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Impact of anthropogenic pressure on three medicinal woody species in Bobo-Dioulasso, Burkina Faso

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ABSTRACT

The irrational exploitation of medicinal plant contributes to their population decline and constitutes a threat to phytodiversity. *Combretum micranthum* G. Don, *Entada africana* Guill. & Perr. and *Carissa edulis* (Forssk.) are highly exploited species in the South-West of Burkina Faso. Thus, this study aimed to evaluate the influence of land use types on the population structure of these species. Vegetation surveys were conducted in a classified forest, a protected village forest and agrosystems using a stratified sampling approach. Dendrometric parameters and indicators of anthropogenic disturbance were analyzed. Land use affected the height of *C. micranthum* ($P=0.002$). Although the densities of *C. micranthum* and *E. africana* didn't vary across land use types, the highest densities were recorded in the classified forest. *E. africana* showed stable population structure under protection in the classified forest. However, *C. micranthum* and *C. edulis* presented disturbed demographic structures under anthropogenic pressure. *C. edulis* had the lowest density (29.86 individuals/ha) and was absent in forests which are refuge areas for threatened and rare plant species, suggesting its vulnerability. Despite signs of regenerative potential in all three species, sustainable use and conservation practices are needed to prevent further degradation.

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Keywords: Medicinal Plants, Land Use, Anthropogenic Disturbance, Population Structure

INTRODUCTION

In Africa, the use of the therapeutic power of plants is an ancestral practice (Ouoba et al., 2006). Despite significant advancements

in modern medicine, the use of plants for the treatment of various pathologies is still a current practice and is experiencing a resurgence of interest throughout the world.

Thus, people's health care depends heavily on medicinal plants and the local knowledge associated with them (Fyhrquist, 2007). In Burkina Faso, traditional medicine and pharmacopoeia are an important part of cultural heritage and provide the primary source of healthcare for approximately 70% of the population (Zerbo et al., 2011). However; this traditional knowledge, mostly transmitted orally, is at risk of being lost due to the disinterest of younger generations, and especially the gradual disappearance of key medicinal plant species (Ouoba et al., 2006; Meunier et al., 2008).

To ensure the sustainability of traditional medicine, it is essential not only to document ethnobotanical knowledge but also to explore strategies for the sustainable management of medicinal plant resources. Several ethnobotanical studies in Burkina Faso have contributed to this effort by documenting traditional remedies used among ethnic groups such as the Gourmantché (Thiombiano et al., 2002), Goin (Ouoba et al., 2006) and San (Zerbo et al., 2007). Other research has focused on the use of plants in the treatment of specific diseases, including oral diseases (Tapsoba and Deschamps, 2006), child care (Zerbo et al., 2007), malaria (Traoré et al., 2009) and hepatitis (Sombié et al., 2018; Traoré et al., 2018; Dakio et al., 2020). However, few research has addressed the conservation and management of these plant species, which are essential for the sustainable practice of traditional medicine.

Many populations of medicinal plants species are in decline, primarily due to unsustainable harvesting driven by market demand and the pursuit of individual income, often with little regard for long-term ecological impact (Ouédraogo et al., 2006). Local preferences for certain species intensify pressure on these plants, that can sometimes lead to their local extinction despite favorable ecological conditions (Thiombiano et al., 2010). Indeed, anthropogenic activities significantly and irreversibly alter natural structure and composition of forest stands,

contributing to the degradation and extinction of many useful woody species (Guindé et al., 2023). The level of this anthropogenic pressure varies according to protection measures taken, which in turn depend on different land use type (Assogba et al., 2021).

Combretum micranthum G. Don, *Entada africana* Guill and Perr and *Carissa edulis* Vahl are among the medicinal species most used in southwestern Burkina Faso (Ouoba et al., 2006; Dakio et al., 2020). In particular, the roots of these three species are mainly used for the treatment of certain dreaded and highly prevalent diseases such as hepatitis, ulcers, hemorrhoids, toxemia and fungal infections (Ouoba et al., 2006; Dakio et al., 2020). This use, which is mainly emphasized on the utilization of their roots in the preparation of medicinal recipes, constitutes a threat to their conservation and sustainable management. Thus, special attention must be paid to them to understand their demographic trend in plant formations, an essential step in the process of their sustainable use. Indeed, the development of a good strategy for the conservation and sustainable use of plant wood resources requires knowledge of the current state and dynamics of their population (Thiombiano et al., 2016). In addition, the evaluation of the influence of land use patterns on a forest stand makes it possible to effectively assess the types of pressures that a forest species undergoes, but also to know their impact on the structure of the stand (Assogba et al., 2021). Thus, this study aims to assess the effects of different land use types on the population structure, spatial distribution, and anthropogenic pressure affecting these three heavily exploited medicinal species.

MATERIALS AND METHODS

Study area

The present study was conducted in western Burkina Faso, in the region of Guiriko. Data were collected in three plant formations located east and north of Bobo-

Dioullasso city (Figure 1). The environment studied belongs to the South Sudanese phytogeographical domain and is, therefore, under the influence of a South Sudanian-type climate characterized by the alternation of a rainy season (May to October) and a dry season (November to April) (Thiombiano et al., 2010). A survey made it possible to locate the populations of the three species in three sites selected based on their accessibility. These three plant formations were the Dindéresso classified forest (DCF), the protected village forest of Kokorowé (FPK) and the agrosystems (Ags) (fallow land and fields) corresponding to different intensities of anthropogenic disturbances following a gradient of protection of these sites. Classified by Decree No. 422 SE/5 of 27 February 1936, Dindéresso Classified Forest (DCF) is located northwest of the city of Bobo-Dioullasso. The removal of wood and non-wood forest products is authorized under the supervision of forest management groups and state services (Coulibaly, 2003). The protected village forest of Kokorowé (FPK), called Kokorowédoussou by its residents, is a natural plant formation made up of wooded and shrubby savannahs. It is protected by the village community of Kokorowé because, according to local sources, it served as a refuge and shelter for the first inhabitants of this village. The extraction of plant resources is authorized during the dry season (from November to May) according to the Bobo custom. Finally, the agrosystems considered were fields and fallow land bordering the two forests of the study and the classified forest of Koua.

