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Populations structure of two food and medicinal plant species (*Crateva adansonii* D.C. and *Sarcocephalus latifolius* (Smith) Bruce) in Burkina Faso (West Africa)

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Abstract

In Burkina Faso, widely used woody species are declining due to uncontrolled exploitation. Populations of *Crateva adansonii* D.C. (Capparaceae) and *Sarcocephalus latifolius* (Smith) Bruce (Rubiaceae), two valued trees for local communities, deserve to be studied in this context of overexploitation of natural resources. The aim of the study was to characterize the stands of the two species. More specifically, the work compares the structures of the stands in anthropized areas with those two protected areas (Classified Forest of Koulbi and Reserves of Bontioli). The research was carried in the South-western region of Burkina Faso (West Africa). Oriented inventories following stratified sampling were carried out in stands of the species in and around the protected areas. A total of 159 relevés were carried out. No adult stands of *C. adansonii* were found in the protected areas, whereas the density of the species ranged from 16 ± 14 to 38 ± 35 trees per ha outside the protected areas. The densities of *S. latifolius* are statistically the same inside and outside protected areas (from 34 ± 19 to 74 ± 39 trees per ha). Regeneration densities of the two species are higher in Koulbi than in Bontioli. Conservation measures must be reinforced by national environmental protection services, with the involvement of local communities in protecting these valued trees.

Keywords: *Crateva adansonii; Sarcocephalus latifolius*; Protected area; Population structure; Regeneration; Seedlings

Introduction

Woody species are an important component of the natural resources of West African savannas. In particular, overgrazing and fraudulent grazing [1], extensive agriculture and uncontrolled exploitation of forest products are exerting considerable pressure on vegetation cover [2]. Uncontrolled exploitation of forest plants, combined with the effects of climate change, is leading to the rapid decline or even disappearance of certain plants that are very useful to rural communities, which derive a large part of their income from the exploitation of woody and non-woody forest products (fodder, fruits, sap, gum, honey, etc.) [3,4].

Against this background of ecosystem degradation and climate change, sustainable environmental management has become a major policy concern in African countries like Burkina Faso. It is important that research contributes to a better understanding of woody stands in order to propose conservation measures. *Crateva adansonii* D.C. and *Sarcocephalus latifolius* (Smith) Buce

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are two widely used and threatened species according to several studies [3,5-7]. *Crateva adansonii* (Capparaceae) is a small tree of 7 m high. Its distribution extends from Senegal to Eritrea [8]. Its leaves are consumed by local communities. *Sarcocephalus latifolius* (Rubiaceae) is a tree, sometimes a sarmentose shrub, varying in height from 4 to 9 m [8]. The species is found from Senegal to Sudan. In Burkina Faso, this plant is used for the treatment of several diseases, such as stomach aches and malaria [9].

However, not enough is known about the availability of these species. It is therefore necessary to characterise their populations in their natural stands. The dependence of populations on natural vegetation affects species richness, population structure, density and basal area of woody species [10,11]. The aim of this study is to characterise the natural stands of the two species. Specifically, the study compares the structure of the populations in anthropised and protected areas. This research hypothesises that protected areas can play a positive role in helping to maintain stable populations of woody species.

Material and Methods

Study site

The work was carried out in the south-western region of Burkina Faso. This region is bounded to the East by the Mouhoun (or Black Volta) River. It comprises four provinces: Poni, Bougouriba, Ioba and Noumbièl. Our work concerns the Bontioli Reserves (between 10°56'10.9'N 3°08'36.3"W and 10°42'33.7"N 3°07'47.4"W) and the Koulbi Classified Forest (between 9°45'16.7"N 2°50'16.4"W and 9°30'52.2"N 2°50'34.4"W) (Figure 1). These two formations offer the advantage of being able to carry out a comparative study between protected areas and those under strong human influence located close to these formations.

Floristic inventory

In order to assess the ecology of the the forests, a prospecting was first carried out. Subsequently, plants inventories were carried out in the stands of the two species, using stratified sampling. The aim was to cover the study area and look for biotopes where the two species are established,

Figure 1: Location of the South-West region, Bontioli Reserves and Koulbi Classified Forest.

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while ensuring that the inner and outer perimeters of the two protected areas were covered as uniformly as possible. In the remainder of this article, the names Bontioli and Koulbi refer to the Bontioli Partial and Total Wildlife Reserves and the Koulbi Classified Forest, respectively.

