

Structure and Diversity of Agroforestry Parks in the Tenghory District (Lower Casamance, Senegal)

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Abstract: In Lower Casamance, farmers deliberately keep certain woody species in their fields to increase their crop yields and generate additional income. The objective of this study is to contribute to a better understanding of the state of agroforestry parks in Lower Casamance. To achieve this objective, vegetation surveys were carried out. Thus, a square plot of 2500 m² (50m x 50m) was installed in the fields of each of the 99 farmers selected in the sample, for a total of 99 plots. This sample is distributed among the different municipalities of the arrondissement in proportion to their demographic weight, ie 18; 14; 14; 53 plots respectively in the municipalities of Coubalan, Ouonck, Niamone and Tenghory. The agroforestry parks in the district of Tenghory have a specific richness of 64 woody species divided into 53 genera and 20 botanical families. The observed density of trees is 21.8 feet / ha, the basal area is 3.3 m² / ha with a coverage rate of 13.7%. The height class structure of the woody stand reveals a predominance of individuals ≥ 10 m in height (50.5%). The diameter class [5-25] is the best represented with 45.8% of the individuals. These results thus constitute a source of useful information for the rational management of agroforestry parks in the district of Tenghory.

Keywords: Characterization, Flora, Woody Vegetation, Agroforestry Parks, Tenghory

1. Introduction

In West Africa, agriculture is marked by a traditional land-use system, where trees dot the cultivated or recently ploughed fields called "agroforestry parks" [1]. In these fields, farmers keep the trees that are not very troublesome or useful and sometimes introduce new species that are part of the cropping system [2]. These parks are exploited by the populations, who earn additional income from tree products. The importance of this traditional land-use system for the populations has been confirmed by several studies in West Africa [3-7]. In spite of the proven importance of agroforestry parks in the life of the populations, a degradation of these systems is observed nowadays. Thus, in the Sudanian zone, anthropic action combined with climatic deterioration has led to a regression of woody vegetation in agroforestry parks [8, 9]. In Senegal, a continuous

degradation of agroforestry parks has been observed [10]. This threatens their sustainability given the increased pressure on them [3]. Therefore, it is of paramount importance to know the current state of agroforestry parks in order to have a basis for proposing a rational and sustainable management of these important ecosystems. However, in Lower Casamance, there are very few studies on the state of agroforestry parks [11]. It is in this context that this work is carried out with the aim of establishing the floristic and structural characteristics of the woody vegetation of the agroforestry parks in the Tenghory district.

2. Materials and Methods

2.1. The Study Area

The Tenghory district is located in the department of Bignona, region of Ziguinchor. It is made up of four rural

municipalities (Tenghory, Niamone, Coubalan and Ouonck) in which the study is carried out. It is located in the southeast of the Bignona department and is bordered to the north by the

district of Sindian, to the south by the department of Ziguinchor, to the west by the district of Tendouck, and to the east by the region of Sédhiou (Figure 1).

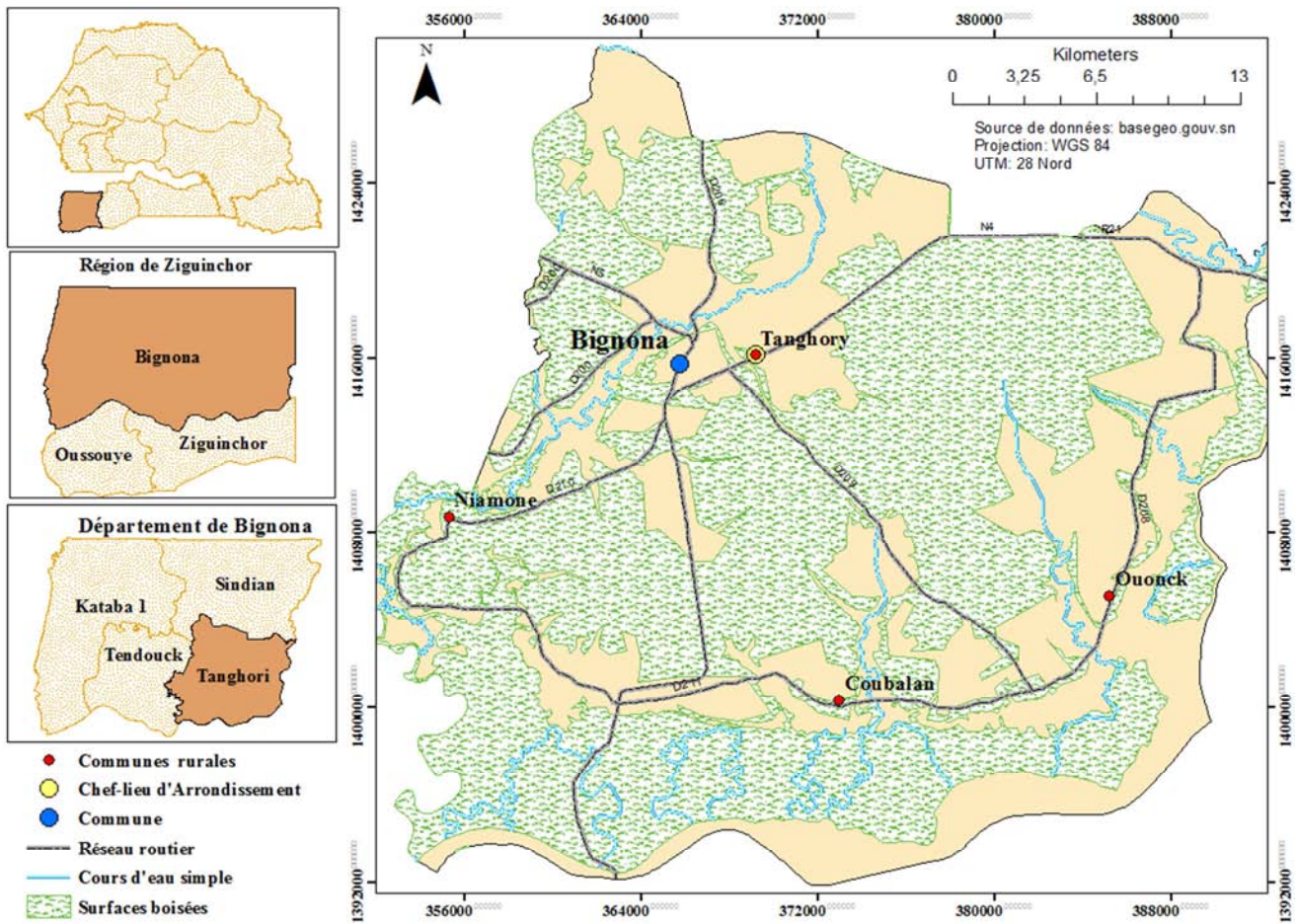


Figure 1. Location map of the district of Tenghory.

The study area in Lower Casamance has a southern Sudanese coastal climate with two seasons: a dry season and a rainy season [12]. The average annual rainfall over the 1980-2018 series is 1302.04mm. The wettest year of the observed series (1999), recorded 1946.1mm of rain, while the

two most deficit years are 1980 (745.6mm) and 2002 (811.7mm) (Figure 2). The mean values of the monthly minimum and maximum temperatures recorded at the Ziguinchor weather station are 21.5°C and 35°C respectively in the period from 1990 to 2016.

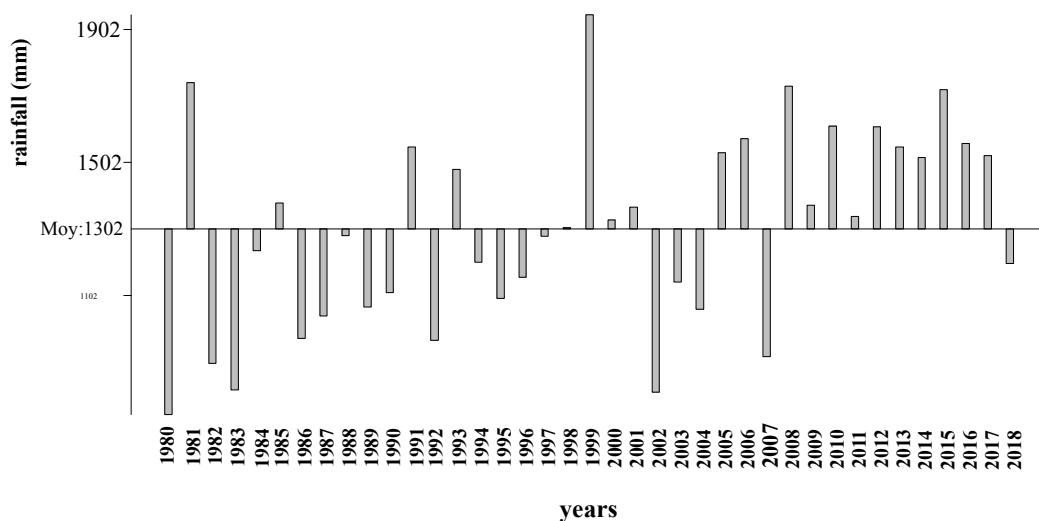


Figure 2. Interannual variation in rainfall from 1980 to 2018 in the Lower Casamance region.

There are two types of soils on the continental shelf: leached tropical ferruginous soils and low to medium desaturated ferralitic soils.

Floodplains are of various forms: raw mineral soils of non-climatic origin with marine and fluviomarine inputs, poorly evolved soils of non-climatic origin with modal inputs, peat hydromorphic organic soils, humic hydromorphic medium organic soils and halomorphic soils with non-degraded structure, saline, acidified [13, 14].

2.2. Woody Vegetation Survey

A stratified sampling was carried out at the agroforestry parks in the Tenthory borough to study the woody vegetation by considering the 4 rural municipalities of the district as strata. For this purpose, a sample of 17 villages out of the 82 villages in the district was selected. These villages are distributed among the four rural communes of the district. Then, 99 square plots of 2500 m² (50 m side) were installed at the rate of one plot in the fields of each selected farmer. The plots were distributed among the communes and then among the selected villages in proportion to their demographic weight. The choice of villages in the commune was made on the basis of their geographical distribution in order to ensure a good network of each municipality. The criterion that guided the choice of farm managers was the ownership of a cultivated field. Thus, throughout the district, 18 plots have been set up in the municipality of Coubalan, 14 in the municipality of Niamone, 14 in the municipality of Ouonck and 53 in the municipality of Tenthory.

The geographical coordinates of each plot were recorded using GPS and an exhaustive census of species was carried out. For each individual, height was measured using a suunto dendrometer, tree trunk diameter at chest height using a forest compass, cross-diameter of the crown (East-West and North-South direction) using a metric tape, and counts of young trees were made to assess regeneration. Woody trees with a diameter of less than 5 cm at 1.30 m were considered regeneration [15].

To delineate the plots, a metric tape, rope and stakes were used. Method 3-4-5 based on the Pythagorean theorem was used to determine the four right angles of the plot.

2.3. Data Processing

Data entry and the preparation of tables and graphs were carried out with the Excel spreadsheet. The Principal Component Analysis (PCA) was carried out using the software R version 3.5.3. Several formulas were used to calculate the vegetation parameters.

Specific frequency: This provides information on the distribution of a species in a stand. It can be expressed as an absolute value or as a percentage (%). It is calculated by the following formula [16]: $F = N_{ri}/N_r$

F = frequency of occurrence expressed as a percentage (%); N_{ri} = number of records where species i is present and

N_r = total number of records

Species richness: This has been assessed on the basis of total species richness, which is the total number of species in the stand in a given ecosystem [17].

Density (true density): is the number of individuals per unit area (ha). It is the ratio of the total number of individuals in the sample (N) by the sampled area (s) $D = N/S$

The basal area, which is the area occupied by the tree at the base of its trunk. It is expressed in square metres per hectare (m². ha.⁻¹),

$$St = \frac{\sum \pi \left(\frac{d_{1.30}}{2} \right)^2}{SE}$$

Where St = basal area; $d_{1.30}$ = trunk diameter in m at 1.30 m from the ground; SE = area of the sample under consideration in ha.

The woody canopy which is the area covered by the vertical projection of the tree crown on the ground. It is calculated in square metres per ha.

$$C = \frac{\sum \pi \left(\frac{dmh}{2} \right)^2}{SE}$$

Where C = woody cover; dmh = mean crown diameter in m; S = area of the sample under consideration in ha

Shannon Weaver's index (H'), which considers both abundance and species richness, 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 [18]. It can be expressed in bits and its formula is:

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

p_i = relative abundance of each species.

The evenness index (E) provides information on the distribution of species abundance in the stand. The regularity index appears to be a more rigorous comparison term [19]. It is between 0 and 1 and tends towards 0 when all the individuals correspond to a single species. It tends towards 1 when each species is represented by the same number of individuals [20]. This index is given by the following formula:

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

$H_{max} = \log_2 (S)$ S = total number of species.

3. Results

3.1. Floristic Composition

The study of the agroforestry parks in the Tenthory district identified sixty-four (64) woody species divided into fifty-three (53) genera and 20 botanical families. Of the 64 species inventoried, the municipality of Tenthory recorded more species (57 species) divided into 49 genera and 19 families.

Table 1. Floristic composition of the agroforestry parks according to the municipalities of the Tenghory district.

Families	Genera	Species	Municipalities			
			Teng.	Ouo.	Coub.	Niam.
Anacardiaceae	Anacardium	<i>Anacardium occidentale</i> L.	+	+	+	+
	Mangifera	<i>Mangifera indica</i> L.	+	+	+	+
	Spondias	<i>Spondias monbin</i> L.	+	-	+	-
Annonaceae	Annona	<i>Annona senegalensis</i> Pers.	+	-	-	-
	Uvaria	<i>Uvaria chamae</i> P. Beauv.	+	-	-	-
Apocynaceae	Calotropis	<i>Calotropis procera</i> (Ait.) Ait. f.	+	-	-	-
	Holarrhena	<i>Holarrhena floribunda</i> (G. Don) Dur. & Schinz	+	-	+	+
	Landolphia	<i>Landolphia heudelotii</i> A. DC.	+	-	+	-
	Saba	<i>Saba senegalensis</i> (A. DC.) Pichon	-	-	+	-
Arecaceae	Borassus	<i>Borassus akeassii</i> Bayton, Ouedraogo & Guinko	+	-	-	+
	Elaeis	<i>Elaeis guineensis</i> Jacq.	+	+	-	+
Bignoniaceae	Markhamia	<i>Markhamia tomentosa</i> (Benth.) K. Schum. ex Engl.	+	-	+	+
	Newbouldia	<i>Newbouldia laevis</i> (P. Beauv.) Seem.	+	+	+	+
Chrysobalanaceae	Neocarya	<i>Neocarya macrophylla</i> (Sabine) Prance	+	-	-	+
		<i>Combretum glutinosum</i> Perr. ex DC.	+	-	-	-
		<i>Combretum lecardii</i> Engl. & Diels	+	+	-	+
Combretaceae	Combretum	<i>Combretum micranthum</i> G. Don	+	-	+	+
		<i>Combretum nigricans</i> Lepr. ex Guill. et Perr.	+	-	+	-
		<i>Combretum paniculatum</i> Vent.	+	-	-	-
		<i>Guiera senegalensis</i> J. F. Gmel.	+	+	+	+
	Terminalia	<i>Terminalia macroptera</i> Guill. & Perr.	+	+	+	+
		<i>Terminalia mollis</i> Laws.	-	-	+	-
	Acacia	<i>Acacia holosericea</i> A. Cunn. ex G. Don	-	-	+	-
	Afzelia	<i>Afzelia africana</i> Smith ex Pers.	+	-	-	-
	Albizia	<i>Albizia adianthifolia</i> (Schumach.) W. F. Wight	+	-	+	-
	Cassia	<i>Cassia sieberiana</i> DC.	+	+	+	+
Fabaceae	Cordyla	<i>Cordyla pinnata</i> (Lepr. ex A. Rich.) Milne-Redhead	+	-	+	-
	Daniellia	<i>Daniellia oliveri</i> (Rolfe) Hutch. & Dalz.	+	-	+	-
	Detarium	<i>Detarium microcarpum</i> Guill. & Perr.	-	-	+	-
		<i>Detarium senegalense</i> Gmel.	+	-	-	+
	Dialium	<i>Dialium guineense</i> Willd.	+	-	-	-
	Dichrostachys	<i>Dichrostachys cinerea</i> (L.) Wight & Arn.	+	+	+	+
	Erythrina	<i>Erythrina senegalensis</i> DC.	+	+	-	+
	Erythrophleum	<i>Erythrophleum africanum</i> Afzel.	+	-	+	-
	Faidherbia	<i>Faidherbia albida</i> (Del.) Chev.	+	+	+	+
	Parkia	<i>Parkia biglobosa</i> (Jacq.) R. Br. ex G. Don	+	+	+	+
	Piliostigma	<i>Piliostigma reticulatum</i> (DC.) Hochst.	+	-	-	-
		<i>Piliostigma thonningii</i> (Schumach.) Milne-Redh.	+	+	-	+
	Prosopis	<i>Prosopis africana</i> (Guill. & Perr.) Taub.	+	+	+	+
	Pterocarpus	<i>Pterocarpus erinaceus</i> Poir.	+	-	+	-
Icacinaeae	Senna	<i>Senna alata</i> (L.) Roxb.	+	-	-	-
	Icacina	<i>Icacina senegalensis</i> Juss.	+	+	+	+
Malvaceae	Adansonia	<i>Adansonia digitata</i> L.	+	+	-	+
	Bombax	<i>Bombax costatum</i> Pellegr. & Vuillet	+	-	+	+
Meliaceae	Cola	<i>Cola cordifolia</i> (Cav.) R. Br.	+	-	-	-
	Azadirachta	<i>Azadirachta indica</i> A. Juss.	+	+	-	+
	Ekebergia	<i>Ekebergia senegalensis</i> A. Juss.	-	+	-	-
	Khaya	<i>Khaya senegalensis</i> (Desr.) A. Juss.	+	-	+	+
	Antiaris	<i>Antiaris africana</i> Engl	+	-	+	-
Moraceae	Ficus	<i>Ficus dicranostyla</i> Mildbr.	+	+	-	-
		<i>Ficus exasperata</i> Vahl	+	-	-	-
		<i>Ficus glumosa</i> Del.	+	-	-	+
		<i>Ficus sycomorus</i> ssp. <i>gnaphalocarpa</i> (Miq.) C. C. Berg	-	-	+	+
Myrtaceae	Eucalyptus	<i>Eucalyptus camaldulensis</i> Dehnh.	-	-	-	+
Polygalaceae	Securidaca	<i>Securidaca longipedunculata</i> Fres.	+	-	-	+
Rhamnaceae	Ziziphus	<i>Ziziphus mauritiana</i> Lam.	+	+	-	-

Families	Genera	Species	Municipalities			
			Teng.	Ouo.	Coub.	Niam.
Rubiaceae	Gardenia	<i>Gardenia ternifolia</i> Schumach. & Thonn.	+	+	-	+
	Sarcocephalus	<i>Sarcocephalus latifolius</i> (Smith) Bruce	+	-	-	-
Rutaceae	Citrus	<i>Citrus limon</i> (L.) Burm. f.	+	-	-	+
		<i>Citrus sinensis</i> (L.) Osbeck	+	-	-	-
Simaroubaceae	Hannoa	<i>Hannoa undulata</i> (Guill. & Perr.) Planch.	+	-	+	-
Ulmaceae	Celtis	<i>Celtis integrifolia</i> Lam.	+	-	+	-
Verbenaceae	Vitex	<i>Vitex doniana</i> Sweet	+	+	+	+
	Gmelina	<i>Gmelina arborea</i> Roxb.	+	-	-	-
Total 20	53	64	57	22	33	32

+: Presence; -: Absence

Legend: Ouo: Ouonck; Teng: Tenghory; Coub: Coubalan; Niam: Niamone

In the municipality of Coubalan, 33 species divided into 31 genera and 12 families were recorded. Niamone municipality recorded 32 species in 30 genera and 16 families. The municipality of Ouonck recorded the fewest species (22 species) divided into 22 genera and 12 families (Table 1). The families that predominate at the district level are the *Fabaceae* (29.7%), the *Combretaceae* (12.5%) and the *Moraceae* (7.8%). The same trend is observed in the municipality of Tenghory with the predominant botanical families being *Fabaceae* (29.8%), *Combretaceae* (12.3%)

and *Moraceae* (7.0%). In the municipality of Coubalan, *Fabaceae* (36.4%), *Combretaceae* (15.2%) and *Anacardiaceae* (9.1%) are the predominant botanical families. These are the same families that predominate in the municipality of Ouonck with 31.8% of the species for the *Fabaceae*, 13.6% of the species for the *Combretaceae* and 9.1% of the species for the *Anacardiaceae*. As for the municipality of Niamone, the families that predominate there are: the *Fabaceae* (25%), the *Combretaceae* (12.5%) and the *Anacardiaceae* with 6.3% of the species (Table 2).

Table 2. Relative importance of families (%) by municipality and Tenghory district.

Families	Municipalities				Tenghory district
	Tenghory	Ouonck	Coubalan	Niamone	
<i>Fabaceae</i>	29,8	31,8	36,4	25,0	29,7
<i>Combretaceae</i>	12,3	13,6	15,2	12,5	12,5
<i>Moraceae</i>	7,0	4,5	6,1	6,25	7,8
<i>Apocynaceae</i>	5,3	0,0	9,09	3,1	6,3
<i>Anacardiaceae</i>	5,3	9,1	9,1	6,3	4,7
<i>Malvaceae</i>	5,3	4,5	3,0	6,25	4,7
<i>Meliaceae</i>	3,5	9,09	3,0	6,25	4,7
<i>Annonaceae</i>	3,5	0,0	0,0	0,0	3,1
<i>Arecaceae</i>	3,5	4,5	0,0	6,3	3,1
<i>Bignoniaceae</i>	3,5	4,5	6,1	6,3	3,1
<i>Rubiaceae</i>	3,5	4,5	0,0	3,1	3,1
<i>Rutaceae</i>	3,5	0,0	0,0	3,1	3,1
<i>Verbenaceae</i>	3,5	4,5	3,0	3,1	3,1
<i>Chrysobalanaceae</i>	1,8	0,0	0,0	3,1	1,6
<i>Icacinaceae</i>	1,8	4,5	3,0	3,1	1,6
<i>Myrtaceae</i>	0,0	0,0	0,0	3,1	1,6
<i>Polygalaceae</i>	1,8	0,0	0,0	3,1	1,6
<i>Rhamnaceae</i>	1,8	4,5	0,0	0,0	1,6
<i>Simaroubaceae</i>	1,8	0,0	3,0	0,0	1,6
<i>Ulmaceae</i>	1,8	0,0	3,0	0,0	1,6

3.2. Frequency Analysis

The woody vegetation of the agroforestry parks in the Tenghory district is rich in 64 species. Of these, *Icacina senegalensis* Juss. is the most common (74.7%). It is followed by *Guiera senegalensis* J. F. Gmel. (64.6%), *Terminalia macroptera* Guill. & Perr. (48.5%) and *Cassia sieberiana* DC. (45.5%).

In the municipality of Tenghory, the most frequent species

in agroforestry parks are *Icacina senegalensis* (77.4%), *Guiera senegalensis* J. F. Gmel. (60.4%) and *Terminalia macroptera* Guill. & Perr. (50.9%).

In the commune of Ouonck, *Icacina senegalensis* is the most frequent species (100%). It is followed by *Guiera senegalensis* J. F. Gmel. (78.6%) and *Faidherbia albida* (64.3%).

The most frequent species in the parks of the municipality of Coubalan are: *Terminalia macroptera* Guill. & Perr. (61.1%), *Pterocarpus erinaceus* Poir. (61.1%) and *Guiera*

senegalensis J. F. Gmel. (55.6%).

And in the municipality of Niamone, the species with a high frequency of occurrence in the parks are *Guiera*

senegalensis J. F. Gmel. (78.6%), *Icacina senegalensis* Juss. (78.6%) and *Cassia sieberiana* DC. (71.4%) (Table 3).

Table 3. Specific frequencies (%) of woody trees in the different municipalities of the Tengu district.

Species	Teng. district	Muni. Teng	Muni. Ou	Muni. Cou	Muni. Niam
<i>Icacina senegalensis</i> Juss.	74,7	77,4	100,0	44,4	78,6
<i>Guiera senegalensis</i> J. F. Gmel.	64,6	60,4	78,6	55,6	78,6
<i>Terminalia macroptera</i> Guill. & Perr.	48,5	50,9	21,4	61,1	50,0
<i>Cassia sieberiana</i> DC.	45,5	47,2	28,6	33,3	71,4
<i>Dichrostachys cinerea</i> (L.) Wight & Arn.	37,4	39,6	14,3	55,6	28,6
<i>Parkia biglobosa</i> (Jacq.) R. Br. ex G. Don	35,4	45,3	28,6	22,2	21,4
<i>Anacardium occidentale</i> L.	33,3	39,6	28,6	16,7	35,7
<i>Combretum lecardii</i> Engl. & Diels	30,3	26,4	50,0	0,0	64,3
<i>Azadirachta indica</i> A. Juss.	27,3	32,1	28,6	0,0	42,9
<i>Combretum micranthum</i> G. Don	27,3	28,3	0,0	50,0	21,4
<i>Newbouldia laevis</i> (P. Beauv.) Seem.	27,3	35,8	7,1	16,7	28,6
<i>Elaeis guineensis</i> Jacq.	26,3	37,7	7,1	0,0	35,7
<i>Vitex doniana</i> Sweet	26,3	24,5	7,1	44,4	28,6
<i>Pterocarpus erinaceus</i> Poir.	25,3	26,4	0,0	61,1	0,0
<i>Prosopis africana</i> (Guill. & Perr.) Taub.	24,2	30,2	21,4	11,1	21,4
<i>Markhamia tomentosa</i> (Benth.) K. Schum. ex Engl.	22,2	18,9	0,0	33,3	42,9
<i>Faidherbia albida</i> (Del.) Chev.	21,2	15,1	64,3	16,7	7,1
<i>Holarrhena floribunda</i> (G. Don) Dur. & Schinz	21,2	22,6	0,0	44,4	7,1
<i>Piliostigma thonningii</i> (Schumach.) Milne-Redh.	20,2	34,0	7,1	0,0	7,1
<i>Borassus akeassii</i> Bayton, Ouedraogo & Guinko	18,2	28,3	0,0	0,0	21,4
<i>Annona senegalensis</i> Pers	15,2	28,3	0,0	0,0	0,0
<i>Daniellia oliveri</i> (Rolfe) Hutch. & Dalz.	15,2	26,4	0,0	5,6	0,0
<i>Hannoa undulata</i> (Guill. & Perr.) Planch.	13,1	11,3	0,0	38,9	0,0
<i>Mangifera indica</i> L.	12,1	13,2	7,1	16,7	7,1
<i>Khaya senegalensis</i> (Desr.) A. Juss.	11,1	17,0	0,0	5,6	7,1
<i>Combretum nigricans</i> Lepr. ex Guill. et Perr.	10,1	1,9	0,0	50,0	0,0
<i>Securidaca longipedunculata</i> Fres.	10,1	17,0	0,0	0,0	7,1
<i>Citrus limon</i> (L.) Burm. f.	8,1	13,2	0,0	0,0	7,1
<i>Gardenia ternifolia</i> Schumach. & Thonn.	8,1	7,5	7,1	0,0	21,4
<i>Bombax costatum</i> Pellegr. & Vuillet	7,1	1,9	0,0	27,8	7,1
<i>Erythrina senegalensis</i> DC.	7,1	9,4	7,1	0,0	7,1
<i>Ficus glumosa</i> Del.	7,1	9,4	7,1	0,0	7,1
<i>Spondias monbin</i> L.	6,1	1,9	0,0	27,8	0,0
<i>Adansonia digitata</i> L.	5,1	5,7	7,1	0,0	7,1
<i>Cola cordifolia</i> (Cav.) R. Br.	5,1	9,4	0,0	0,0	0,0
<i>Landolphia heudelotii</i> A. DC.	5,1	1,9	0,0	22,2	0,0
<i>Celtis integrifolia</i> Lam.	4,0	5,7	0,0	5,6	0,0
<i>Cordyla pinnata</i> (Lepr. ex A. Rich.) Milne-Redhead	4,0	3,8	0,0	11,1	0,0
<i>Erythrophleum africanum</i> Afzel.	4,0	5,7	0,0	5,6	0,0
<i>Neocarya macrophylla</i> (Sabine) Prance	4,0	5,7	0,0	0,0	7,1
<i>Detarium senegalense</i> Gmel.	3,0	3,8	0,0	0,0	7,1
<i>Ziziphus mauritiana</i> Lam.	3,0	1,9	14,3	0,0	0,0
<i>Azelaia africana</i> Smith ex Pers.	2,0	3,8	0,0	0,0	0,0
<i>Albizia adianthifolia</i> (Schumach.) W. F. Wight	2,0	1,9	0,0	5,6	0,0
<i>Antiaris africana</i> Engl.	2,0	1,9	0,0	5,6	0,0
<i>Calotropis procera</i> (Ait.) Ait. f.	2,0	3,8	0,0	0,0	0,0
<i>Citrus sinensis</i> (L.) Osbeck	2,0	3,8	0,0	0,0	0,0
<i>Combretum paniculatum</i> Vent.	2,0	3,8	0,0	0,0	0,0
<i>Dialium guineense</i> Willd.	2,0	3,8	0,0	0,0	0,0
<i>Eucalyptus camaldulensis</i> Dehnh.	2,0	0,0	0,0	0,0	7,1
<i>Ficus dicranostyla</i> Mildbr.	2,0	1,9	0,0	0,0	0,0
<i>Ficus exasperata</i> Vahl	2,0	1,9	0,0	0,0	0,0
<i>Ficus sycomorus</i> (Miq.) C. C. Berg	2,0	0,0	0,0	5,6	7,1
<i>Gmelina arborea</i> Roxb.	2,0	1,9	0,0	0,0	0,0
<i>Sarcocephalus latifolius</i> (Smith) Bruce	2,0	1,9	0,0	0,0	0,0
<i>Senna alata</i> (L.) Roxb.	2,0	1,9	0,0	0,0	0,0
<i>Uvaria chamae</i> P. Beauv.	2,0	3,8	0,0	0,0	0,0
<i>Acacia holosericea</i> A. Cunn. ex G. Don	1,0	0,0	0,0	5,6	0,0
<i>Combretum glutinosum</i> Perr. ex DC.	1,0	1,9	0,0	0,0	0,0
<i>Detarium microcarpum</i> Guill. & Perr.	1,0	0,0	0,0	5,6	0,0
<i>Ekebergia senegalensis</i> A. Juss.	1,0	0,0	7,1	0,0	0,0

Species	Teng. district	Muni. Teng	Muni. Ouo	Muni. Coub	Muni. Niam
<i>Piliostigma reticulatum</i> (DC.) Hochst.	1,0	1,9	0,0	0,0	0,0
<i>Saba senegalensis</i> (A. DC.) Pichon	1,0	0,0	0,0	5,6	0,0
<i>Terminalia mollis</i> Laws.	1,0	0,0	0,0	5,6	0,0

Legend: Teng. district: Tenthory district; Muni. Ouo: Municipality of Ouonck; Muni. Teng: Municipality of Tenthory; Muni. Coub: Municipality of Coubalan; Muni. Niam: Municipality of Niamone

3.3. Structural Characteristics of Woody Vegetation in Parks

The average coverage rate for all agroforestry parks in the Tenthory district is 13.7%. It is higher in the municipality of Tenthory (15.9%) followed by that of Ouonck (15.3%). The municipalities of Coubalan and Niamone have coverage rates of 11.7 per cent and 6.4 per cent respectively (Table 4). The species with the highest recovery rates at the district level are *Faidherbia albida* (2.5%), *Parkia biglobosa* (1.8%) and *Pterocarpus erinaceus* (0.9%).

The basal area of all the agroforestry parks in the district is 3.3 m²/ha. It varies from 4.1 m²/ha in the municipality of Tenthory to 1.8 m²/ha in that of Niamone, and 2.8 m²/ha and 2.2 m²/ha in the municipalities of Coubalan and Ouonck respectively (Table 3). The species with the largest land areas at the district level are *Adansonia digitata* (0.41 m²/ha),

Faidherbia albida (0.31 m²/ha), *Cola cordifolia* (0.25 m²/ha) and *Parkia biglobosa* (0.25 m²/ha).

In the Tenthory district, the density observed is 21.8 plants/ha. It is higher in the municipality of Coubalan (29.6 individuals/ha) than in the municipalities of Tenthory (22.9 individuals/ha), Ouonck (16.9 individuals/ha) and Niamone (12.6 ft/ha) (Table 4). The species with the highest densities in the parks are: *Pterocarpus erinaceus* (2.9 individuals/ha), *Elaeis guineensis* (2.5 individuals/ha), *Faidherbia albida* (2.3 individuals/ha), *Anacardium occidentale* (2.0 individuals/ha) and *Parkia biglobosa* (1.7 individuals/ha).

The agroforestry parks in Tenthory District are very diversified with Shannon Weaver (H') and Pielou (E) indices of 3.8 bits and 0.64 bits respectively (Table 4). At the municipal level, this diversity is higher in Coubalan (H'=4; E=0.79) and lower in Ouonck (H'=2.2; E=0.50).

Table 4. Structural parameters of woody vegetation in agroforestry parks according to municipalities and Tenthory district.

Ecological parameters	Tenthory district	Communes			
		Tenthory	Ouonck	Coubalan	Niamone
Canopy cover (%)	13,7	15,9	15,3	11,7	6,4
Basal area (m ² /ha)	3,3	4,1	2,2	2,8	1,8
Density (individuals/ha)	21,8	22,9	16,9	29,6	12,6
Shannon Diversity Index	H'	3,7	2,2	4,0	3,2
Pielou regularity Index	E	0,64	0,50	0,79	0,63

Legend: H'= Shannon Weaver Index E= Pielou Index.

3.4. Characteristics of the Agroforestry Parks in the Tenthory District

Table 5 presents the distribution of variances from the Principal Component Analysis (PCA) of the characteristics of the parks in Tenthory district according to the municipalities. The first axis (F1) accounts for 51% of the variance and the second axis (F2) accounts for 31.6%. The first two axes thus account for 82.6% of the total variance. The factorial design F1xF2 thus allowed a good representation of the information contained in the matrix.

Table 5. Distribution of eigenvalues or variances along PCA factor axes.

	F1	F2	F3
Eigenvalues	3.570	2.215	1.215
Inertia (%)	51,000	31.638	17.362
Cumulated inertia (%)	51,000	82.638	100.000

On the basis of the floristic and structural characteristics of the agroforestry parks in the Tenthory district, Principal Component Analysis (PCA) made it possible to discriminate

between different groups of agroforestry parks (Figure 3). Thus, along the F1 axis, two large groups of agroforestry parks can be distinguished:

- 1) Group A, located on the positive x-axis, which is divided into two subgroups (A1 and A2) along the y-axis. Sub-group A1, located on the positive y-axis, is characteristic of the agroforestry parks in the municipality of Tenthory with a high coverage rate (CT), specific richness (S) and basal area (ST). Sub-group A2, representing the agroforestry parks of the municipality of Coubalan, is characterized by a high density (DENS) and specific diversity (Shannon-Weaver index (H') and Pielou equitability index (E)) but with a low regeneration rate (TR).
- 2) Group B, located on the negative x-axis side, contrasts with Group A. It contains sub-groups B1 and B2. Sub-group B1, representing the parks of the commune of Ouonck, is characterized by a low density (DENS), and a low specific diversity (H' and E) but with a high regeneration rate (TR). Sub-group B2, representing the parks of the municipality of Niamone, is characterized by a low coverage rate

(TC), a low specific richness (S) and a low basal area (ST). It thus appears that the x-axis, which has made it possible to distinguish between the parks in group A characterised by high specific diversity, and the parks in group B characterised by low diversity, corresponds to a diversity gradient.

3.5. Structure of Woody Vegetation in Parks (Trees of $D1.3 \geq 5$ cm)

3.5.1. Vertical Structure

It appears from figure 4 that individuals of height greater than or equal to 10 m are the most represented in the 4 communes and at the district level. The proportion of woody individuals greater than 10 m in height is 71.2%, 54.5%, 48.8% and 43.6% respectively in the municipalities of Ouonck, Niamone, Tenghory and Coubalan. At the level of the district this proportion is 50.5%.

At the level of the district, the height class [2-4] groups the least number of individuals with 9.1% of woody individuals.

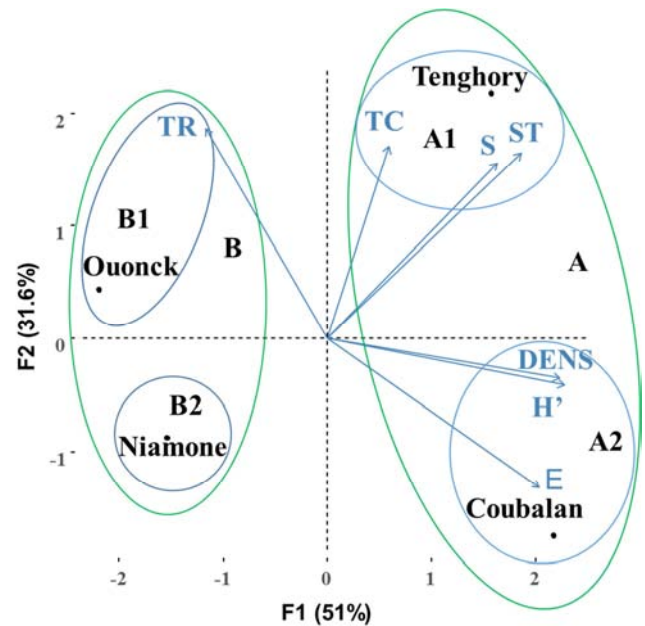


Figure 3. Characteristics of agroforestry parks in the Tenghory district.

Legend: DENS (Density), TC (coverage rate), ST (basal area), H (shannon wearver index), E (Pielou index), S (Specific richness), TR (Regeneration rate).

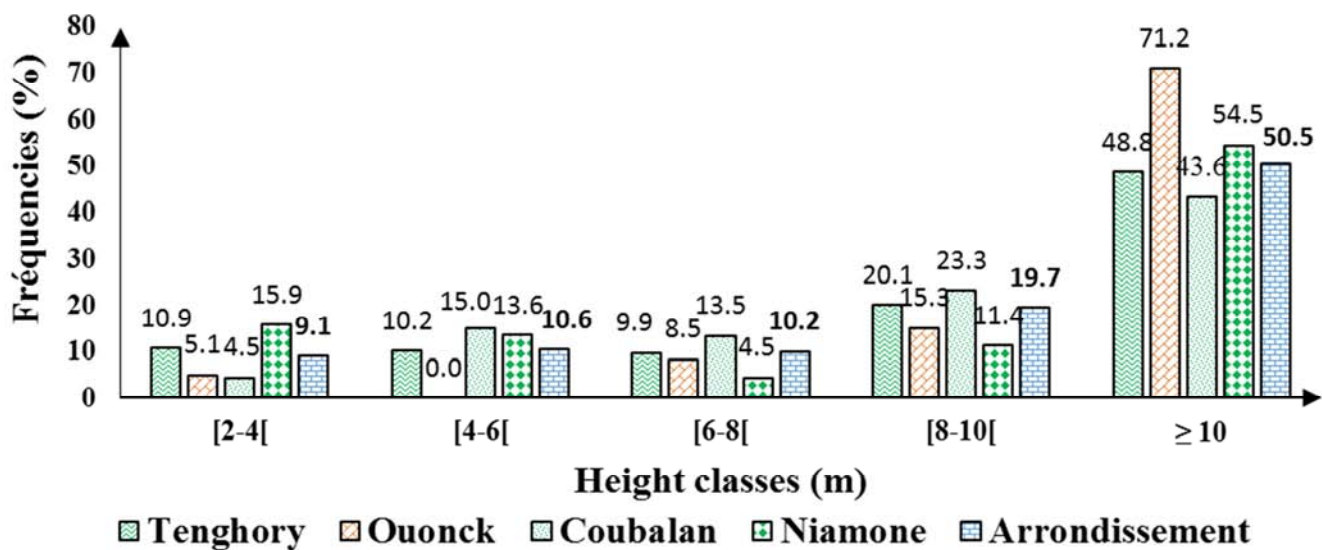


Figure 4. Distribution in height classes of woody stand individuals (trees of $D1.3 \geq 5$ cm) in agroforestry parks according to communes and the Tenghory district.

3.5.2. Horizontal Structure

In the agroforestry parks of the Tenghory district, the diameter class [5-25] is the best represented with 45.8% of the individuals. This diameter class is also more represented in the municipalities of Coubalan and Tenghory with 72.2% and 41.3% of the individuals in the woody stand of the parks, respectively. In the municipalities of Niamone and Ouonck it is the class of diameter between 25 and 45 cm that is the most represented with respectively 54.5 and 45.8% of the individuals in the woody stand of the parks. Globally, the horizontal structure of the woody vegetation

in the parks is characterized by a predominance of individuals with a diameter < 45 cm. At the district level, these individuals represent 80.5% of the woody stand in the parks. According to the municipalities, individuals with diameter < 45 cm constitute 89.5, 79.9, 78.6 and 71.2% of the woody population of the agroforestry parks in the municipalities of Coubalan, Niamone, Tenghory and Ouonck respectively. Overall, it appears that for the municipalities of Niamone and Ouonck, the structure by diameter classes of the individuals in the woody stand presents a normal distribution with a predominance of individuals of

intermediate classes. In the municipalities of Tenthory, Coubalan and in the district, the structure is L-shaped with a predominance of young individuals, with a diameter

between 5 and 25 cm and a low representation of large-diameter individuals (Figure 5).

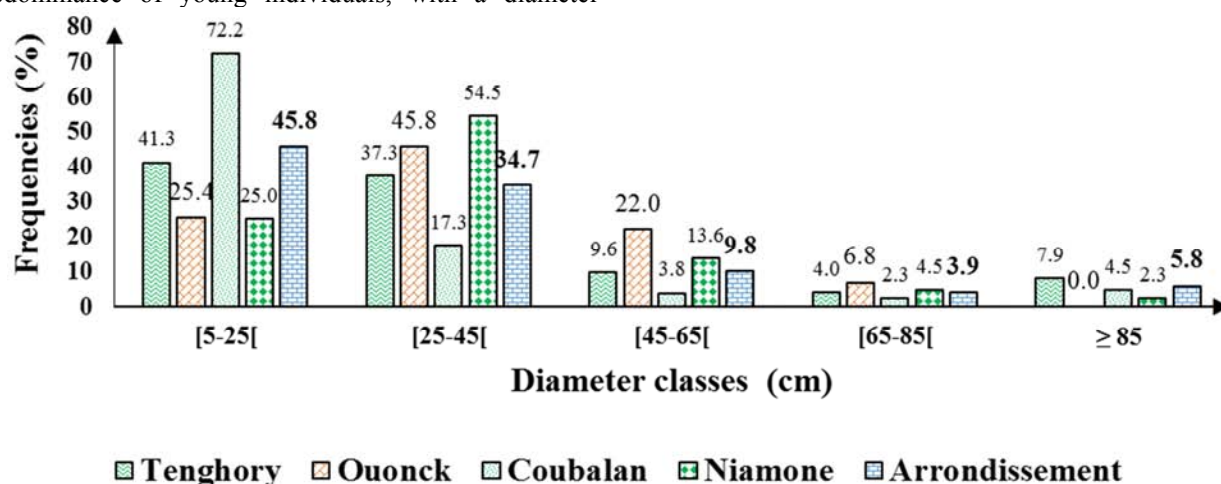


Figure 5. Distribution by diameter classes of individuals in the woody stand of agroforestry parks according to municipality and district.

4. Discussion

The purpose of this work is to contribute to a better knowledge of the state of the agroforestry parks in the Tenthory district. The study revealed the presence of 64 woody species divided into 53 genera and 20 botanical families in the agroforestry parks of the Tenthory district. The predominant families were *Fabaceae* (29.7%), *Combretaceae* (12.5%) and *Moraceae* (7.8%). Of the 64 species inventoried, the municipalities of Tenthory, Coubalan, Niamone and Ouonck recorded 57; 33; 32 and 22 species respectively. These parks are quite diversified with a Shannon index of 3.8 bits in the district. This index varies from 4 bits in Coubalan to 2.2 bits in Ouonck. These results are close to those of [20] who obtained in the traditional agroforestry parks in *Elaeis guineensis* in Lower Casamance a specific richness of 69 woody species divided into 58 genera, belonging to 23 botanical families. Moreover, they observed a predominance of *Fabaceae* (20%) and *Moraceae* (16.18%), which confirms our results. In addition, for species diversity, the authors observed Shannon indices of 4.12 bits at Kaguite; 3.27 bits at Carouate and 2.93 bits at Kabiline. The floristic richness obtained in the parks of the Tenthory district is less important than that of *Elaeis guineensis* parks in Guinea Bissau in the Cacheu region where 75 species distributed in 63 genera and 25 botanical families were recorded [21].

The high frequency of presence of *Icacina senegalensis* (74.7%) and *Guiera senegalensis* (64.6%) species in the district reflects the high regeneration capacity of the latter after clearing. These results corroborate those of [22] who cited *Icacina senegalensis* (40.3%) and *Guiera senegalensis* (59.7%) as the most frequent species in the fields and fallows of the southwestern groundnut basin in Senegal. The inverse correlation observed between regeneration rate and species diversity could be explained

by the predominance of a few species such as *Icacina senegalensis* and *Guiera senegalensis* in the woody stand. This is due to their high regeneration capacity. The relatively low values of cover rate (13.7%), basal area (3.3 m²/ha) and density (21.8 feet/ha) in the parks of the Tenthory district reflect the impact of human intervention on woody trees in the parks. Indeed, farmers tend to reduce the total number of plants and species while favouring a few preferred species [23]. Also, it is difficult to cultivate with a certain density of trees in the fields [8].

Overall, the woody stand in the agroforestry parks of the Tenthory district presents a vertical structure with a predominance of large individuals (≥ 10 m) and a horizontal "L" structure indicating a predominance of small diameter individuals (between 5 and 25 cm). As a result, agroforestry parks are characterized by a predominance of individuals with small trunk diameter but relatively large size (≥ 10 m). These results are in contrast to those [24] who found a predominance of large-diameter individuals (diameter ≥ 50 cm) in the anthropogenic savannahs of *Parkia biglobosa* and *Piliostigma reticulatum* in Burkina Faso.

5. Conclusion and Perspectives

At the end of this study, the characteristics of the woody flora and vegetation of the agroforestry parks in the Tenthory district were established. These parks present a specific richness of 64 woody species divided into 53 genera and 20 botanical families. The most represented families are those of *Fabaceae* and *Combretaceae* with respectively 29.7% and 12.5% of the individuals inventoried. *Icacina senegalensis* (74.7%) and *Guiera senegalensis* (64.6%) are the most frequent species in these parks. The density of trees is 21.8 trees/ha, and the basal area and cover rate are 3.3 m²/ha and 13.7% respectively. It would be important: to continue this study in the other departments of Lower Casamance (Ziguinchor and Oussouye) in order to lay the foundations

for a more rational management of these important ecosystems; and finally to raise awareness among farmers in order to prepare them for a more rational management of agroforestry parks.

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