Sampling design

Directed sampling based on the presence of at least one individual of the study species was adopted. Thus, an individual of the target species was used as the center of the plot of 900 m² (30 m x 30 m) in forests and 2500 m² (50 m x 50 m) in agrosystems (Thiombiano et al., 2016). In environments where dense stands

are observed, plots were spaced 200 m apart (Bognounou, 2009).

Data collection

Data collected concerned dendrometric parameters, geographical coordinates and ecological characteristics (species list, vegetation type, topography, rate of cover of woody trees cover rate, soil texture) for each plot. Measurements of dendrometric parameters were based on a stem diameter at 1.30 m from ground (DBH: Diameter at Breast Height ≥ 5 cm) (Tiendrébeogo et al., 2022) for *C. micranthum* and *E. africana* and at 20 cm above ground (dbh ≥ 4 cm) for *C. edulis* due to its biological characteristics, which is a predominantly small-diameter shrub (Thiombiano et al., 2016).

Data analyses

Ecological and structural characteristics

To identify the characteristic species associated with the ecosystems of the three plant species under study, an indicator species analysis was carried out using the Indicator Value Index (IVI) method developed by Dufrêne and Legendre (1997). This analysis was performed with the software PC-ORD (version 7.10) (Ouoba, 2006; Tiendrébeogo, 2022). It combines both species specificity and fidelity to provide an index (IVI) ranging from 0 to 100. The statistical significance of the results was assessed using Monte Carlo permutations (n = 4999) at a 0.05 significance level. After that, two indices were calculated to assess the three species distribution patterns. These were:

Blackman Index (IB): it allows us to assess trees distribution of a given species within a given plant group (Jayaraman, 1999).

$$IB = \frac{\sigma^2}{N}$$

With σ^2 : the variance and N: a means of species density in plant formation. Interpretation is done in relation to unity. Indeed, if: $IB < 1$, distribution is regular (or

uniform); IB = 1, distribution is fishmongery (or random); IB > 1, it is aggregated (or in bunches).

Green's Index (IG): This is an improved version of Blackman's index. This index assess spatial distribution of each species.

$$IG = \frac{IB - 1}{n - 1}$$

n = total number of adult individuals in the plot. IG ranges from -1 to 1: GI < 0 (regular distribution), GI = 0 (random distribution) and GI > 0 (aggregative distribution).

To assess the condition of the populations, the following parameters were calculated:

Average density (trees/ha) : $Dm = \frac{n}{s}$

The average number of trees per hectare n being the total number of individuals and s the surface area of the plot in ha.

Average diameter (cm) : $Dg = \sqrt{\frac{1}{n} \sum_{i=1}^n di^2}$

Mean square diameter in cm ; n being the total number of individuals in the plot ; di is the Diameter at Breast Height (DBH) of the individual i.

The average Lorey height (m): $H = \frac{\sum_{i=1}^n gi \cdot hi}{\sum_{i=1}^n gi}$

With $gi = \frac{\pi}{4} \times di^2$ Weighted average height of trees inventoried within a plot by their basal area (HL, in m) ; gi is the basal area ; hi is the total height of the individual i ; di is the diameter of the individual i.

Basal area (m²/ha) : $G = \frac{\pi}{40000S} \sum_{i=1}^n di^2$ Some of the cross-sections of the individuals ; di is the DBH of the individual i. and S the surface area of the plot in .

Establishment of tree diameter structures

The diameter distribution of individuals was analyzed using 3 cm diameter classes (Kabr  et al., 2020). To model population structure, the Weibull three-parameter distribution (Husch et al. 2003) was fitted using Minitab 16 software. Its probability density

function *f* translates to the following formula:

$$f(x) = \frac{c}{b} \left[\left(\frac{x-a}{b} \right) \right]^{c-1} \text{Exp} \left[- \left(\frac{x-a}{b} \right) \right]^c$$

x: trees diameter, f(x): probability density value, a: position parameter: it is equal to 0 if all categories of trees are considered during the inventory, it is not-zero if the trees considered having a diameter or height greater than or equal to a. In this study, a is equal to 5 cm with respect to trees diameters; b: scale or size parameter. It is linked to the central value of trees diameters of the stand-in question; c: shape parameter related to the structure in diameter or height considered. A fit test based on log-linear analysis was performed to ensure an appropriate fit of the observed structure to the theoretical distribution using the software.

Statistical analysis

The data were entered into Microsoft Excel and then analyzed using R (R Core Team, 2015) and Minitab 16 software. The dendrometric data were used to calculate several parameters. The dendrometric and distribution parameters were evaluated according to land use types. The mean value of these parameters was calculated for each land use type considered. The nonparametric Kruskal–Wallis test was applied to the mean values of these parameters to test the effect of land use type on the dendrometric parameters of each species. This analysis was performed using R Core Team, 2024 software. When the Kruskal–Wallis test revealed significant differences, a post hoc multiple comparison procedure based on Dunn's test was used to identify significant differences between land use types. This approach made it possible to determine precisely which land use types differed significantly from each other for each parameter studied, while controlling for the risk of type I error associated with multiple comparisons. Differences were considered statistically significant for a probability threshold set at 5% (p < 0.05).

2). For *Entada africana*, no significant differences were found for the four dendrometric parameters ($p > 0.05$) across land use types. However, the highest density was observed in the DCF (132 individuals/ha), followed by the FPK (107.78 individuals/ha), and Agrosystems (AgS) (92.31 individuals/ha) (Figure 2). Although not statistically significant, this trend suggests decreasing abundance with increasing anthropogenic disturbance. *Carissa edulis* was absent from the two land use types (DCF and FPK) and found in the AgS with a low density of 29.86 individuals/ha (Figure 2). Its average height was 2.92 m and a basal area of 1.01 m²/ha (Table 2).

Green's dispersal index for *C. micranthum* were 0.27 (DCF) and 0.24 (FPK), indicating an aggregated distribution pattern. Similarly, *E. africana* exhibited aggregated distributions across all sites with Green's dispersal index values of 0.17 (DCF), 0.13 (FPK), and 0.15 (AgS). *C. edulis* found exclusively in Ags, had Green's dispersal index of 0.26 (Table 2). The Blackman index values for all three species in all land use types exceeded 1, further confirming aggregated spatial distribution (Table 2).

Diameter class structures

The diameter structure of adult individuals of the three species had an inverted J-shaped distribution (Figure 3) and a positive asymmetric distribution indicating a predominance of young individuals in the populations. Also, the value of the "c" form parameter of the Weibull distribution between 1 and 3.6 is characteristic of a population with a predominance of young individuals. Only the diameter class structure of *E. africana* populations in the DCF showed a gradual decrease in the density of individuals towards the higher diameter classes (Figure 3). This indicated a stable population of the species in this plant formation. In addition, in agrosystems, the structure of individuals of the species had an inverted J-shaped appearance with a value of "c" = 0.73. This value of less than one (<1) indicated a population with high potential for regeneration in this plant formation. Furthermore, the other structures showed a sudden decrease in this density from

the second diameter class (Figure 3). This revealed the problem of recruitment of young individuals into the classes of older individuals in these plant formations. B 3 shows the only structure in diameter classes of the species *C. edulis* in the agrosystems, as it is absent in the two forests. This structure indicates low density, compared to the other two species in the study, in the different diameter classes and a virtual absence of large diameter individuals. However, the density of individuals in the smallest diameter class reveals potential for regeneration of the species.

Anthropogenic disturbance

Different forms of anthropogenic pressures characterized by a high level of exploitation of the wood resource are exerted on the populations of the three species in their habitats. These forms of threats were mainly: debarking, uprooting, fires and cutting. The relative frequency of threats varied by species and doesn't guarantee the survival of the species (Figure 3). Cutting (23.91%), uprooting (10.86%) and debarking (4.44%) were the forms of threat to *C. edulis* populations in the Koro AgS (Figure 4). The ANOVA test showed that the frequency of cutting ($p = 0.001$) and uprooting ($p = 0.000$) pressures on *C. micranthum* varied according to the type of land use. The strongest pressures were observed on populations in the village forest, including 37% of individuals of the species cut down and 10.23% uprooted (Figure 4). However, no significant difference was noted between the proportion of individuals of the species burned in the classified forest and the village forest ($P > 0.05$). In addition, the intensity of human actions with regard to debarking, uprooting and bush fires on *E. africana* stands varied according to the mode of land use ($P < 0.05$). Debarking was the most frequently encountered type of anthropogenic pressure on this species in AgS (25.93%) and DCF (20.70%). Furthermore, in these localities the species is spared from traces of bush fires. In addition, the frequency of logging on these populations doesn't differ statistically at the three sites. However, a higher proportion was observed in AgS (24.07%) and in DCF (23.87%).

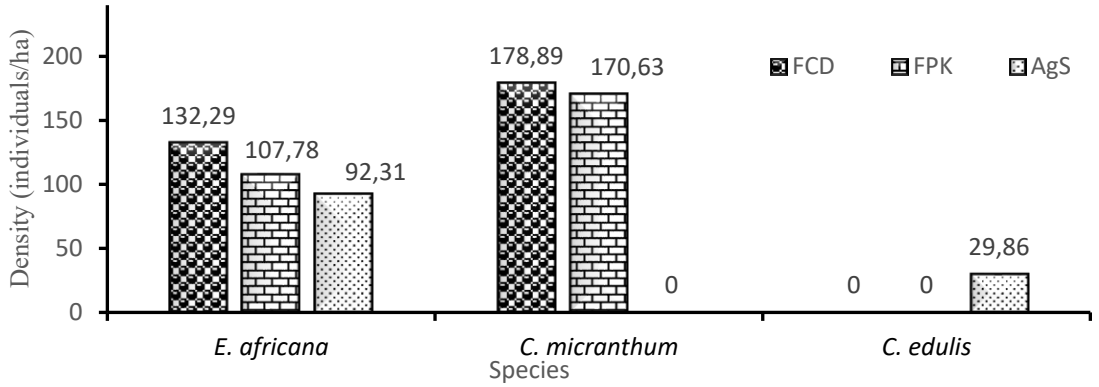


Figure 2 : Population density of *C. edulis*, *C. micranthum* and *E. africana* at the DCF, FPK and AgS.

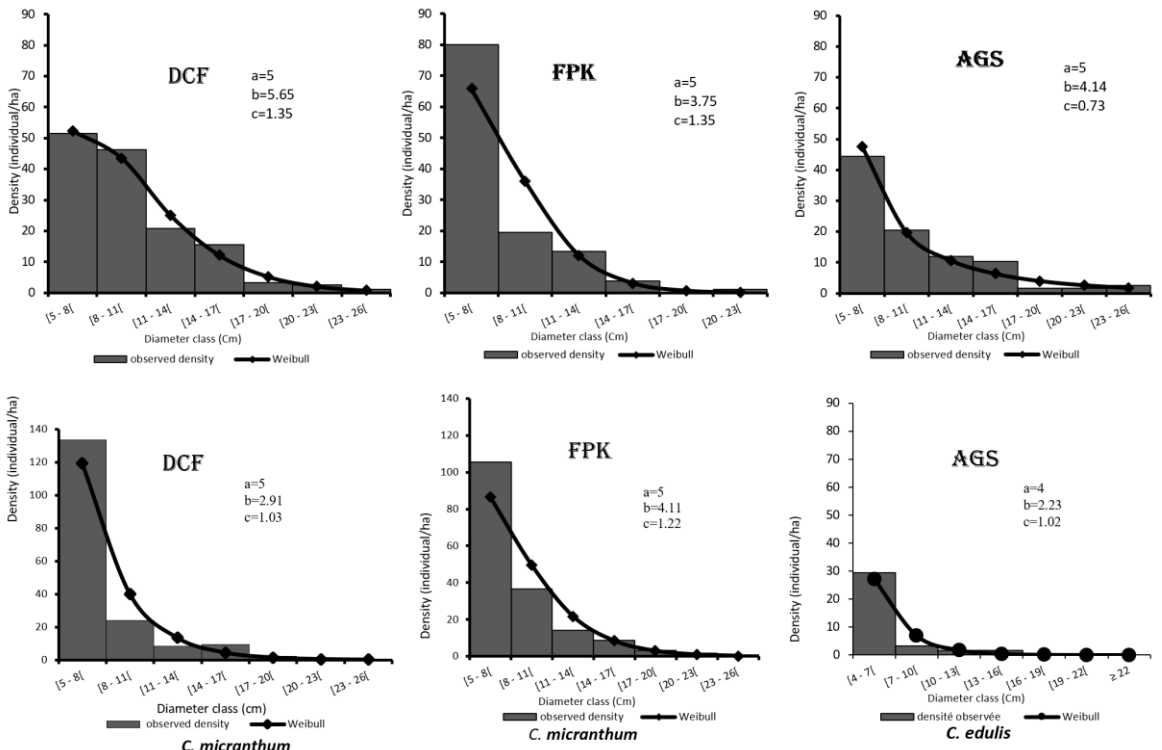
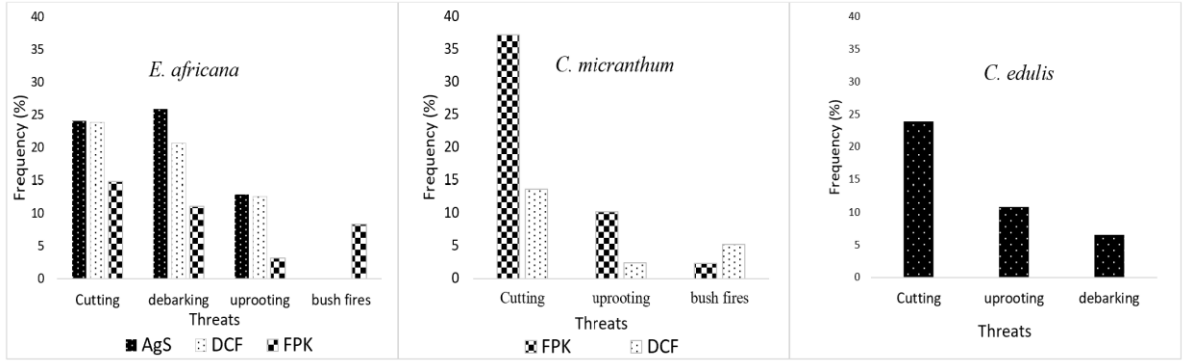


Figure 3 : Structure in diameter class of individuals of: *E. africana* in classified forest (DCF), village forest (FPK) and agrosystems (AgS); *C. micranthum* in DCF and FPK and *C. edulis* in AgS



Legend: DCF: Dindéresso classified forest; FPK :Kokorowé, Ags:agrosystems.

Figure 4: Traces of human exploitation on the three species.

Tableau 1 : Floristic composition and key associated species in the habitats of three species.

	<i>C. micranthum</i>	<i>E. africana</i>	<i>C. edulis</i>	p-value
Characteristic species	IVI	IVI	IVI	
<i>Acacia macrostachya</i> Reichenb. ex DC.	40.3			0.0014
<i>Dichrostachys cinerea</i> (L.) Wight & Arn.	28.5			0.009
<i>Terminalia macroptera</i> Guil. et Perr.	28.4			0.0048
<i>Detarium microcarpum</i> Guill. & Perr.	24			0.4599
<i>Combretum nigricans</i> Lepr. ex Guill. et Perr.	22.6			0.0282
<i>Hexalobus monopetalus</i> (A Rich .) Engl. et Diels	22.1			0.0138
<i>Combretum collinum</i> Fresen	19.3			0.1556
<i>Combretum glutinosum</i> Perr. ex DC.	18.4			0.1728
<i>Holarrhena floribunda</i> (G. Don) T. Durand & Schinz	16.8			0.1688
<i>Cassia sieberiana</i> DC.	16.5			0.2054
<i>Strychnos spinosa</i> Lam.	14			0.2136
<i>Kaya senegalensis</i> IDesr.) A Juss.	13.9			0.0626
<i>Pterocarpus erinaceus</i> Poir.	13			0.2182
<i>Combretum fragrans</i> F. Hoffm.	13			0.3931
<i>Combretum molle</i> R. Br.	11.9			0.1986
<i>Manilkara multinervis</i> (Bak.) Dubard	11.8			0.0574
<i>Carapa procera</i> DC.	11.4			0.0124
<i>Securidaca longipedunculata</i> Fres	10.4			0.1092
<i>Hymenocardia acida</i> Tul.	7			0.2492
<i>Acacia erythrocalyx</i> Brenan	6.8			0.0728
<i>Azelia africana</i> Sm. ex Pers.	5.2			0.6155
<i>Strychnos innocua</i> Delile	4.8			0.3071
<i>Tectona grandis</i> Linn.f.	4.5			0.3409
<i>Erythrina senegalensis</i> A. DC.	4.2			0.5969
<i>Grewia barteri</i> Burret	3.8			0.6775

<i>Erythrophleum africanum</i> (Welw. ex Benth.) Harms	2.8		0.7694
<i>Leucaena leucocephala</i> LAM.	2.3		0.4513
<i>Ficus platyphylla</i> Delile	2.3		0.4533
<i>Monotes kerstingii</i> Gilg	2.3		0.4533
<i>Strophantus sarmentosus</i> DC.	2.3		0.4569
<i>Ochna schweinfurthiana</i> F. Hoffm.	1.4		1
<i>Lannea microcarpa</i> Engl. et K. Krause		17.2	0.3837
<i>Burkea africana</i> Hook		16	0.1366
<i>Gardenia ternifolia</i> Schumach. & Thonn.		14.7	0.167
<i>Prosopis africana</i> (Guili. et Perr.) Taub.		14.5	0.3629
<i>Annona senegalensis</i> Pers.		11.6	0.7463
<i>Pteleopsis suberosa</i> Engl. & Diels		11.1	0.4259
<i>Bridelia ferruginea</i> Benrh.		10.3	0.3143
<i>Lannea velutina</i> A. Rich.		7.3	0.853
<i>Xeroderris stuhlmannii</i> (Taubert) Mendonça et E.P. De Sousa		7	0.6227
<i>Terminalia laxiflora</i> Engl. & Diels		6.9	0.8338
<i>Parinari curatellifolia</i> Planch. ex Benth.		4.6	0.6931
<i>Zanthoxylum zanthoxyloides</i> (Lam.) Zepern. & Timler		4.2	0.3381
<i>Sterculia setigera</i> Delile		3.9	0.4467
<i>Bombax costatum</i> Pellegr. et vuillet		3.5	0.7616
<i>Margaritaria discoidea</i> (Baill.) G.L.Webster		1.4	1
<i>Vitex doniana</i> Swett		1.4	1
<i>Gardenia erubescens</i> Stapf & Hutch		60.6	0.0002
<i>Acacia dudgeonii</i> Craib ex Holl.		60.5	0.0002
<i>Acacia seyal</i> Del.		51.2	0.0002
<i>Vitellaria paradoxa</i> Gaertn. F Hepper		49.5	0.0002
<i>Diospyros mespiliformis</i> Hochst. ex. A. DC.		49.3	0.0002
<i>Maytenus senegalensis</i> (Lam.) Exell		47.4	0.0002
<i>Guiera senegalensis</i> J.F. Gmel		42.1	0.0004
<i>Sclerocarya birrea</i> (A. Rich.) Hochst.		37.1	0.0002
<i>Lannea acida</i> A. RICH.		32.7	0.0384
<i>Ozoroa insignis</i> Delile		28.7	0.0014
<i>Parkia biglobosa</i> (Jacq.) R.Br.		28	0.0492
<i>Flacourtia flavescens</i> Willd.		25	0.0004
<i>Securinega virosa</i> (Roxb. EX Willd.) Baill.		25	0.0016
<i>Saba senegalensis</i> (A. DC.) Pichon		23.1	0.0042
<i>Grewia lasiodiscus</i> K.Schum.		22.6	0.0122
<i>Isoberlinia doka</i> Craib & Stapf		201	0.017
<i>Piliostigma thonningii</i> (Schumach.) Milne-Redh.		15.8	0.1106
<i>Opilia celtidifolia</i> (Guill. & Perr.) Endl.		14	0.0216
<i>Daniellia oliveri</i> (Rolfe) Hutch. & Dalziel		12.9	0.4115
<i>Tacazzea apiculata</i> Oliv.		12.5	0.0122

<i>Landolphia heudelotii</i> A. DC.	12.5	0.0126
<i>Isoberlinia tomentosa</i> (Harms) Craib & Stapf	10.2	0.0336
<i>Crossopteryx febrifuga</i> (Afz ex G.Don) Benth	9.8	0.6659
<i>Gardenia aqualla</i> Stapf & Hutch.	9.7	0.0644
<i>Feretia apodanthera</i> Delile	7.9	0.1692
<i>Sarcocephalus latifolius</i> (Sm.) Bruce	7.2	0.1986
<i>Pericopsis laxiflora</i> (Benth.) Meeuwen	6.8	0.9436
<i>Phyllanthus muellerianus</i> (Kuntze) Exell	6.2	0.1152
<i>Cissus populnea</i> Guill. & Perr.	6.2	0.1194
<i>Terminalia avicennioides</i> Guill. and Perr.	5.2	0.7099
<i>Baissea multiflora</i> A. DC.	3.6	0.5229
<i>Anogeissus leiocarpa</i> (DC.) Guill. & Perr.	3.1	0.6961
<i>Swartzia madagascariensis</i> Desv.	2.9	0.8144
<i>Tamarindus indica</i> L.	2.8	0.8616

Legend: IVI: Indicator Value Index

Tableau 2 : Mean of *C. edulis*, *C. micranthum* and *E. africana* dendrometric parameters.

Species	Land use type	Diameter (Cm)	Height (m)	Basal area (m ² /ha)	IB Index	IG Index
<i>C. micranthum</i>	DCF	9.48±3.48	4.84±1.36	0.90±0.86	129.9	0.27
	FPK	8.48±2.29	4.16±0.39	1.04±0.95	52.72	0.24
	AgS	0	0	0	0	0
<i>E. africana</i>	DCF	9.64±2.37	5.33±1.12	1.13±0.97	67.94	0.17
	FPK	8.50±1.41	4.66±0.55	0.63±0.32	17.77	0.13
	AgS	9.31±2.42	4.95±0.96	1.06±1.13	17.69	0.15
<i>C. edulis</i>	DCF	0	0	0	0	0
	FPK	0	0	0	0	0
	AgS	4.50±2.07	2.92±1.01	0.05±0	8.66	0.26

Legend: IB=Blackman's index; GI: Green's Index; DCF: Dindéresso classified forest; FPK::Kokorowé;; Ags:agrosystems

DISCUSSION

Impact of land use patterns on dendrometric characteristics

In this study, the impact of land use on the population status of three medicinal woody species was investigated. Although the *E. africana* species does not show a significant difference in population abundance according to land use types, a downward trend in density is observed from the Classified Forest to Agrosystems (AgS). Also, the highest frequencies of traces of human exploitation such as cutting, debarking and uprooting were recorded in agrosystems. Lowest density being recorded in the agrosystems, this indicates that a strong anthropogenic pressure is exerted on this species. Similar observations have been made by a study (Abdourhamane et al., 2017) on another woody species (*Sclerocarya birrea*) in Niger. Indeed, poor agricultural practices have a strong impact on the survival of populations of woody species in agrosystems. However, the value of this density found in agrosystems is relatively higher than that found by other authors on woody species, including *Boswellia dalzielii* Hutch (62 individuals/ha) and *Vitex doniana* Sweet (5.44 individuals/ha) in similar plant formations, shows a resilience capacity of the *E. africana* species in the face of these pressures (Sabo et al., 2022; Guindé et al., 2023).