In the centre of each stand, a circular plot of 900 m^2 was established for the natural formations and a square plot of 2500 m^2 for the agroforestry parks. A total of 159 relevés were carried out (Table 1), respecting the minimum inventory areas in the Sudanese zone.

For adult individuals (dbh ≥ 5 cm), dbh (diameter at 1.3 m above ground) and small and large diameter of the crown were measured. The intensity of visible damage to these species was recorded with scores of 0 (no damage, individuals completely undamaged), 1 (1-25% of branches, roots and/or bark cut or dead), 2 (26-50%) and 3 (more than 50%) depending on the degree of cutting and/or various traumas observed on the individuals. These scores were inspired by Cunningham [12] and Nacoulma et al. [13]. Here we consider a plant with more than 25% of different traumas to be vulnerable and of reduced potential.

Table 1: Number of survey points by ecosystem and species.

	Bontioli		Koulbi		Total
	Inside	Outside	Inside	Outside	
S. latifolius	16	16	21	20	73
C. adansonii	21*	26	12*	27	86
Total	37	42	33	47	159

*Only regeneration is found in these surveys, adults being totally absent.

An exhaustive inventory of the woody species of these two species stands was carried out. Their regeneration was counted in five square subplots of 25 m^2 each. In the agroforestry parks, however, the count was carried out on the entire surface of the plots because of the weakness of the regeneration. The regeneration of both species (dbh < 5 cm) was classified into four (4) height classes: [0-0.5[; [0.5-1[; [1-1.5[and ≥ 1.5 m [14].

Data analysis

Data analysis consisted of calculating the mean values of structural and ecological parameters and producing graphs to help interpret the structure of species populations. For this purpose, the evaluated parameters were calculated using the following formulae:

Density (D):

$$D = \frac{n}{s}$$

Where n: number of individuals of the species in question; s: plot area in ha.

Basal area at 1,30 m (G) :

$$G = \frac{\pi}{4s} \sum_{i}^{n} d_i^2$$

Where di: dbh of individual 'i' in m; n: number of individuals of the species; s: plot area in ha

Average crown diameter (dh):

$$Dh = \frac{1}{n} \sum \frac{Dg + Dp}{2}$$

With Dg and Dp respectively the large and small diameter of the crown

n: number of individuals of the species

$$Ci = \frac{j}{a + b - j}$$ 15] (Ci):

Where j is the number of species common to both sites A and B; a is the number of species from site A; b is the number of species from site B.

The Jaccard index is an ecological parameter that assesses the diversity β between two sites: it varies between 0 and 1. Low diversity between two sites results in an index close to 1 [15,16]. The structural dynamics of species were investigated using histograms of dbh distribution classes. The Weibull distribution was applied to this distribution as it is mathematically easy to interpret and has been widely used in studies of population structure of woody species [17].

The Weibull distribution has the probability density function f(x) [18]

$$f(x) = \frac{c}{b}((x - a)/b)^{c-1} e^{-((x-a)/b)^c}$$

Where a is the position parameter, b is the scale or size parameter and c is the shape parameter related to the observed structure.

The Cramer von Mises W-test proposed by the JMP 9.0.0 software [19] was used to assess the goodness of fit of the Weibull distribution. The data fit the Weibull distribution (H0) if the probability found is less than 0.05, otherwise H0 is rejected. The percentages of the different healthy individuals and those with different degrees of damage were calculated and used to construct graphs. The Mann-Whitney test with a 5% significance level was used to compare density, area and average crown diameter between the different environments. Data were processed using XLSTAT 7.5.2 and JMP 9.0.0 [19].

Results

Density and basal area

Densities of both species are higher in Koulbi than in Bontioli (Table 2). *S. latifolius* densities were statistically identical inside and outside each reserve. The best stands of

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S. latifolius were found in the lowlands, on clay soils. No adult stands of *C. adansonii* were found in the protected areas, whereas the density of the species ranged from 16 ± 14 to 38 ± 35 outside the protected areas, which in this case are agroforestry parks. The area covered by the two species is greater in Koulbi than in Bontioli (Table 3). There was no significant difference between inside and outside the individual reserves.

Crown diameter

Table 3 shows the average crown diameter of the two species. The crown of *S. latifolius* is relatively more developed at Koulbi than at Bontioli (4.96 ± 1.86 m compared to 6.55 ± 2.43 m). However, the diameter of the crown did not vary significantly between sites. The average crown of *C. adansonii* outside the two reserves is about 4 m.

Health status of plants

The results (Table 4) show that *C. adansonii* does better in unprotected areas than in protected areas. The same result can be observed with *S. latifolius* when comparing plants inside and outside the Koulbi classified forest. Populations of the species have more vulnerable individuals inside protected areas than outside. Vulnerable individuals of *S. latifolius* represent 26% and 24% in Bontioli and 45% and 20% in Koulbi, respectively, in protected and anthropised areas. In protected areas, *S. latifolius* was mainly affected by annual fires. In anthropised areas, root cutting is the main cause of damage to *S. latifolius* plants. In the case of *C. adansonii*, although the leaves are necessarily harvested by cutting, it is mainly severe and repeated cutting that makes the plants vulnerable and stunted (51% around Bontioli compared to 39% around Koulbi).

Structure of adult individuals

The population structure of *C. adansonii* is very degraded in both reserves; adults are very rare. Its seedlings can only be found along watercourses. On the other hand, outside these protected areas, in the agro-systems, the population structure of *C. adansonii* is asymmetrically straight, reflecting a predominance of young individuals (Figure 2). All these individuals were planted. The Weibull distribution did not fit the observed values ($P > 0.05$). The structure of *S. latifolius* fits the Weibull distribution in anthropised areas ($P < 0.05$), with a c parameter between 1 and 3.6, characteristic of a population with low regeneration potential. However, its structure does not fit the Weibull distribution in protected areas ($P > 0.05$) (Figure 3). There is a problem with the regeneration of the species, as the first class has fewer individuals than the following class.

Table 2: Densities (plantes perha) and basal areas (m^2 per ha) of adult individuals of species according to ecosystem (mean ± standard deviation).

Sites	Area's status and statistical parameters	Density		Basal area	
		S. latifolius	*C. adansonii*	*S. latifolius*	*C. adansonii*
Bontioli	Protected areas	34 ± 19	-	0,32 ± 0,20	-
	Outside protected areas	34 ± 29	16 ± 14	0,40 ± 0,36	0,46 ± 0,33
	Z	0,93		0,04	-
	P	0,352		0,97	-
Koulbi	Protected areas	70 ± 51	-	0,92 ± 0,67	-
	Outside protected areas	74 ± 39	38 ± 35	0,88 ± 0,46	0,74 ± 0,34
	Z	- 0,921		- 0,34	-
	P	0,357		0,73	-

Z: observed test value; P: probability (Mann-Whitney test).

Table 3: Average crown diameter (m) of species according to the site.

Site	Area's status and statistical parameters	*S. latifolius*	*C. adansonii*
Bontioli	Protected areas	4,96 ± 1,86	-
	Outside protected areas	5,64 ± 1,56	4,00 ± 1,36
	Z	1,595	
	P	0,111	
Koulbi	Protected areas	6,55 ± 2,43	-
	Outside protected areas	6,34 ± 2,30	4,19 ± 1,06
	Z	0,543	
	P	0,587	

Z: observed test value; P: probability (Mann-Whitney test).

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Table 4: Proportion (%) of adult *Crateva adansonii* and *Sarcocephalus latifolius* showing damage according to the site.

Levels of damage observed on adult trees	*Crateva adansonii*			
	Bontioli Reserves	**Outside of the reserve**	**Classified forest of Koulbi**	**Outside classified forest**
No damage	-	13	-	10
0-25% of damage	-	36	-	52
25-50% of damage	-	28	-	23
More than 50% of damage	-	23	-	16
	Sarcocephalus latifolius			
No damage	28	62	14	34
0-25% of damage	48	12	41	46
25-50% of damage	14	6	31	10
More than 50% of damage	10	20	14	10

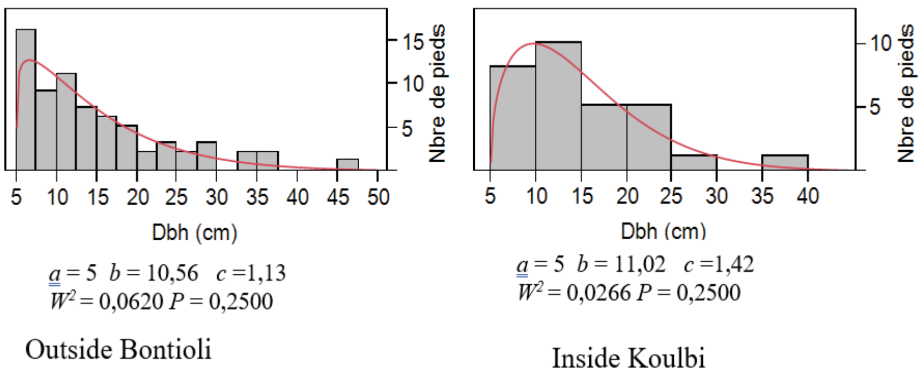

Figure 2: Adult population structures of *C. adansonii* according to the site.

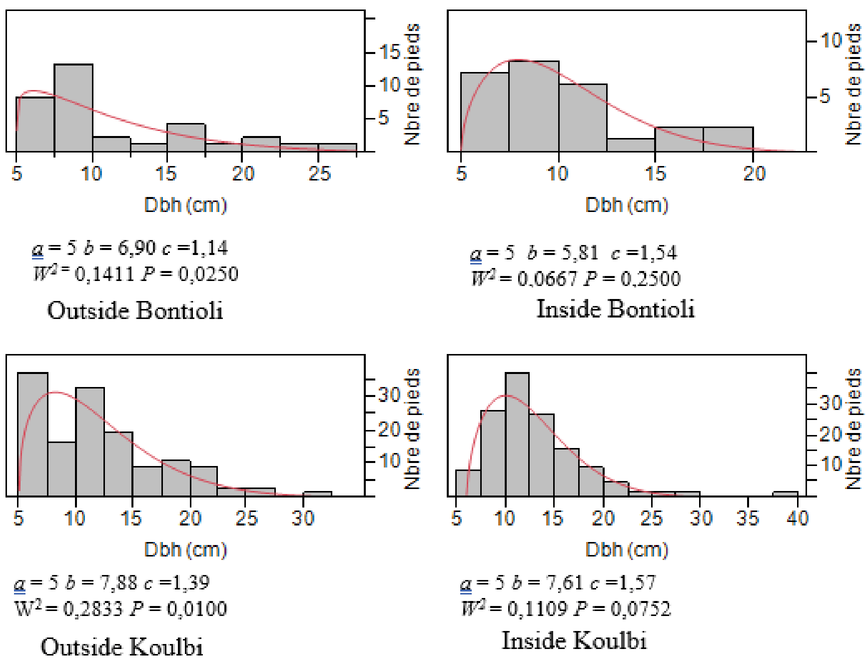

Figure 3: Adult population structures *of S. latifolius* according to the site.

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Juvenile populations and regeneration potential

Regeneration densities of the two species are higher in Koulbi than in Bontioli. Although adult stands of *C. adansonii* are rare in the wild, strong regeneration is found in places, with densities reaching 1300 plants. ha^{-1} in the Koulbi classified forest and 340 plants. ha^{-1} in the Bontioli reserves (Figure 4). *Crateva adansonii* regenerates in the wild on well-drained soils, often flooded in the middle of the rainy season. This regeneration is limited to a thin strip along the Mouhoun River. In the agroforestry parks, regeneration reaches densities of around 50 plants. ha^{-1} around Bontioli, compared to 1330 plants. ha^{-1} around Koulbi. This regeneration consists mainly of suckers and stump shoots, due to the lack of seedlings in the natural environment and the absence of fruit in the agroforestry parks after very frequent pruning.

The structure of the *Sarcocephalus latifolius* regeneration is J-shaped, reflecting a lack of seedling recruitment (Figure 5). It is almost impossible to find seedlings less than 10 cm high, which are normally seedlings, despite good fruit production. The density of regeneration is very low, whatever the environment. We counted 127 plants. ha-1 in the Koulbi classified forest, compared to 380 plants perha outside the forest. This density is 30 plants per ha in the reserves compared to 14 plants per ha outside the reserves.

Species richness and Jaccard index

Jaccard indices for *S. latifolius* stands in protected areas and those in anthropised areas show a lack of similarity in their woody diversity (Table 5). These stands contain more species in Koulbi than in Bontioli (73 species compared to 61 species). Conversely, *S. latifolius* stands outside Bontioli contain more species (69 species) than those outside Koulbi (62 species). The number of species in *S. latifolius* stands outside Bontioli is higher than inside; the opposite is true in Koulbi.

Non-native species such as *Moringa oleifera* Lam., *Anacardium occidentale* L, *Blighia sapida* Koenig, *Azadirachta indica* A. Juss. et *Mangifera indica* L. are found in anthropised areas, in contrast to protected areas. Comparisons are not possible due to the absence of *C. adansonii* populations in protected areas.

Discussion

The dendrometric study of the species provides information on their physiognomic characteristics in relation to their habitats. The relatively low basal area of *C. adansonii* (between 0.46 and 0.74 m^2ha-1) can be explained by its low density in agroforestry parks and by the high number of small-diameter trees. The average diameter of its crown,

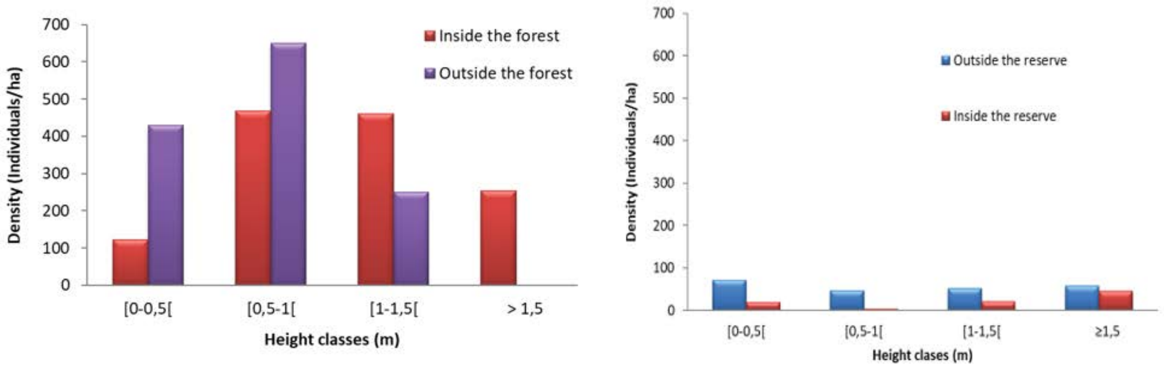

Figure 4: Structures of *Crateva adansonii* regeneration according to the site.

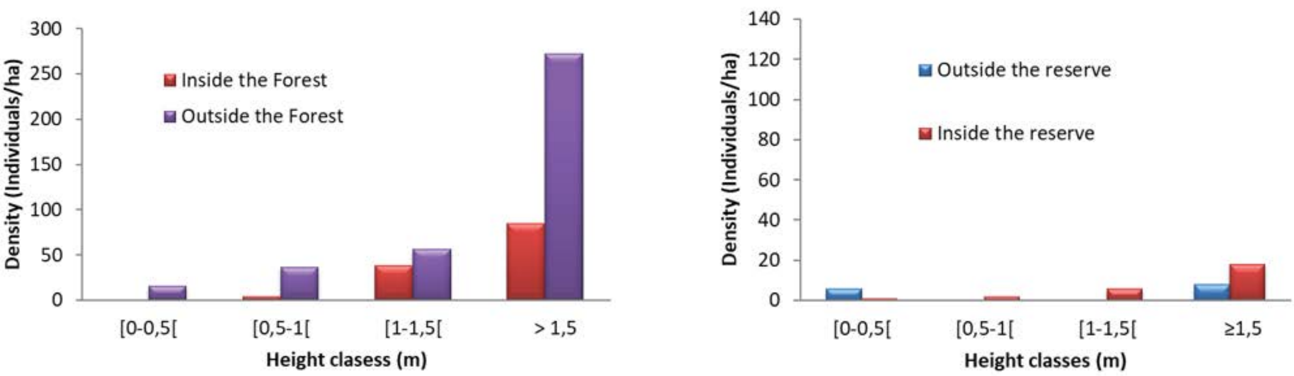

Figure 5: Structures of *Sarcocephalus latifolius* regeneration according to the site.

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Table 5: Species richness and Jaccard indices for *Sarcocephalus latifolius* populations in different ecosystems.

Sites	Area's status	Number of species	Jaccard index
Bontioli	Protected areas	61	0,44
	Outside protected areas	69	
Koulbi	Protected areas	73	0,27
	Outside protected areas	62	

around 4 m, is relatively small, which is an advantage for its integration with crops, as it provides little shade.

Like *C. adansonii*, the basal area of *S. latifolius* remains relatively low (between 0.32 and 0.92 m^2 per ha) and is not statistically different between protected and anthropised areas. