Medicinal species of Fathala forest and their demography in relation to human disturbances

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Research

Abstract

Background: Forests provide essential ecosystem services, and their capacity to deliver these benefits depends on their ecological integrity. In many African forests, biodiversity loss remains has reduce the availability of useful plants species. Among these, medicinal plants are particularly important for primary healthcare but are frequently subjected to intensive and often unsustainable harvesting. This study aims to identify the woody species harvested for medicinal purposes and assess the population status of these species in the Fathala classified forest, Senegal.

Methods: Data were collected through ethnobotanical surveys and a floristic inventory. Statistical analysis were perform to evaluate the different medicinal uses of woody species, the frequency of their use and the population structure and demography of harvested species in relation to different harvesting practices.

Results: A total of 32 woody species were identified are being used to treat a wide range of aliments, with leaves, bark, and roots representing the principal plant parts harvested. *Combretum glutinosum, Terminalia avicennioides, Terminalia macroptera, Cordyla pinnata, Combretum micranthum* and *Sclerocarya birrea* were the most frequently used species used in traditional healthcare. Several of these species exhibited low density and basal area, together with irregular diameter class distributions, indicating disturbed population structures. Among the disturbances assessed, medium-intensity fires and medium-intensity pruning had the greatest effects on the population demography and stand structure of medicinal species comaped with debarking, grazing and root excavation.

Conclusions: The findings highlight the urgent need to strengthen the conservation and sustainable management of medicinal plants by reducing harvesting pressure on this valuable biological resource. Effective implementation of existing forest management and conservation strategies is essential to ensure the long-term availability of medicinal plants and the ecosystem services they provide to local communities.

Keywords: Degradation; Ethnobotanical knowledge; Therapeutic uses; Protected area; Population structure

Background

Forests are reservoirs of biodiversity where plants play an essential role thanks to the many ecosystem services they provide and the various functions they perform (Tankoano 2017). For example, woody species are widely used to meet socio-economic needs, particularly in developing countries of Africa (Nacoulma *et al.* 2017), where they contribute significantly to health and well-being (Saulnier 2024).

On the African continent, herbal therapy is a practice commonly adopted by the majority of the population despite advances in modern medicine (Gonzaleze *et al.* 2024). Furthermore, in a context marked by inadequate health infrastructure and financial resources, compounded by cultural heritage, the use of plants as a source of remedies becomes the most appropriate solution (Sala 2024). However, the high demand for plant products extracted mainly from natural forests is reducing the populations of woody species (Mykhailenko *et al.* 2025, Nacoulma *et al.* 2017). For example, the harvesting of leaves, roots and bark is generally carried out without consideration for the survival of these species (Fedorca *et al.* 2020). The methods used to harvest these organs damage the plants and expose them to disease and external attacks, which can sometimes cause their death (Workneh & Wasie 2024). In addition to these harvesting practices, other human factors such as fires have made certain species so vulnerable that they are now threatened (Silverio *et al.* 2025, Ayena *et al.* 2016). These human pressures do not spare protected areas such as classified forests (Angoni *et al.* 2018).

In Senegal, classified forests, despite their status as protected areas, are in continuous decline (Solly 2021). In the Fathala classified forest, part of the Delta du Saloum National Park, many woody species are exploited for traditional medicine (Diop *et al.* 2022). This forest ecosystem is also under other pressures, particularly from timber exploitation and bush fires, which have negative repercussions on flora and vegetation (Niang-Diop *et al.* 2011, Kaly *et al.* 2021). In this forest, intensive bush fires contribute massively to the degradation of species by altering the composition of plant formations while preventing young trees and seedlings from reaching maturity (Niang-Diop *et al.* 2011). Grazing leads to a drastic reduction in the number of individuals undergoing natural regeneration, which compromises the survival of certain woody species in the Fathala forest (Diop *et al.* 2011, Niang-Diop *et al.* 2011). At the same time, other woody species that are more tolerant to the stresses of their natural environment proliferate (Solly *et al*. 2020). Depending on the intensity and persistence of the disturbance factors, the structure of the stand is modified (Orihuela-Torres *et al.* 2026). These changes in the demographics of harvested species are a cause for ecological concern, especially since the role of protected areas is to ensure the preservation of the natural state of forests (Yoh *et al.* 2024). Thus, in this classified forest surrounded by a high human population density, the questions arise as to (i) which species are harvested for medicinal purposes, what are these main medicinal uses and (ii) how the populations of species targeted for the harvesting of plant products for medicinal use are behaving. We assume that: (i) diverse woody species in the Fathala classified forest are harvested for various medicinal uses, and (ii) the population structure of woody species of medicinal interest is influenced by their exploitation and other factors such as fire and grazing in the forest. The present study therefore aims to identify (i) the woody species harvested for medicinal purposes and their main medicinal uses and (ii) the status of their populations.

Materials and Methods

Study area

The study was conducted in the Fathala classified forest, located in west-central Senegal, in the Foundiougne department of the Fatick region (Fig. 1). It is situated between 13°36'-13°42' north latitude and 16°26'-16°30' west longitude. The forest is one of 15 forests in the region's classified forest domain and is located in the Sudanian domain (White 1983). A classified forest is defined in the Senegalese Forest Code as a ‘forest established for the conservation of soil, water, biological diversity and specific or fragile ecosystems and to ensure sustainable production by any appropriate means of management or protection’ (Republic of Senegal 2018). The Fathala classified forest represents the terrestrial part of the Delta du Saloum National Park, which covers an area of 76,000 ha (Lykke & Goudiaby 1999) and which has been designated a biosphere reserve in 1981 (Diouck 1999). Between 1991 and 2020, average rainfall was around 595 mm. This series is marked by a slight predominance of deficit years, of which there were 17, with 2007 being the year with the lowest rainfall (-268 mm compared to the average). Average monthly temperatures range between 25.4 °C and 30.4 °C (Agence Nationale de l’Aviation Civile et de la Météorologie 2020).

Data collection

Floristic inventory

In order to evaluate the demography of woody medicinal species, data were collected using the same stratified random sampling method of Lykke (1996). Forest stratification was done with Landsat images using ENVI (version 56) and ArcGis (version 108) software with the ArcMap tool. A total of 102 historical surveyed coordinates from Lykke inventory in 1992 were projected on the land use map. From each historical coordinate point four-square plots were implemented, in order to minimize accuracy errors. A total of 408 plots were inventoried, distributed across the four strata determined for the vegetation.

The measurements taken on individuals with a diameter ≥ 5 cm at 1.3 m above ground level are height, diameter and crown diameter. Samples were collected for the identification of unknown species at the herbarium of the Faculty of Sciences at Cheikh Anta Diop University in Dakar.

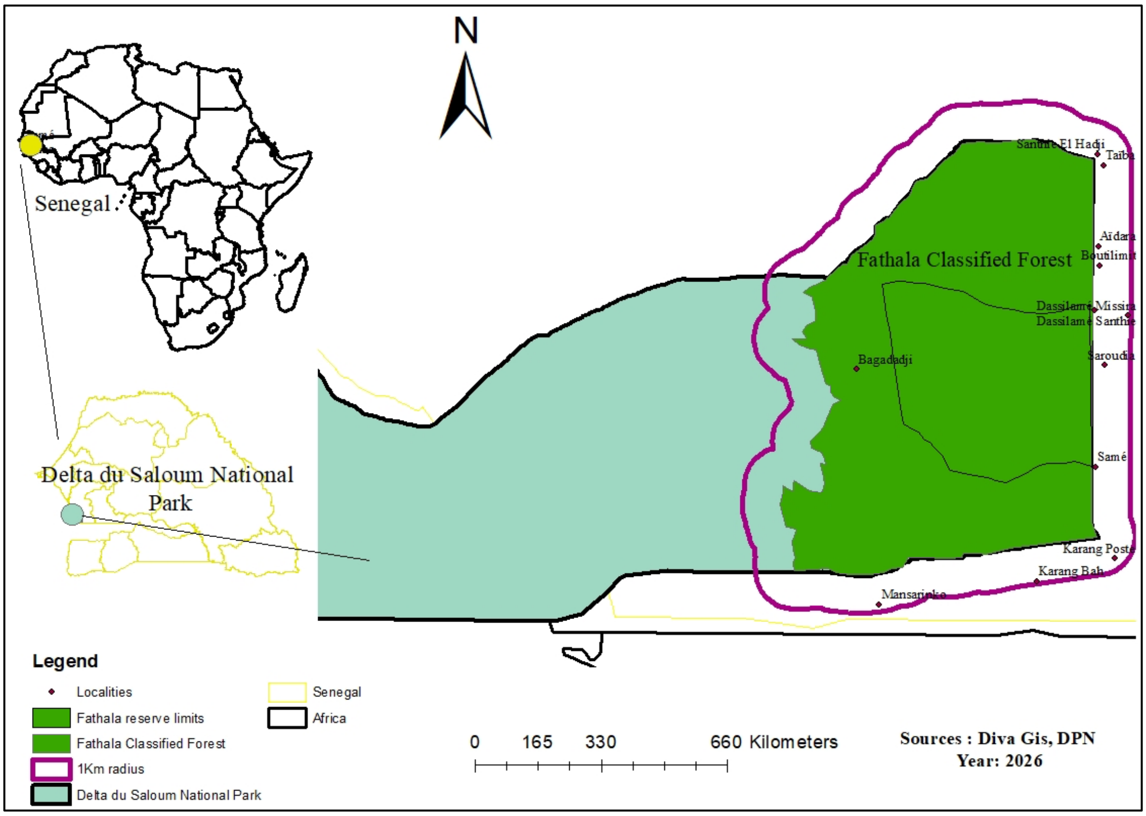

Figure 1. Map showing the location of the Fathala Classified Forest and surrounding areas

The observation was used to assess the condition of species showing signs of disturbance. The following traces were recorded: excavation, pruning, debarking, grazing and fire. The intensity of anthropogenic factors was estimated on the tree and on the plot, based on the method proposed by Cunningham (2001) and adapted for this study. This method makes it possible to classify the level of disturbance, which is an important indicator of plant health in their natural environment. A 5-level scale (Table 1) was used to assess pruning, debarking and fire, ranging from zero intensity (0) to the highest intensity (4):

- code (0) refers to no damage;
- code (1) refers to a low level (1 to 25% of bark or branch);
- code (2) refers to a medium level (26 to 50% of bark or branch);
- code (3) refers to a severe level (51 to 75% of bark or branch);
- code (4) refers to a more severe level (76 to 100% of bark or branch)

Table 1. 5 level scale for assessing disturbance factors affecting woody species

Codes	Intensity of debarking	Intensity of pruning	Impact of fire
0	Null	Null	Null
1	Low	Low	Low
2	Medium	Medium	Medium
3	High	High	High
4	Very high	Very high	Very high

The rate of branches removed (pruning) was estimated by the number of branches cut in relation to the number of branches in the crown of an individual tree. The percentage of bark removal, whether internal or external layers, was assessed as the percentage of bark removed from the base of the trunk to the first branch (Nacoulma *et al.* 2017). fires were assessed based on their severity on the trees or at the plot level. Grazing and excavation at the base of the trees was recorded using the criteria "presence" and "absence."

Socioeconomic survey data

Quantitative socio-economic data were collected through a questionnaire (Kurzhals 2021). This technique was used among communities living near the Fathala classified forest, where people have close ties to forest resources. The sampling method applied for this purpose is a stratified cluster method with two levels. The shelving system applied by Dieng *et al.* (2016) and Diop *et al.* (2011) was adapted to determine the first sampling level. This consisted of drawing a radius of one kilometer from the forest edge towards the village terroirs. This step made it possible to identify eleven localities in the forest's direct area of influence. In each locality, the entity selected was the household, with one member of the household as the sampling unit, which constituted the second sampling level. The sample size (n) was then defined using the Slovin formula n=N/((1+N×e^2)) for a sampling rate of 10% (Assalé *et al*. 2020, Sina *et al.* 2019). Thus, the surveys were conducted among 100 households selected at random and proportionally to the household size in each locality yields the following number of households.

Data analysis

Floristic data

The demography of plant species was analyzed based on different structural parameters. Density (D) is obtained by dividing the number of woody individuals (N) with Dbh ≥ 5 cm by the area (S) expressed in hectares (Mouhamadou *et al.* 2013) : D= N/S. The basal area (St) or basal cover is defined as the sum of the areas of trees at 1.30 m, measured at the base of the trunk. The basal area adopted St (m²/ha) according to Ngom *et al.* (2013) is given by the calculation: $\boxed{St = \sum \pi \frac{\left[\frac{D}{2}\right]^2}{SE}}$: St = basal area; D=trunk diameter in meters; SE=area of the sample considered in hectares.

The diameter structure of these species was determined using diameter distribution histograms established by diameter class using R software. The structures are adjusted to the theoretical Weibull distribution with three parameters (a, b and c) with density function f according to the formula: $(x)=c\ b \,/\, [(x-a)\,/b]\ c-1\ e-[x-a/b]$. In this formula, *x* is the diameter or height of the individuals, *a* is the location parameter, *b* represents the scale (size) parameter, and *c* is the shape parameter of the structure in diameter or height. The value of the shape parameter c imposes several shapes on the Weibull distribution (Kızılersü *et al.* 2018). The distribution is inverted 'J' shaped (population dominated by individuals with small diameters) for a value of c< 1. With c between 1 and 3.6, the distribution is positively skewed or right-skewed, characteristic of artificial monospecific stands with a relative predominance of young individuals with small diameters. For c=3.6, the structure is said to be normal, characteristic of populations of species with low regeneration linked to exogenous actions or characteristics of the species. When c> 3.6, the distribution becomes negatively skewed, characteristic of monospecific stands with a predominance of older individuals with large diameters.

Statistical analysis of floristic data

Numerous tests were carried out to analyze the variation in the structural parameters of woody species of medicinal importance following human disturbances. These disturbances consisted of the establishment of a private game reserve in the Fathala forest, fire, grazing, pruning, debarking and excavation.

Generalized linear mixed models using the lmer function of the lme4 package were used to assess the influence of the effects on human activities (fire, grazing, excavation, pruning, debarking) on the dendrometric structures of medicinal species population (basal area, density and diameter). Significant effects (p<0.05) reveal an influence of degradation factors on the structural parameters studied, with fairly narrow confidence intervals, characteristic of good parameter estimation accuracy. An Analyse of Variance was performed to test the significance of the models results and a Tukey post-hoc test was applied to compare pairs of means for the different explanatory variables.

Ethnobotanical data

Following the development of the questionnaire using Kobo Toolbox, the socio-economic data were collated and processed using the R interface. The analysis is based on the Citation Frequency (CF) of a species (i) according to Yasser *et al*. (2018), which is calculated by dividing the number of citations of the species by the total number of citations of all species, multiplied by 100: CFi=(Number of citations of species *i*)/(Total number of citations of all species) × 100. The relative frequency of citations of therapeutic recipes is given by the formula (RF): RF=Ncr/N×100 where Ncr is the number of citations of a recipe treating a given disease and N is the total number of citations of all recipes treating the disease (Joel *et al.* 2017). The species usage importance value index (SUIVI) corresponds to the sum of the Citation Frequency (CFi), the species usage value (UVi) and the species usage diversity index (SUDIi) (Sema *et al*. 2018, Zabouh *et al.* 2018): SUIVI= CFi+UVi+SUDI. According to Gadikou *et al.* (2022), the use of this index makes it possible to highlight species of great interest in a category of use, the relationship between informants' knowledge of species, diversity and the common nature of uses. The SUDIi is given by dividing the number of specific uses of species i by that of the species with the maximum number of specific uses.

Results

Main species used

Surveys conducted among communities living near the Fathala classified forest show that 78 plant species have therapeutic properties and used to treat several diseases. Among these species, 32 have been inventoried in the Fathala forest. *Combretum glutinosum, Terminalia avicennioides, Terminalia macroptera, Cordyla pinnata, Combretum micranthum* and *Sclerocarya birrea* are mainly used local populations for medicinal uses, with the highest citation frequencies (CF) and usage importance index values (UII) (Table 2). The species are grouped into three families, namely *Combretaceae* (78.5%), *Fabaceae* (16.7%) and *Anacardiaceae* (4.8%).

Table 2. Frequency of citation of species from the Fathala classified forest used for therapeutic purposes

Numbers	. . . .Species. .	Citation Frequency (CF)	SUIVI
1	*Combretum glutinosum* Perr. ex DC.	29.36	30.00
2	*Terminalia avicennioides* Guill. & Perr.	24.49	24.92
3	*Terminalia macroptera* Guill. & Perr.	11.83	12.68
4	*Cordyla pinnata* (Lepr. ex A. Rich.) Milne-Redh.	8.01	9.02
5	*Combretum micranthum* G. Don	4.75	5.18
6	*Sclerocarya birrea* (A. Rich.) Hochst.	4.32	4.96
7	*Pterocarpus erinaceus* Poir.	3.92	4.35
8	*Detarium microcarpum* Guill. & Perr.	3.56	4.41
9	*Guiera senegalensis* J.F. Gmel.	3.53	3.74
10	*Prosopis africana* (Guill. & Perr.) Taub.	1.37	2.01
11	*Cassia sieberiana* DC.	1.18	2.01
12	*Parkia biglobosa* (Jacq.) R. Br. ex G. Don	0.82	1.46
13	*Saba senegalensis* (A. DC.) Pichon	0.42	1.06
14	*Annona senegalensis subsp. senegalensis*	0.39	0.6
15	*Hymenocardia acida* Tul.	0.34	0.77
16	*Piliostigma reticulatum* (DC.) Hochst.	0.31	0.52
17	*Ximenia americana* L.	0.24	0.45
18	*Ziziphus mauritiana* Lam.	0.24	0.88
19	*Lannea velutina* A. Rich.	0.13	0.34
20	*Anacardium occidentale* L.	0.12	0.76
21	*Hexalobus monopetalus* (A. Rich.) Engl. & Diels	0.1	0.31
22	*Stereospermum kunthianum* Cham.	0.1	0.31
23	*Securidaca longipedunculata* Fresen.	0.09	0.3
24	*Bobgunnia madagascariensis* (Desv.) J.H. Kirkbr. & Wiersema	0.08	0.29
25	*Afzelia africana* Sm. ex Pers.	0.07	0.28
26	*Ficus sycomorus* L.	0.05	0.26
27	*Piliostigma thonningii* (Schumach.) Milne-Redh.	0.05	0.26
28	*Balanites aegyptiaca* (L.) Delile	0.04	0.47
29	*Lepisanthes senegalensis* (Poir.) Leenh.	0.04	0.25
30	*Adansonia digitata* L.	0.03	0.67
31	*Strychnos spinosa* Lam.	0.013	0.22
32	*Celtis toka* (Forssk.) Hepper & J.R.I. Wood	0.01	0.22

Categories of medicinal uses of woody species

The woody species of the Fathala forest make a significant contribution to therapeutic care. Analysis of the data collected shows that 34 diseases are treated with the plant organs of the main woody species identified (Figure 2). The pathologies mentioned are grouped into various categories relating to the human organs affected. The frequencies obtained indicate a diversity of pathological groups mainly treated by the designated medicinal flora. These disorders include infectious (14.5%), asthenic (12.8%), hematological (12%), gynecological-obstetric/urological/sexual and infantile (11.1%) and cardiovascular (10%). Other categories, including pulmonary or respiratory, digestive and stomach, muscular or nervous, articular, ophthalmological and dermatological diseases, receive little attention, recording the lowest frequencies.

Figure 3 shows relationship between ailments and woody species from the Fathala classified forest. Most of the information on the uses of species is contained in the first axis. Several species distributed on either side of axis 1 remain closely associated with various categories of diseases. On one side, treatments for the main conditions, including asthenic and infectious diseases, are provided by a relatively large group of species, while on the other side, a second group of species remains more closely linked to gynecological-obstetric-urological-infantile, muscular, nervous, digestive, stomach, pulmonary and respiratory diseases. The close proximity of these two distinct groups of species to axis 1 seems to reflect the multiple functions of these plants in local health. On the opposite side of axis 1, only two categories of diseases can be distinguished. These are hematological diseases associated with more species and cardiovascular diseases more specific to a small number of species (one species).

Demographics of medicinal species

Dendrometrical parameters of medicinal woody species

The structural parameters were calculated for the species most commonly used in the healthcare sector: *Combretum glutinosum, Terminalia avicennioides, Terminalia macroptera, Cordyla pinnata* and *Combretum micranthum.* The average diameter of species used by local populations in traditional medicine is relatively small. The few species with a large average diameter are *Combretum micranthum (*37.22 cm) and *Combretum glutinosum* (22.91 cm). *Cordyla pinnata and Terminalia macroptera* are characterised by a low average diameter (Table 3).

The density of species of medicinal importance is 420 individuals per hectare in the Fathala classified forest. Among the species most commonly used for healthcare, *Terminalia macroptera* (52.31 individuals/ha) *and Terminalia avicennioides* (12.04 individuals/ha) have the highest densities (Table 3).

The average basal area of medicinal species is 12 m² per hectare. This value varies from one species to another. Among the species commonly used for medicinal purposes, *Terminalia avicennioides* and *Terminalia macroptera* (Table 3) have the largest basal areas (14.19 m²/ha and 4.74 m²/ha).

Table 3. Structural parameters of the main species of medicinal importance

Species	**Average diameter (cm)**	**Specific density (individuals/ha)**	**Basal area (m2/ha)**
Combretum glutinosum	22.91	7.64	2.12
Terminalia avicennioides	18.75	12.04	4.19
Terminalia macroptera	14.75	52.31	4.74
Cordyla pinnata	14.61	3.94	2.66
Combretum micranthum	37.22	2.55	0.2

Diameter structure of medicinal species population

Figure 4 shows the diameter structure of the main species of medicinal importance in the forest. These are *Combretum glutinosum, Terminalia avicennioides, Terminalia macroptera, Cordyla pinnata, Combretum micranthum* and *Sclerocarya birrea*. The diameter structure of the species shows irregularity in the distribution of diameter class. It describes a bell curve for species used for medicinal purposes. The density of individuals of *Combretum glutinosum, Terminalia avicennioides, Terminalia macroptera, Cordyla pinnata* and *Combretum micranthum* is greater in the low and intermediate diameter class. Overall, the shape parameter c ranges from 1 to 3.6. It describes a positive or right-skewed distribution, characteristic of monospecific stands with a predominance of young individuals with small diameters.

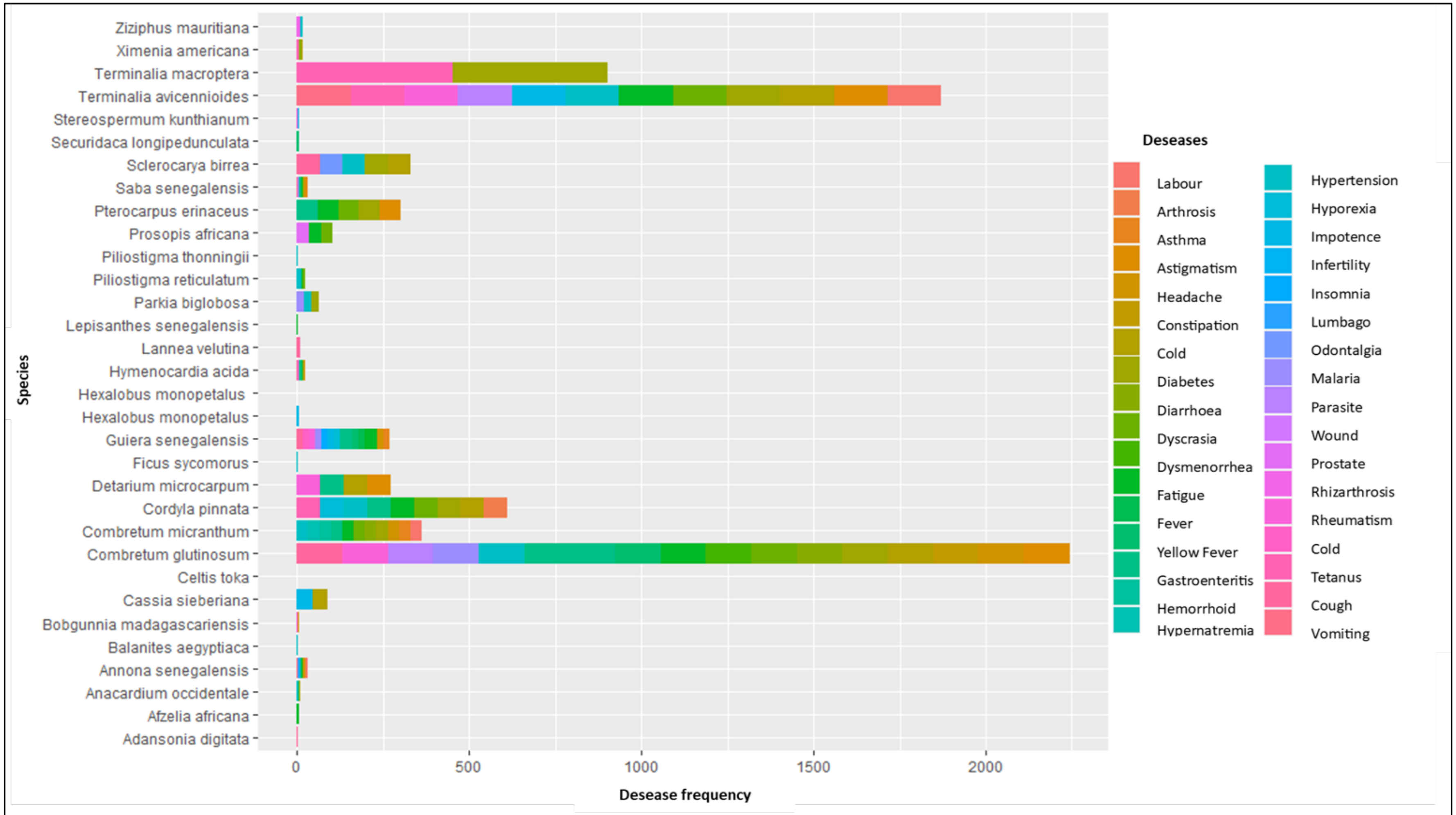

Figure 2. Diseases treated according to species

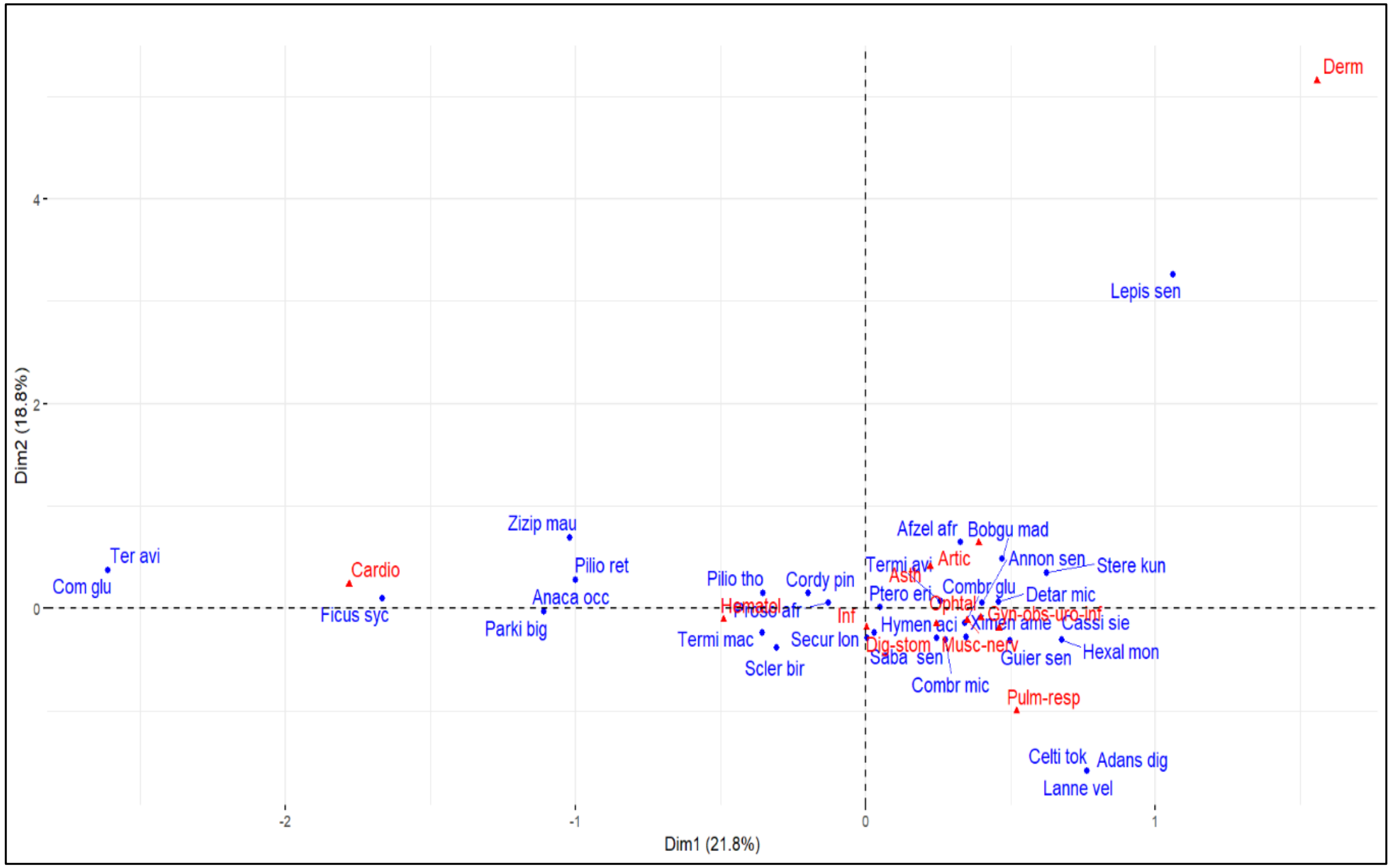

Figure 3. Correspondence factor analysis of disease categories according to species

*Species: *Adans dig: Adansonia digitata; Afzel afr: Afzelia africana; Anaca occ: Anacardium occidentale; Annon sen: Annona senegalensis; Bobgu mad: Bobgunnia madagascariensis; Cassia sie: Cassia sieberiana; Celti tok: Celtis toka; Comb glu: Combretum glutinosum; Combretum micranthum; Cordy pin: Cordyla pinnata; Detar micr: Detarium microcarpum; Ficus syc: Ficus sycomorus ; Guier seneg : Guiera senegalensis ; Hexal mon : Hexalobus monopetalus; Hymen aci : Hymenocardia acida; Lanne vel: Lannea velutina; Lepis sen: Lepisanthes senegalensis; Parki bigl: Parkia biglobosa; Pilio ret: Piliostigma reticulatum; Pilio tho: Piliostigma thonningii; Pros afr: Prosopis Africana; Ptero eri: Pterocarpus erinaceus; Saba sen: Saba senegalensis; Scler bir: Sclerocarya birrea; Secur lon: Securidaca longipedunculata; Stere kun: Stereospermum kunthianum; Ter avi: Terminalia avicennioides; Ter mac: Terminalia macroptera; Ximen ame: Ximenia americana; Zizip mauri: Ziziphus mauritiana.*

*Desease categories : *Artic: Articular; Asth: Asthenic; Cardio: Cardiovascular; Derm: Dermatological; Dig-stom: Digestive-stomach; Gyn-obs-uro-inf: Gynaecological-obstetric-urological-infantile; Haematol: Haematological; Musc-nerv: Muscular-nervous; Ophtal: Ophthalmological; Pulm-rep: Pulmonary-respiratory.*

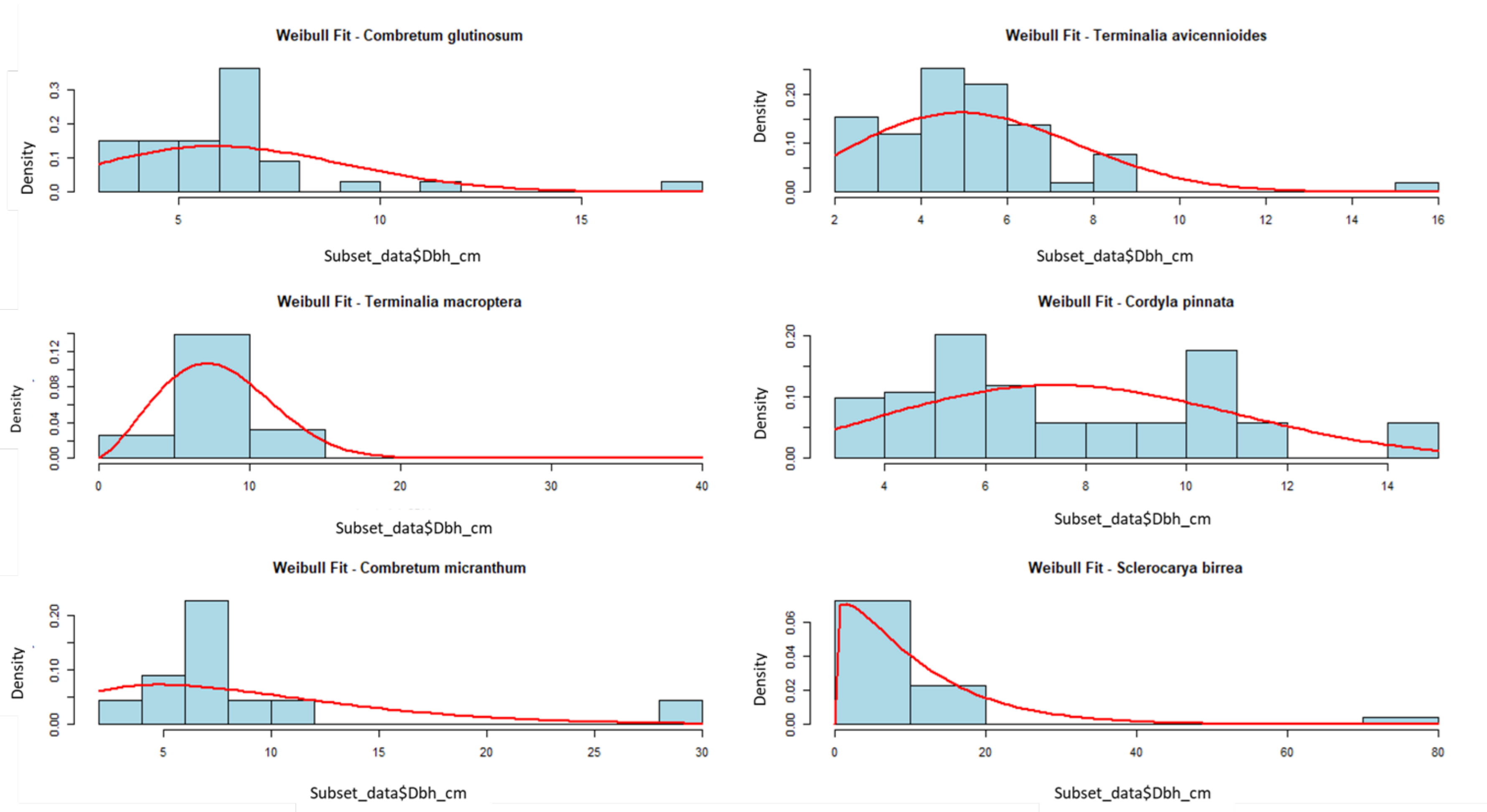

Figure 4. Distribution by diameter class *of Combretum glutinosum, Terminalia avicennioides, Terminalia macroptera, Cordyla pinnata, Combretum micranthum* and *Sclerocarya birrea*

Effects of human disturbances on the demography of medicinal woody species

The results from the models that evaluate the effects of human disturbances on demography parameters are shown in Table 4.

Fire has different effects on the dendrometrical parameters. For the explored plots, its effects is significantly positive on tree density at high and very high intensities (p<0.001). The effect of fire is negative on basal area particularly when its intensity is low to high, as demonstrated by the negative beta coefficients and significant p-values (p<0.001). Tree diameter is likely to decrease in the "Fathala classified forest" in the event of very intense fires (negative Beta, p<0.001).

Moderate pruning is associated with a significant negative effect (p<0.001) on density and basal area compared to heavy pruning, which appears to indicate a statistically significant effect of high-intensity pruning on density and basal area (p<0.001). Diameter emerges as a dendrometric parameter that varies inversely with pruning intensity. Among the trees studied, it was found that diameter follows a downward trend when pruning is carried out at moderate to high intensities (p<0.05).

Debarking on the trunks of mature trees is statistically and significantly associated with density, basal area, and measured diameter (p < 0.05). An increase in these parameters can be expected when the intensity of debarking is very high.
Excavation and grazing are significantly associated with the density, basal area, and diameter of the medicinal species studied.

Table 4. Summary of mixed linear regression models of structural parameters in relation to human disturbance

	Density			**Basal area**			**Diameter**		
Characteristic	Beta	95% CI[1]	P-value	Beta	95% CI[1]	P-value	Beta	95% CI[1]	P-value
Impact_Fire									
.Low-	-5.15	-5.69, -4.61	<0.001	-4,625	-5,288, -3,962	<0.001	0.41	0.25, 0.56	<0.001
.High-	1.85	1.41, 2.29	<0.001	5,936	5,398, 6,475	<0.001	-0.21	-0.33, -0.08	<0.001
.High-Low	7.00	6.34, 7.66	<0.001	10,561	9,750, 11,372	<0.001	-0.61	-0.80, -0.42	<0.001
.Medium-	3.44	2.99, 3.90	<0.001	5,046	4,490, 5,602	<0.001	0.41	0.28, 0.54	<0.001
.Medium-Low	8.59	7.92, 9.27	<0.001	9,671	8,844, 10,499	<0.001	0.00	-0.19, 0.20	>0.9
.Medium-High	1.59	1.01, 2.18	<0.001	-890	-1,610, -170	0.007	0.62	0.45, 0.79	<0.001
Very high-	3.67	3.33, 4.01	<0.001	4,535	4,114, 4,956	<0.001	0.17	0.07, 0.27	<0.001
Very high-Low	8.82	8.22, 9.42	<0.001	9,16	8,418, 9,902	<0.001	-0.23	-0.41, -0.06	0.002
Very high-high	1.82	1.32, 2.32	<0.001	-1,401	-2,021, -781	<0.001	0.38	0.23, 0.53	<0.001
Very high-Medum	0.23	-0.30, 0.75	0.8	-511	-1,154, 131	0.2	-0.24	-0.39, -0.09	<0.001
Pruning intensity									
.Low-	1.27	0.06, 2.49	0.035	-5,477	-6,978, -3,977	<0.001	-0.17	-0.52, 0.19	0.7
.High-	11.4	9.56, 13.3	<0.001	7,786	5,496, 10,077	<0.001	0.21	-0.33, 0.75	0.8
.High-Low	10.1	7.93, 12.4	<0.001	13,264	10,531, 15,996	<0.001	0.38	-0.26, 1.02	0.5

.Medium-	-1.31	-3.11, 0.48	0.3	-10,93	-13,144, -8,716	<0.001	-0.59	-1.11, -0.07	0.016
.Medium-Low	-2.59	-4.75, -0.42	0.010	-5,453	-8,118, -2,788	<0.001	-0.43	-1.05, 0.20	0.3
.Medium-High	-12.7	-15.3, -10.2	<0.001	-18,717	-21,886, -15,547	<0.001	-0.81	-1.55, -0.06	0.027
Very high-	17.4	13.7, 21.2	<0.001	16.9	-4,606, 4,640	>0.9	-1.28	-2.37, -0.19	0.012
Very high-Low	16.2	12.2, 20.1	<0.001	5,494	643, 10,346	0.017	-1.11	-2.25, 0.03	0.061
Very high-high	6.01	1.83, 10.2	<0.001	-7,77	-12,915, -2,625	<0.001	-1.49	-2.70, -0.28	0.007
Very high-Medum	18.7	14.6, 22.9	<0.001	10,947	5,824, 16,070	<0.001	-0.69	-1.89, 0.52	0.5
Intensity-debarking									
. Low-	-4.04	-4.88, -3.20	<0.001	-6,187	-7,222, -5,152	<0.001	0.04	-0.21, 0.28	>0.9
. Very high-	10.2	6.74, 13.7	<0.001	23,166	18,860, 27,473	<0.001	1.19	0.17, 2.20	0.017
. Very high-Low	14.3	10.7, 17.9	<0.001	29,354	24,930, 33,777	<0.001	1.15	0.11, 2.19	0.026
Grazing	0.03	0.02, 0.04	<0.001	0.00	0.00, 0.00	<0.001	0.58	0.54, 0.63	<0.001
Excavation	78,006	29,477, 206,432	<0.001	*	*	<0.001	0.54	0.41, 0.72	<0.001

1 CI = Confidence Interval: a narrow 95% confidence interval that does not include zero (0) indicates a better estimate and that the effect is statistically significant at the 5% level.

Characteristic: represents anthropogenic factors at different levels of severity, which are used as explanatory variables for the structural parameters of density, basal area, and diameter.

*: Cannot be calculated because the sample size is too small (zero) for this variable category.

P-value< 0.05: describes a significant correlation between the parameters and the anthropogenic factors studied.

P-value> 0.05: describes a lack of relationship between the parameters and the anthropogenic factors.

Discussion

Woody medicinal flora of Fathala classified forest

This study identified 32 woody species in the Fathala forest that are used in traditional medicine. Although this result highlights the forest's important role as a source of medicinal plants, it is lower than the 43 medicinal species recorded by Sène (2019) in a study conducted in the Fathala classified forest. Conversely, it is higher than the 22 species of medicinal plants recorded by Lykke (1993) amongst communities living on the fringes of the Fathala classified forest. These differences may be explained by variations in the study objectives, sampling methods, survey periods or by changes in plant availability and local ethnobotanical knowledge over time. Overall, the diversity of medicinal species recorded in this study reflects the rich plant biodiversity characteristic of semi-arid ecosystems (Bakar *et al.* 2023). The use of medicinal plants remains widespread in Africa, particularly in rural communities, where traditional medicine continues to play a vital role in primary healthcare. According to Shukla (2023), the pharmacological potential of medicinal plants is attributed to the bioactive compounds presenting their various plant parts which confer their therapeutic properties. In the present study, *Combretum glutinosum, Terminalia macroptera, Terminalia avicennioides, Cordyla pinnata* and *Sclerocarya birrea* were identified as the most frequently used species to treat various health problems. Their widespread use may reflect local communities' confidence in their therapeutic efficacy, as suggested by Lougbegnon *et al.* (2011), who reported that the popularity of medicinal species is closely linked to users' satisfaction with their efficacy. The high demand for these species is further supported by their well-documented therapeutic properties, which have been reported in previous ethnobotanical studies (Musa *et al.* 2016, N'diaye *et al.* 2017, Atunwa *et al.* 2021).

The plants listed in this study are used to treat a wide range of conditions, ranging from minor ailments to chronic or serious diseases. This diversity of uses is consistent with numerous phytochemical studies that have highlighted the presence of bioactive compounds in various plant organs, which may explain their therapeutic properties (Aboughe Angone *et al.* 2015, Hiba & Laghmari 2023, Kouchadé *et al.* 2017). The results show that hematological diseases, including diabetes, are among the conditions most frequently treated with preparations based on *Terminalia avicennioides*. The importance attached to this species by communities living on the fringes of the classified forest has also been reported by Diop *et al.* (2022). This widespread use could be explained by the numerous biological activities attributed to this species, notably its antifungal properties highlighted by Ali *et al.* (2022), as well as other pharmacological activities reported in the literature. Furthermore, phytochemical analyses carried out on the bark of *Anacardium occidentale*, which is also used by local communities to treat diabetes, have revealed the presence of bioactive compounds, notably polyphenols, which are recognized for their powerful antioxidant properties (N'guessan *et al.* 2025).

Finally, the use of medicinal plants for the treatment of cardiovascular diseases, lung and respiratory conditions, and infectious diseases, as observed in this study, is consistent with the findings of numerous ethnobotanical surveys carried out in Senegal and other countries in the sub-region (Dongock *et al.* 2018, Alexandre *et al.* 2018, Ba 2024, Tine *et al.* 2023).

The categories of diseases identified in this study correspond to the main pathological groups previously reported by Diop *et al.* (2019) among communities in western Senegal. In the north of the country, the study by Cisse *et al.* (2016) showed that *Sclerocarya birrea* is not only used to treat high blood pressure, but also to manage diabetes and certain skin conditions. In Burkina Faso, Sereme *et al.* (2011) reported that young leaves of *Anacardium occidentale* prepared as a macerate are used to treat cough in children, while the fruit, ground into a powder, is used to relieve chest pain. Similarly, in Mali, Ballo *et al.* (2021) confirmed the anti-infective properties of the leaves of *Terminalia macroptera*. The therapeutic uses observed in this study are also supported by the phytochemical composition of several medicinal species. Indeed, Adiko-Tape *et al.* (2024) demonstrated that the bark of *Securidaca longipedunculata* and the leaves of *Annona senegalensis* contain quinones, saponosides, tannins, polyphenols, sterols and polyterpenes, whilst the leaves of *Piliostigma thonningii* and *Annona senegalensis* are particularly rich in flavonoids. These are components with remarkable pharmacological properties. Flavonoids, for example, in addition to their ability to trap free radicals, have vasculoprotective, anti-infectious, anti-hepatotoxic, anti-allergic, anti-ulcer, and antispasmodic activities (Bruneton 2016). Sparg *et al.* (2004), Tine *et al.* (2023), Tine *et al.* (2019) and Ladekan-Yayi *et al.* (2021) have reported the antibacterial, hypotensive, and antifungal effects of tannins.

These secondary metabolites are widely recognized for their numerous biological and pharmacological activities. Tannins, for their part, exhibit antibacterial, hypotensive and antifungal properties, as reported by Sparg *et al*. (2004), Tine *et al.* (2019, 2023) and Ladekan-Yayi *et al.* (2021).

Anthropogenic factors influence the dynamics of medicinal plants

In the Fathala classified forest, human-induced disturbances influence the population dynamics and structure of woody species used in traditional medicine. The results of this study showed that high fire intensity significantly reduces the basal area of medicinal species. These findings are consistent with those reported by Kagambega (2019), Sokpon *et al.* (2006) and Sawadogo *et al.* (2002), who documented the adverse effects of repeated bushfires on woody vegetation in savannah ecosystems. According to these authors, recurrent fires lead to high mortality among mature trees, resulting in a decline in the stand's basal area and changes to the forest structure. Similarly, Doamba *et al.* (2020) and Koffi (2019) reported that many fire-sensitive species do not survive repeated end-of-season fires, leading to a gradual reduction in their populations. This study also showed that severe fires are associated with a reduction in tree diameter within the classified forest. This finding is consistent with the results of Sawadogo *et al.* (2018) who identified bushfires as one of the main factors responsible for the predominance of small-diameter individuals in *Senegalia macrostachya* populations in Burkina Faso. Fire is widely recognised as a major ecological factor that regulates the distribution, structure and functioning of savannah vegetation (He and Lamont 2018). Frequent fires limit tree growth by repeatedly damaging stems and preventing trees from reaching higher size class (Bellefontaine *et al.* 2000, Akiyo *et al.* 2022).

Moderate and high-intensity pruning had a significant impact on the density and basal area of medicinal species in the Fathala classified forest. Similar results were reported by Ntoupka (1999) who observed a significant decline in the number of mature stems subjected to pruning in the Sudano-Sahelian zone of northern Cameroon. Intensive pruning can reduce stem circumference growth, and this effect may persist for several years (Courdier *et al.* 2002). Similarly, Jiang et al. (2026) demonstrated that high-intensity pruning significantly reduced diameter growth in several European tree species during the year of pruning.

In the Fathala forest, pruning is mainly carried out to harvest tree foliage for livestock feed. Repeated pruning, combined with the trees' response of growing upwards to avoid grazing, can accelerate the depletion of accessible biomass and increase stress on the trees (Garde *et al.* 2013). Our results confirm that intensive pruning negatively affects the diameter growth of mature trees, which is consistent with the findings of Gbesso *et al.* (2014) who reported negative effects of pruning on dendrometric characteristics in heavily disturbed ecosystems.

This study shows that partial debarking has a negative impact on the density and basal area of medicinal species. These findings are consistent with those of Mapongmetsem *et al.* (2011) who reported that debarking can lead to tree mortality. Due to the slow rate of bark regeneration, debarked trees become more vulnerable to external disturbances that may jeopardise their survival. Guedje (2002) also noted that debarking of socio-economically important species can reduce the number of mature, harvestable trees within a short period of time. Severe debarking damages the phloem and increases the trees' vulnerability to pest attacks, particularly in species such as *Adansonia digitata, Acacia seyal and Acacia tortilis* (Ganaba *et al.* 2005).

Grazing in the Fathala classified forest has had a significant impact on the basal area of medicinal woody species. In contrast to our findings, several studies have reported negative effects of grazing on woody plant populations in Sudanese savannahs (Kagambèga, 2019; Sokpon *et al.* 2006). Pressure from livestock can reduce species abundance by limiting their regeneration and increasing their mortality. Similarly, Sarr *et al.* (2013) showed that highly palatable woody species in west-central Senegal often have low densities or disappear due to anthropogenic pressures and livestock. However, in the present study, grazing had no negative effect on tree diameter and appeared to contribute to the recovery of species. According to Ntoupka (1999), moderate grazing can reduce fire intensity by lowering fuel loads and improve soil fertility through the supply of nutrients from animal dung. These contrasting effects suggest that grazing intensity plays a key role in determining its impact on vegetation dynamics.

Root excavation, rarely observed in the Fathala classified forest, was positively associated with the density, basal area and diameter of medicinal species. By contrast, intensive root harvesting has been reported as a major threat to tree species in other regions (Mbayngone & Thiombiano 2011), particularly where such harvesting prevents regeneration through uprooting or excessive root extraction (Betti 2001).

Conclusion

The Fathala classified forest is home to a rich and diverse flora, comprising 32 species with therapeutic properties, which contributes significantly to the well-being of local communities. These species are used to treat around thirty conditions, including infectious and hematological diseases, through preparations made from various parts of the plants, notably the leaves, roots and bark. This highlights the important role of traditional medicine in local healthcare systems. The demographic structure of these species revealed low values for density and basal area, with an irregular diameter distribution dominated by young individuals, suggesting regeneration constraints. Fires and pruning were identified as the main anthropogenic disturbances affecting the density, basal area and diameter structure of medicinal tree species.

To ensure the sustainable management of these valuable resources, strategies should be implemented to reduce human pressures and preserve the ecosystem services provided by medicinal plants. Located on the land boundary of the Delta du Saloum National Park, the Fathala classified forest provides valuable baseline data for improving management plans and conservation actions. Regular monitoring of medicinal species is essential for assessing their dynamics

Declarations

List of abbreviations: Floristic Index abbreviations: D-Density, St-basal area. Ethnobotany index abbreviations: CF-citation frequency, RF-relative frequency, SUIVI-species usage importance value index, UV-species usage value, SUDI-species usage diversity index.

Ethics approval and consent to participate: This study was conducted in accordance with the ethical and legal guidelines governing research on the use of biological resources in healthcare. It is conducted in accordance with the Code of Ethics of the International Society for Ethnobiology, with the informed consent of the participants. The project was approved by the National Ethics Committee for Health Research under the number: 0000169 of 23/06/2022. The participation of local communities was subject to the acceptance of the Free and Informed Consent Form.

In addition to institutional ethical approval, this research was conducted in strict compliance with the principles of Access and Benefit-Sharing (ABS) under the Nagoya Protocol regarding associated traditional knowledge. To this end, Prior Informed

Consent (PIC) was formally granted by the competent national and local authorities to the legitimate representatives of Toubacouta.

Consent for publication: Not applicable

Availability of data and materials: Not applicable

Competing interests: The authors confirm no conflict of interest.

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Author contributions: M.D. collected the data, analyzed, and wrote the text. F.N. participated in the theoretical background, monitoring data collection and analysis, helping with discussions, and wrote the final version of the text.

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Literature cited

Aboughe AS, Aworet Samseny RRR, Eyele MMV. 2015. Quelques propriétés des huiles essentielles des plantes médicinales du Gabon. Phytothérapie 13 (5): 283-87.

Adiko-Tape NM, TBBF, Yao K. 2024. Investigations ethnobotanique et phytochimique de plantes médicinales utilisées contre les envenimations de serpents à Aboisso en Côte d'Ivoire. Pharmacopée et Médecine Traditionnelle Africaine 23 (1): 83-94.

Agence Nationale de l'Aviation Civile et de la Météorologie. 2020. Données climatiques de la région de Fatick.

AGP. 2003. An Update of the Angiosperm Phylogeny Group Classification for the Orders and Families of Flowering Plants: APG II. Botanical Journal of the Linnean Society 141 (4): 399-436.

Akiyo RB, Thierry H, Narcisse Y, Teka O, Yabi I, Tente B. 2022. Occurrence spatio-temporelle et effet comparé des feux tardifs et précoces sur la structure des habitats de savane au centre du Bénin. Revue Marocaine des Sciences Agronomiques et Vétérinaires 10 (3): 428-36.

Alexandre LB, Elisee M, Mapongmetsem M. 2018. Etude ethnobotanique et phytochimique des quelques plantes utilisées dans le traitement des maladies cardio-vasculaires dans le Logone occidental au Tchad (Afrique Centrale). Revue Scientifique du Tchad-série B.

Ali BM, Youssouf AG, Djamalladine MD. 2022. Study of the pharmacological properties of the three plants used in medicine. European Journal of Biomedical 9 (9): 400-407.

Angoni H, Raymond SO, Melingui JBN, Mpeck MLN. 2018. Composition floristique, structure et menaces de la végétation de la ligne côtière de la Réserve de Faune de Douala-Edéa. International Journal of Biological and Chemical Sciences 12 (2): 915-926.

Assalé AAY, Yao SSB, Yao C. SD, Bleu KCR, Kouassi BK. 2020. Évaluation des services d'approvisionnement fournis par les espaces domaniaux anthropisés : cas de la forêt classée du Haut-Sassandra (Centre-Ouest de la Côte d'Ivoire). Canadian Journal of Forest Research 50 (10): 1002-11.

Atunwa SA, Amali MO, Lawal SO, Usman SO, Olapade AI. 2021. Anti-Nociceptive Potential of Ethanol Extract of Terminalia Macroptera Guill&Perr (Combretaceae) Stem Bark in Mice. Nigerian Journal of Pharmaceutical Research 16 (S): S.

Ayena AC, Agassounon DTM, Assogbadjo AE. 2016. Usages Et Vulnerabilite De *Pterocarpus santalinoides* L'her. Ex De (Papillionoidae), Une Plante Utilisée Dans Le Traitement Des Gastro-Enterites Dans Le Sud Du Benin. European Scientific Journal, ESJ 12 (6): 218.

Ba A. 2024. Étude phytochimique et propriétés anti-infectieuses de plantes médicinales sénégalaises: molécules bioactives de *Zanthoxylum zanthoxyloides* et de *Terminalia avicennioides*. PhD dissertation, Cheikh Anta Diop of Dakar University.

Ballo M, Estelle NHY, Mahamane H. 2021. Étude des constituants chimiques et activités antiradicalaires des extraits de huit plantes médicinales récoltées au Mali. Pharmacopée et médecine traditionnelle africaine 20 (2): 72-79.

Bellefontaine R, Gaston A, Petrucci Y. 2000. Management of natural forests of dry tropical zones. Food and Organization (FAO), no 32.

Betti JL. 2001. Vulnérabilité des plantes utilisées comme antipaludiques dans l'arrondissement de Mintom au sud de la réserve de biosphère du Dja (Cameroun). Systematics and Geography of Plants, 661-78.

Bouko BS, Sinsin B, Goura SB. 2007. Effets de la dynamique d'occupation du sol sur la structure et la diversité floristique des forêts claires et savanes au Bénin. Tropicultura 25 (4): 221-27.

Bruneton J. 2016. Pharmacognosie: Phytochimie-plantes médicinales. Ede. Lavoisier Tec & Doc, Paris.

Charahabil MM, Aly D, Daouda N, Babacar D, Léonard EA. 2013. Importance of Combretaceae in community forests in the Sudano-Sahelian region of Senegal. Sécheresse 24 (1): 39-47.

Cisse A, Mathieu G, Abdou K, François N, Soulèye K, Léonard EA. 2016. Ethnobotanique Des Plantes Médicinales Chez Les Bergers Peuls de Widou Thiengoly de La Commune de Téssékéré (Ferlo-Nord Sénégal). Journal of Applied Biosciences 98 (mars): 9301-9308.

Courdier F, Catherine S, Didier B. 2002. Effet de l'élagage artificiel sur la croissance et le statut social du Pin maritime dans les landes de Gascogne. Revue forestière française 54 (3): 239-252.

Cunningham A B. 2001. Applied Ethnobotany: People, Wild Plant Use and Conservation. Avec Fonds mondial pour la nature, Unesco, et Royal botanic gardens. People and Plants Conservation Manuals. Earthscan.

D, Batawila K, Akpagana K. 2018.Une forme de spécialisation de la médicine traditionnelle au Togo: cas de la préfecture de Doufelgou. Journal de la Recherche Scientifique de l'Université de Lomé 20 (4): 29-43.

Dieng SD, Diop M, Goudiaby A. 2016. Caractérisation des services écosystémiques fournis par *Cordyla pinnata* dans la périphérie de la Forêt classée de Patako au Sénégal. VertigO-la revue électronique en sciences de l'environnement¡ 16(2).

Diop M, Niang-Diop F, Dieng SD. 2022. Ethnobotanical Study of Medicinal Plants for Treatment of Diabetes and Hypertension Used in Communities near Fathala Forest, Senegal. Ethnobotany Research and Applications 23.

Diop M, Sambou B, Goudiaby A, Idrissa G, Niang-Diop F. 2011. Ressources végétales et préférences sociales en milieu rural sénégalais. Bois & Forets des Tropiques 310: 57-68.

Diop RD, Mame SM, Ibou D. 2019. Usages médicinales des plantes par la population riveraine du conservatoire botanique Michel Adanson de Mbour (Sénégal). Journal of Animal & Plant Sciences 40 (3): 6690-6711.

Diop, FN, Lykke AM, Sambou B. 2011. Régénération naturelle de *Cordyla pinnata* (Lepr. Ex. A. Rich.) Milne-Redh. dans une savane soumise au feu et au pâturage. Science et changements planétaires/Sécheresse 22 (3): 186-191.

Diouck D. 1999. Adaptations aux modifications du milieu des Colobs bais (*Colobus badius temmincki*) de la forêt de Fathala, Parc National du Delta du Saloum, Sénégal. PhD dissertation, Cheikh Anta Diop of Dakar University.

Doamba, SWMF, Bassiaka O, Patrice S, Bismarck HN. 2020. Facteurs écologiques et intensités du feu en savane soudanienne au Burkina Faso. Afrique Science 17: 236-246.

Dongock DN, Alexandre LB, Pierre MM, Elysée B. 2018. Étude ethnobotanique et phytochimique des plantes médicinales utilisées dans le traitement des maladies cardiovasculaires à Moundou (Tchad) 203-216.

Fedorca A, Marius P, Ramon J, Georgeta I, Ovidiu I, Mihai F. 2020. Assessing the regional landscape connectivity for multispecies to coordinate on-the-ground needs for mitigating linear infrastructure impact in Brasov–Prahova region. Journal for Nature Conservation 58: 125903.

Gadikou KJ, Wouyo A, Hodabalo E, Bimare K, Komlan B, Koffi A. 2022. Valeur d'importance d'usage des plantes médicinales vulnérables de la Région Maritime du Togo. Agrobiologia 12 (2): 3009-3023.

Ganaba S, Jean MO, Ouétian B. 2005. Exploitation traditionnelle des végétaux spontanés en région sahélienne du Burkina Faso. VertigO-la revue électronique en sciences de l'environnement, 6(2).

Garde L, Bernard C, Joanna F, Emmanuelle G, Pascal T. 2013. Produire durablement du lait avec des chèvres en forêt méditerranéenne. Forêt méditerranéenne 34 (2): 99-106.

Gbesso F, Yedomonhan B, Tente B, Akoegninou A. 2014. Distribution géographique des populations de rôniers (Borassus aethiopum Mart, Arecaceae) et caractérisation phytoécologique de leurs habitats dans la zone soudano-guinéenne du Benin. Journal of Applied Biosciences 74 (1): 6099.

Gonzaleze JRM, Ndombe T, Grace TLT. 2024. Les plantes médicinales, une ressource précieuse et véritable trésor à protéger: Une étude ethnobotanique de l'écosystème forestier d'Eyalé en République Démocratique du Congo. International Journal of Innovation and Applied Studies 43 (1): 82-95.

Guedje NM. 2002. La gestion des populations d'arbres comme outil pour une exploitation durable des produits forestiers non-ligneux: l'exemple de Garcinia lucida (sud-Cameroun). Tropenbos-Cameroon Programme.

Hahn-Hadjali K, Thiombiano A. 2000. Perception des espèces en voie de disparition en milieu Gourmantché (Est du Burkina Faso). Berichte des Sonderforschungsbereichs 268 (14): 285-297.

He T, Byron BL. 2018. Baptism by fire: the pivotal role of ancient conflagrations in evolution of the Earth's flora. National Science Review 5 (2): 237-254.

Hiba F, Yamina L. 2023. Revue bibliographique sur les polysaccharides extaits des plantes médicinales: Propriétés physico-chimiques et activités biologiques.

Houinato M, Brice S, Jean L. 2001. Impact des feux de brousse sur la dynamique des communautés végétales dans la forêt de Bassila (Bénin). Acta Botanica Gallica 148 (3): 237-251.

Jiang X, Xiaohong W, Suyun Z. 2026. Effects of different stand densities and pruning on timber volume and ecosystem carbon sink in subtropical secondary forests: A Case study from Zhejiang Province, China. Forest Ecology and Management 613: 123785. doi: 10.1016/j.foreco.2026.123785.

Joel AD, Dassou GH, Adomou AC, Houenon GHA, Tente B, Sinsin AB. 2017. Impact Des Caractéristiques De La Végétation Sur La Diversité D'usages Des Plantes Autour De Deux Grandes Forêts Classées Et D'une Réserve Botanique Au Sud-Bénin. European Scientific Journal 13 (30): 376.

Kagambega F. 2019. Impact des activités anthropiques sur la diversité ligneuse et la structure de *Vitellaria paradoxa* Gaertn.: 3-15.

Kaly E, Oumar S, Sékouna D, Abdoul AD, Djibril D, Daouda N. 2021. Characterization and Risk Assessment of the Collapse of the Woody Stand of Ecosystems of the Fathala Forest (Saloum Delta Biosphere Reserve-Senegal). American Journal of Plant Sciences 12 (0): 975-993.

Kızılersü A, Markus K, Anthony W. 2018. The Weibull distribution. Significance 15 (2): 10-11.

Koffi KF. 2019. Impact du feu sur la démographie des Graminées de savane (Lamto, Côte d'Ivoire). PhD Thesis, Sorbonne Université; Université Nangui Abrogoua (Abidjan).

Konan D, Adama B, Fezan HTB, Bley AB, Serge CP. 2015. Dynamisme de La Structure Diamétrique Du Peuplement Ligneux Des Différents Biotopes de La Forêt Classée de Yapo-Abbé, Sud de La Côte d'Ivoire. Journal of Applied Biosciences 94: 8869-8879.

Kouchadé SA, Arlette RA, Aristide CA, Hospice GD, Akpovi A. 2017. Phytochimiques des plantes médicinales utilisées dans la prise en charge des maladies infantiles au Sud-Bénin. European Scientific Journal 13 (3): 471-488.

Kurzhals K. 2021. Quantitative Research: Questionnaire Design and Data Collection. In Resource Recombination in Firms from a Dynamic Capability Perspective, by Kerstin Kurzhals. Gabler Theses. Springer Fachmedien Wiesbaden. doi: 10.1007/978-3-658-35666-8_5.

Ladekan-Yayi EC, Placide MT, Durand D. 2021. Anthelmintic and antimicrobial activities of tannin extracts of *Mitragyna inermis* (Willd.) Kuntze (Rubiaceae) and *Combretum glutinosum* Perr. ex DC (Combretaceae). American Journal of Applied Chemistry 9 (5): 145-153.

Ladoh-Yemeda CF, Vandi T, Dibong SD. 2016. Étude ethnobotanique des plantes médicinales commercialisées dans les marchés de la ville de Douala, Cameroun. Journal of Applied Biosciences 99 (1): 9450.

Lougbegnon TO, Tente BAH, Amontcha M. 2011. Importance culturelle et valeur d'usage des ressources végétales de la réserve forestière marécageuse de la vallée de Sitatunga et zones connexes. Bulletin de la Recherche Agronomique du Bénin 70: 35-46.

Lykke AM, Goudiaby A. 1999. Structure, Floristic Composition, and Conservation Potentials of a Remnant Gallery Forest at 'Mare Du Dragon', Senegal. Nordic Journal of Botany 19 (5): 561-574.

Lykke AM. 1996. Structure, Floristic Composition, and Dynamics of Woody Savanna Vegetation-Studies from Fathala Forest in Delta Du Saloum National Park, Senegal. PhD dissertation, University of Aarhus, Department of Systematic Botany, Institute of Biological Sciences.

Mapongmetsem PM, Bernard AN, Gilbert R, Delphine ND, Bernard D. 2011. Impact des systèmes d'utilisation des terres sur la conservation de *Vitellaria paradoxa* Gaerten. F. (Sapotaceae) dans la région des savanes soudano-guinéennes. International Journal of Environmental Studies 68 (6): 851-872.

Mbayngone E, Thiombiano A. 2011. Dégradation Des Aires Protégées Par l'exploitation Des Ressources Végétales : Cas de La Réserve Partielle de Faune de Pama, Burkina Faso (Afrique De l'Ouest). Fruits 66 (3): 187-202.

Momo S, Marie C, Ghislain KK. 2017. Modifications anatomiques après écorçage de trois espèces au sud-ouest Cameroun. Journal of Applied Biosciences 115 (1): 11490.

Mouhamadou IT, Imorou IIT, Gbègbo MC, Sinsin B. 2013. Structure et composition floristiques des forêts denses sèches de la région des Monts Kouffé au Bénin. Journal of Applied Biosciences 64 (1): 4787.

Mpondo E, Didier SD, Richard JP, Alfred N, Christelle FLY. 2012. État actuel de la médecine traditionnelle dans le système de santé des populations rurales et urbaines de Douala (Cameroun). 10.

Musa FM, Ameh JB, Ado SA, Olonitola OS. 2016. Evaluation of Phytochemical and Antibacterial Properties of *Terminalia Avicennioides* Crude Extract against Selected Bacteria from Diarrhoeic Patients. Bayero Journal of Pure and Applied Sciences 9 (1): 1.

Mykhailenko O, Banaz J, Lyndy J. M, Javier E, Marce T, Michael H. 2025. Climate change and the sustainable use of medicinal plants: a call for "new" research strategies. Frontiers in Pharmacology 15: 1496792. doi: 10.3389/fphar.2024.1496792/full.

N'diaye D, Mbaye DM, Abdoulaye G, Catherine L, Serge P. 2017. Détermination structurale de triterpenoïdes isolés des feuilles de *Combretum glutinosium* Perr. Ex DC (Combretaceae). International Journal of Biological and Chemical Sciences 11 (1): 488

N'guessan OE, Ahmont LCK, Ouayogode AA. 2025. Criblage phytochimique, évaluation de l'activité antiradicalaire et de la toxicité aigüe d'un médicament traditionnel à visée antidiabétique à base de *Anacardium occidentale* L., *Alternanthera repens* (L.) link., *Ageratum conyzoides* L. vendu à Ko. Pharmacopée et Médecine Traditionnelle Africaine 24 (1): 54-66.

Nacoulma BMI, Lykke AM, Salifou T, Sinsin B, Thiombiano A. 2017. Impact of Bark and Foliage Harvesting on Fruit Production of the Multipurpose Tree *Afzelia africana* in Burkina Faso (West Africa). Agroforestry Systems 91 (3): 565-576.

Ngom D, Thioro F, Omar S, Sékouna D, Léonard EA. 2013. Caractéristiques écologiques du peuplement ligneux de la réserve de biosphère du Ferlo (Nord Sénégal). Journal of Applied Biosciences 65: s 66:5008-5023.

Niang F, Philippe M, Bienvenu S, Nicole F. 2024. Exploring the effects of forest management on tree diversity, community composition, population structure and carbon stocks in sudanian domain of Senegal, West Africa. Forest Ecology and Management 559: 121821.

Niang F. 2005. Etude des facteurs limitant la régénération naturelle de *Bombax costatum* Pell. Et Vuill, *Cordyla pinnata* (Lepr.) Minl. Red., *Parkia biglobosa* (Jacq.) Benth., *Prosopis africana* (Guill., Perrot. Et Rich) Taub. et *Pterocarpus erinaceus* Poir., dans la forêt de Fathala, Parc National du Delta du Saloum, SENEGAL. PhD dissertation, Cheikh Anta Diop of Dakar University.

Niang-Diop F, Sambou B, Lykke AM. 2011. Contraintes de régénération naturelle de *Prosopis africana* : facteurs affectant la germination des graines. International Journal of Biological and Chemical Sciences 4 (5): 1693-1705.

Ntoupka, Mama. 1999. Impacts des perturbations anthropiques (pâturage, feu et coupe de bois) sur la dynamique de la savane arborée en zone soudano-sahélienne nord du Cameroun. Thesis, UPV. h

Ouédraogo A. 2006. Diversité et dynamique de la végétation ligneuse de la partie orientale du Burkina Faso.

République du Sénégal. 2018. Loi-2018-25-du-12-11-2018-code-forestier.

Riera B. 1995. Rôle des perturbations actuelles et passées dans la dynamique et la mosaïque forestière. Revue d'Écologie (La Terre et La Vie) 50 (3): 209-222.

Rout S, Vijay KR, Kushal S. 2023. Flora diversity and conservation status of medicinal plants: Insights from a semi-arid to sub-humid subtropical region. Plant Science Archives, 23-25. https://plantarc.com/wp-content/uploads/2023/12/Flora-Diversity-and-Conservation-Status-of-Medicinal-Plants-Insights-from-a-Semi-Arid-to-Sub-Humid-Subtropical-Region-2.pdf.

Ryniker KA, Bush JK, Van A OW. 2006. Structure of *Quercus gambelii* communities in the Lincoln National Forest, New Mexico, USA. Forest Ecology and Management 233 (1): 69-77.

Sala I. 2024. Pour une diffusion éthique des connaissances de la médecine traditionnelle: L'intersection de la culture Yoruba et des besoins médicaux. 44. Saulnier P. 2024. Plantes médicinales et soins en Afrique. BoD-Books on Demand.

Sawadogo L, Robert N, François P. 2002. Effects of livestock and prescribed fire on coppice growth after selective cutting of Sudanian savannah in Burkina Faso. Annals of Forest Science 59 (2): 185-195.

Sawadogo Y, Souleymane G, Elycée T, Antoine N S. 2018. Caractérisation des populations naturelles d'une légumineuse alimentaire sauvage, *Senegalia macrostachya* (Reichenb. ex DC. Kyal & Boatwr) dans le secteur Nord-soudanien du Burkina Faso. International Journal of Biological and Chemical Sciences 11 (5): 2408.

Sema M, Atakpama W, Kanda M, Koumantiga, Sène MB. 2019. Diversité floristique et étude ethnobotanique des plantes ligneuses médicinales de la forêt classée de Fathala. Mémoire de master. Institut des sciences de l'Environnement.

Shukla S K. 2023. Conservation of medicinal plants: challenges and opportunities. Journal of Medicinal Botany 7: 5-10.

Silverio DV, Eddie L, Letícia G, Lucas P, Paulo B, Marcia M. 2025. Fire in South American Tropical Forests: Examining the Past to Understand the Present and Predict the Future. Ecological Studies 250. Springer Nature Switzerland.

Sina AKS, Abdou A, Amadou G, Laouali A, Mahamane A. 2019. Perceptions Communautaires, Usages Socio-Économiques et Importance Agroécologique Des Peuplements de *Acacia senegal* (L.) Willd. Dans Le Sud-Ouest Du Niger: Cas Du Site Gommier de La Grappe de Lido Dans La Commune de Guéchémé. International Journal of Biological and Chemical Sciences 13 (7): 7.

Sokpon N, Samadori HB, Christine O, Ousman H. 2006. Bases techniques pour une gestion durable des forêts claires du Nord-Bénin : rotation, diamètre minimal d'exploitabilité et régénération. Bois et Forets des Tropiques 287 (mars): 45-57.

Solly B, Charahabil MM, Dièye EHB. 2020. Impacts des facteurs naturels et anthropiques sur la flore ligneuse de la haute Casamance (sud Sénégal): de la perception à la réalité 117-131.

Solly B. 2021. Dynamique des formations forestières de la haute-Casamance (Sénégal) de 1965 a 2018, incidences sur les activités agro-sylvo-pastorales et stratégies d'adaptation. Thèses, Université Assane Seck de Ziguinchor (Sénégal).

Sparg SG, Light ME, Van S J. 2004. Biological activities and distribution of plant saponins. Journal of Ethnopharmacology 94 (2-3): 219-243.

Tankoano B. 2017. Contribution de la télédétection et des Systèmes d'informations géographiques à l'évaluation de l'impact des activités humaines sur la couverture végétale du Parc National des Deux Balé (PNDB) à l'Ouest du Burkina Faso. 135.

Thiffault N, Vincent R, Guy P, Guillaume C. 2003. La sylviculture des plantations résineuses au Québec. Le naturaliste canadien 127 (1).

Thiombiano A. 1996. Contribution à l'étude des Combretaceae dans les formations végétales de la région est du Burkina Faso. https://dicames.online/jspui/handle/20.500.12177/2414

Tine D, Fall AD, Dieng SIM, Sarr A, Bassene E. 2019. Total polyphenol, tannin and flavonoid contents of *Combretum micranthum* leaves harvested in three regions of Senegal: Diass, Sandiara and Essyl. International Journal of Biological and Chemical Sciences 13 (3): 1817-1820.

Tine Y, Sene M, Thiam K, 2023. Revue Des Usages Traditionnels, Composition Chimique et Propriétés Pharmacologiques de *Combretum Glutinosum* (Combretaceae): Review of Traditional Uses, Chemical Composition and Pharmacological Proprieties of *Combretum Glutinosum* (Combretaceae). International Journal of Biological and Chemical Sciences 17 (6): 2475-2489.

Vilatte J. 2007. Méthodologie de l'enquête par questionnaire. Université d'Avignon.

White F. 1983. The vegetation of Africa. Natural resources research, XX, Unesco, Paris.

Workneh Y, Dessale W. 2024. Effects of Selective Harvesting on Diversity, Structure, and Regeneration of Woody Plants in Mixed Plantation of Menagesha Suba Forest, Central Ethiopia. International Journal of Forestry Research 2024 (1): 3355857. doi: 10.1155/2024/3355857.

Yasser K, Moussaoui A, Benmebarek A. 2018. Étude ethnobotanique de quelques plantes médicinales dans une région hyper aride du Sud-ouest Algérien Cas du Touat dans la wilaya d'Adrar. Journal of Animal & Plant Sciences 36 (2): 5844-5857.

Yedmel M, Barima Y, Kouamé N, Barbier N. 2010. Impact de la perturbation par les interventions sylvicoles et le feu sur la dynamique d'un peuplement forestier en zone semi-décidue de Côte d'Ivoire. Sciences & Nature 7 (2).

Yoh N, Walter M, Benjamin L. Gottesman BL. 2024. Impacts of logging, hunting, and conservation on vocalizing biodiversity in Gabon. Biological Conservation 296: 110726. doi: 10.1016/j.biocon.2024.110726.

Zabouh KW,.Atakpama W, Tittikpinan K, Akpavi S, Batawila K, Akpagana K. 2018. Plantes Utilisées En Ethnomédecine Vétérinaire Dans La Région Des Savanes Du Togo. Journal de La Recherche Scientifique de l'Université de Lomé 20 (3): 3