.

The demographic structure of the woody vegetation in the agroforestry parks of the Katabal district is characteristic of a young and balanced stand with a predominance of individuals with a height of between 2 and 4 m and a diameter of between 5 and 20 cm. This could be explained by the high regeneration capacity of woody vegetation in the parks and the good level of recruitment of young individuals to the intermediate classes. These results are consistent with those of [24] who conducted their study in the groundnut basin of Senegal, in the regions of Kaolack and Fatick. They are also in line with those of [25] who worked on the structure and dynamics of the flora and vegetation of the Noflaye Special Botanical Reserve.

## 5. Conclusions

The objective of the study was to characterize the woody vegetation of the agroforestry parks of the Katabal district. A total of seventy-five (73) species divided into fifty-five (55) genera and twenty-eight (27) families were inventoried, with a predominance of the *Fabaceae* family in the agroforestry parks of the Katabal district. The density, cover rate, basal area and regeneration rate are 56.12 individuals/ha, 27.9%, 5.9 m<sup>2</sup>/ha and 84.17% respectively. The demographic structure of the woody stand is characteristic of a young and balanced stand with a predominance of individuals of height between 2 and 4 m (48.07%) and diameter between 5 and 20 cm (39.19%).

It seems appropriate to continue this study in the other departments of the Lower Casamance in order to have a database for more rational and sustainable management of the parks.

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## Conflicts of Interest

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

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