The species *C. micranthum*, relatively dense in the DCF and FPK, is, however, absent in the AgS. This is due to the species' ecological preference for difficult soils such as shallow soils, shallow armour, as well as degraded termite mounds that are almost impermeable or skeletal soils (Bognounou, 2009). Among the dendrometric parameters of this species, height is the only dendrometric characteristic that varies significantly in the two forests. This can be explained by the difference in anthropogenic pressure that the two forests are under. Indeed, the protection status of the DCF reduces the intensity of the withdrawal pressure on woody species. These results corroborate those found by Yehouenou et al. (2012) who showed that anthropogenic pressure reduces height growth of the three species.

C. edulis is the least dense and not found in the classified forest and the protected forest. Logging, in particular, for the purpose of land clearing, is the most observed evidence of human exploitation of this species. This low density could be due, in addition to the direct exploitation of the species, to the effect of intensive clearing and the selection of utility species by farmers. Also, the strong use of the species in traditional medicine, in particular the use of roots, whose poor harvesting practices often lead to the felling of the individual, constitutes a threat to its sustainable management (Ouoba et al., 2006; Zima et al., 2018). This overexploitation and the fragmentation of its habitat for agricultural expansion considerably reduces the populations of this species and constitutes a real threat to its sustainable management.

Impact of land use type on structural characteristics

The diameter class structure of the three species reveals an abundance of individuals in the small diameter classes in general. This indicates potential for a renewal of their populations. The protective effect is more noticeable on the population structure of *E. africana*, which is characterised by a gradual decrease in density in the higher diameter classes in the classified forest of Dindéresso. Populations of the species are more stable compared to protected forest and agrosystems. In the latter two plant formations, a sudden decrease in the density of individuals is observed from the second diameter class in the structure of the species as well as in that of *C. micranthum* and *C. edulis*. This reveals an instability of their populations characterised by a problem of recruitment of young individuals in the upper diameter classes. This could be due to the strong anthropogenic pressures exerted on these different species. The instability of *C. micranthum* populations in the classified forest is explained by fraudulent harvesting of its populations due to its use in several types of activities: crafts (making baskets, chairs, daba handles), construction and traditional medicine (Bognounou, 2009). Specifically, the use of almost all its organs in the treatment of a wide range of diseases leads to high-harvesting rates

that could disrupt the dynamics of its populations (Amakpe et al., 2023).

In the FPK, the most observed traces of anthropogenic activities on the populations of *C. micranthum* and *E. africana* are cutting, debarking and uprooting. These multiple exploitations constitute a threat that can disrupt development and thus affect the survival and conservation of populations of these woody species, despite their high potential for regeneration. Several studies have similarly shown the impact of overexploitation, which threatens the survival and conservation of woody species in Sudanian savannahs (Kabr   et al., 2020; Traor   et al., 2020; Guind   et al., 2023). The absence of *C. edulis* in classified and protected forests reflects its rarity and vulnerability due to its ecological preference. Indeed, these agrosystems are not sites that guarantee the conservation of this species in view of the diverse and growing anthropogenic pressure on these sites (Guind   et al., 2023). In addition, the diameter structure determined for its populations in agrosystems, characterized by a high density of small-diameter individuals and a virtual absence of larger-diameter individuals, reflects a degradation of its populations in these formations with high anthropogenic activity. In these plant formations, agricultural expansion weakens the evolution of this species, unlike other woody species such as *Vitellaria paradoxa* C. F. Gaertn., *S. birrea*, *Parkia biglobosa* (Jacq.) R. Br. ex G. Don f. (Ouoba et al., 2018), it doesn't benefit from any conservation measures when converting fallow land into a field.

Also, poor practices of removing parts for the pharmacopoeia product needs, often manifested by damage of various forms that can lead to the death of individuals, most often constitute a threat to the survival of the species (Traor   et al., 2019; Kabr   et al., 2020). Investigations into this species in other countries have reached similar conclusions about its vulnerability. Olou et al. (2018) found that the abusive exploitation of the species' roots in traditional medicine is a real threat to its conservation in Benin. While Akwuma (2023) finds that the once-abundant species is now rare and endangered in Nigeria due to

inappropriate harvesting methods and habitat fragmentation. The intensity of these pressures considerably reduces the regenerative capacity of this species. In short, anthropogenic activities, especially the removal of plant organs for medicinal purposes, combined with poor harvesting methods (debarking by encircling around the trunk, along the trunk of the individual and the excavation of large quantities of roots) weaken the ability of these three woody species to maintain themselves within plant populations and compromise their long-term survival.

In the perspective that their heavy use is not a cause of erosion of these species in this locality, protection measures must be taken to guarantee the sustainability of these resources for the benefit of the future generation. Knowledge of the structure and ecology of these species makes it possible to develop good strategies for their sustainable management in preferred habitats. With regard to the methods of collection, emphasis must be placed on raising awareness among local populations and especially actors in the field of traditional medicine in order to raise awareness of the negative impact of the harvesting of vital plant organs (roots and bark) on the sustainability of medicinal woody species. Harvest monitoring measures must be strengthened in protected areas to counter any possible destabilization of stand structure by abusive and fraudulent harvesting.

Conclusion

This study examined the impact of land use types on the structural and dendrometric characteristics of three medicinal woody species in the South Sudanese sector of Burkina Faso. It showed that the way in which the land is used affects the population structure of the three species differently. The present results show that anthropogenic pressure disrupts and contributes to the destabilization of populations of these species. Indeed, excessive cutting, uprooting and debarking hinder the proper recruitment of young individuals of these species despite their potential for regeneration. Although these species show a certain resilience through their

good regenerative capacity, they remain vulnerable due to their strong use by local populations, particularly in traditional medicine. The combined effect of high-harvesting pressure and the lack of a good endogenous conservation strategy compromises the sustainable use of these species. This situation reveals the urgency of implementing sustainable management planning such as their preservation in the fields, their integration into programs for the domestication of local plants. In this perspective, investigations must continue to assess the suitability of these species for vegetative propagation, an essential step in their domestication. In addition, particular attention should be paid to the training of medicinal plant harvesters on the methods of harvesting the various plant organs as well as harvesting regulations to reconcile the satisfaction of needs and the sustainable management of natural resources.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS CONTRIBUTIONS

BD and RNT designed the study and conducted field data collection under the supervision of PO, JMB, IS and BHN. BD performed the statistical analyses and drafted the first version of the manuscript.

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REFERENCES

Abdourhamane H, Rabiou H, Diouf A, Morou B, Mahamane A, & Bellefontaine R. 2017. Structure démographique et répartition spatiale des populations de *Sclerocarya birrea* (A. Rich.) Hochst. du secteur sahélien du Niger. *Bois et Forêts des Tropiques*, **333** (3) : 55-66. DOI :

<https://doi.org/10.19182/bft2017.333.a31468>

Akwuma OD. 2023. The Status and Ecological Impacts of *Carissa edulis* in Oju Local Government Area of Benue State, Nigeria. *International Journal of Advanced Academic Research*, **9**(9) : <https://www.openjournals.ijaar.org/index.php/ijaar/article/view/194>

Amakpe F, Graaf DC, Sinsin B, Biaou HS. 2023. Stem cuttings assessment for domesticating the medicinal melliferous plant, *Combretum micranthum* G. Don. in the Republic of Benin. *Net Journal of Agricultural Science*. **11**(1): 1-12. DOI: <https://doi.org/10.30918/NJAS.111.23.003>

Assogba GA, Fandohan AB, Gandji K, Salako KV, Adomou A, Assogbadjo AE. 2021. Impacts des affectations des terres sur la structure des peuplements de *Bombax costatum* en zone soudanienne du Bénin. *Bois et Forêts des Tropiques*, **348** : 37-48. DOI: <https://doi.org/10.19182/bft2021.348.a36743>

Bognounou F. 2009. Restauration écologique et gradient latitudinal : utilisation, diversité et régénération de cinq espèces de Combretaceae au Burkina Faso. Thèse de Doctorat Unique, Université de Ouagadougou, 179p.

Coulibaly S. 2003. Résultat du traitement des données de l'inventaire forestier réalisé dans la forêt classée de Dindéresso. BKF07-PAFDK. Burkina Faso, 41p.

Dakio B, Bangou MJ, Ouoba P, Ouoba YH, Guenné S, Meda RNT, Zangré AK, Tiendrebeogo R, Ouédraogo AG. 2020. Medicinal Plants used in the Treatment of Hepatitis in Bobo-Dioulasso: Studying the Availability and Analyzing the Phytochemical Properties of *Combretum micranthum* G. Don and *Entada africana* Guill. et Perr. *The Natural resources of tropical Africa*, **16**(40). DOI: <https://doi.org/10.19044/esj.2020.v16n40p1>

Fyhrquist P. 2007. Traditional medicinal uses and biological activities of some plants

- extract of African *Combretum* Loebl.; *Terminalia* L. and *Pteleopsis* Engl. Species (Combretaceae). Ph.D. Dissertation, University of Helsinki, Finland, p. 185.
- Guindé HT, Sabo P, Ouattara B, Ouédraogo A. 2023. Effet du type d'utilisation des terres sur l'état des populations de *Vitex doniana* Sweet en zone soudanienne du Burkina Faso. *Bois et Forêts des Tropiques*, **357**: 71-84. DOI: <https://doi.org/10.19182/bft2023.357.a37026>
- Husch B, Beers TW, Kershaw JA. Jr. 2003. *Forest Mensuration* (4th Edn). John Wiley: Hoboken, NJ, USA; 343 p.
- Jayaraman K. 1999. *A Statistical Manual for Forestry Research*. FAO: Bangkok, Thailand; 231p.
- Kabré B, Belem/Ouédraogo M., Lankoandé B, Ouédraogo A. 2020. Variabilité démographique de *Saba senegalensis* (A. DC.) Pichon suivant le gradient climatique au Burkina Faso. *Bois et Forêts des Tropiques*, **345** : 73-83. DOI : <https://doi.org/10.19182/bft2020.345.a31930>
- Meunier Q, Bellefontaine R, Monteuis O. 2008. La multiplication végétative d'arbres et arbustes médicinaux au bénéfice des communautés rurales d'Ouganda. *Bois et Forêts des Tropiques* **296**(2): 71-82. <http://agritrop.cirad.fr/543933>
- Olou BA, Bio A, Koko DKIE, Djego JG, Sinsin BA. 2018. Connaissances ethnobotaniques et valorisation de deux plantes antihypertensives (*Carissa edulis* L. et *Crateva adansonii* DC) au Sud et au Centre du Bénin (Afrique de l'Ouest). *International Journal of Biological and Chemical Sciences*, **12**(6): 2602-2614. DOI: <https://dx.doi.org/10.4314/ijbcs.v12i6.11>
- Ouédraogo A, Thiombiano A, Hahn-Hadjali K, Guinko S. 2006. Diagnostic de l'état de dégradation des peuplements de quatre espèces ligneuses en zone soudanienne du Burkina Faso. *Sécheresse*, **17**(4) : 485-91. <https://www.researchgate.net/publication/256662633>
- Ouoba HY, Bastide B, Coulibaly-Lingani P, Kabore AS, Boussim JI. 2018. Connaissances et perceptions des producteurs sur la gestion des parcs à *Vitellaria paradoxa* C. F. Gaertn. (karité) au Burkina Faso. *International Journal of Biological and Chemical Sciences*, **12**(6): 2766-2783. DOI: <https://doi.org/10.4314/ijbcs.v12i6.23>
- Ouoba P. 2006. Flore et végétation de la Forêt Classée de Niangologo, Sud-Ouest du Burkina Faso. Thèse de doctorat unique, Université de Ouagadougou, 140 p.
- Ouoba P, Lykke AM, Boussim J, Guinko S. 2006. La flore médicinale de la Forêt Classée de Niangoloko (Burkina Faso). *Etude sur la Flore et la Végétation du Burkina Faso et des Pays Avoisinants*, **10**: 5-16.
- Sabo P, Ouédraogo A, Gbemavo DSJC, Salako KV, Glèlè Kakaï R. 2021. Land use impacts on *Boswellia dalzielii* Hutch., an African frankincense tree in Burkina Faso. *Bois et Forêts des Tropiques*, **349**: 51-63. DOI : <https://doi.org/10.19182/bft2021.349.a31960>
- Sombié EN, Tibiri A, N'do JY, Traore TK, Ouédraogo N, Hilou A, Guissou PI, Nacoulma GO. 2018. Ethnobotanical study and antioxidant activity of anti-hepatitis plants extracts of the Comoé province, Burkina Faso. *International Journal of Biological and Chemical Science*, **12**(3): 1308-1319.
- Tapsoba H, Deschamps J-P. 2006. Use of medicinal plants for the treatment of oral diseases in Burkina Faso. *Journal of Ethnopharmacology*, **104**: 68-78.
- Thiombiano A, Glèlè Kakaï R, Bayen P, Boussim JI, Mahamane A. 2016. Méthodes et dispositifs d'inventaires forestiers en Afrique de l'Ouest : état des lieux et propositions pour une harmonisation. *Annales des Sciences Agronomiques 20 spécial Projet Undesert-UE*: 15-31.

- Thiombiano A, Ouôba P, Guinko S. 2002. Place des Combretaceae dans la société gourmantché à l'est du Burkina Faso. *Études sur la Flore et la Végétation du Burkina Faso et des Pays Environnants*, 7: 17-22.
- Thiombiano A, Schmidt M, DaS, Hahn-Hadjali K, Zizka G, Wittig R. 2010. Les plantes vasculaires : Les plantes à fleurs. In *Atlas de la Biodiversité de l'Afrique de l'Ouest Tome II, Burkina Faso*, Thiombiano A, Kampmann D (eds). Ouagadougou & Frankfurt/Main; 184- 192.
- Thiombiano A, Schmidt M, Dressler S, Ouédraogo A, Hahn K, Zizka G. 2012. Catalogue des plantes vasculaires du Burkina Faso. In *Boissiera* (Vol. 65). Genève, Suisse, Conservatoire et Jardin botaniques de la Ville de Genève, 391 p. <http://goo.gl/1hizQw>
- Tiendrébeogo NR, Ouoba P, Bastide B, Ouoba YH, Nacoulma BMI, Somda I, Nacro BH, Boussim IJ. 2022. Structure and dynamics of Classified Forest of Péní's woody flora in western Burkina Faso. *Journal of Biodiversity and Environmental Sciences*, 21 (6): 80-93.
- Tiendrébeogo NR. 2022. Phytodiversité, végétation et services écosystémiques de la Forêt Classée de Péní au Sud-Ouest du Burkina Faso. Thèse de Doctorat Unique, Université Nazi Boni, 184 p.
- Traoré A, Derme AI, Sanon S, Gansane A, Ouattara Y, Nebié I, Sirima SB. 2009. Connaissances ethnobotaniques et pratiques phytothérapeutiques des tradipraticiens de santé de la Comoé pour le traitement du paludisme : processus d'une recherche scientifique de nouveaux antipaludiques au Burkina Faso. *Médecine Traditionnelle en Afrique: Ethnopharmacologia* ; 43p.
- Traoré GH, Sanou L, Koala J. 2019. Diversité d'utilisations et de connaissances des espèces locales préférées dans le corridor forestier de la Boucle du Mouhoun, Burkina Faso. *Science et Technique, Sciences Naturelles et Appliquées*, 38 (1): 101-117.
- Traore L, Sambare O, Savadogo S, Ouédraogo A, Thiombiano A. 2020. Effets combinés des facteurs anthropiques et climatiques sur l'état des populations de trois espèces ligneuses vulnérables. *International Journal of Biological and Chemical Sciences*, 14(5): 1763-1785. DOI: <https://doi.org/10.4314/ijbcs.v14i5.21>
- Traoré TK, Tibiri A, Ouédraogo N, Sombié NE, N'do JY, Ouédraogo S; Guissou IP. 2018. Ethnopharmacological plants used to treat hepatitis and their anti-oxidant activity of district of Bobo-Dioulasso (Burkina Faso). *International Journal of Pharmacological Research*, 8 (3): 15-23.
- Yehouenou TDR, Akouehou GS, Ganglo JC. 2012. Caractéristiques structurales et écologiques des populations de *Antiaris toxicaria* (Pers.) Lesch et de *Ceiba pentandra* (L.) Gaertn dans les forêts reliques du Sud-Benin. *International Journal of Biological and Chemical Sciences*, 6 (6) : 5056-5067.
- Zerbo P, Millogo-Rasolodimby J, Nacoulma-Ouedraogo OG, Van Damme P. 2007. Contribution à la connaissance des plantes médicinales utilisées dans les soins infantiles en pays San, au Burkina Faso. *International Journal of Biological and Chemical Sciences*, 1(3): 262-274.
- Zerbo P, Millogo-Rasolodimby J, Nacoulma-Ouedraogo OG, Damme PV. 2011. Plantes médicinales et pratiques médicales au Burkina Faso: cas des Sanan. *Bois et Forêt des Tropiques*, 307(1) : 41-53.
- Zima GG, Mialoundama F, Yangakola JM, Kossa I. 2018. Importance Des Produits Forestiers Non Ligneux Médicinaux D'origine Végétale Et Impacts Des Activités Anthropiques Sur Leur Durabilité Dans Le Sud-Ouest De La République Centrafricaine. *European Scientific Journal*, 14(33). DOI : <https://doi.org/10.19044/esj.2018.v14n33p202>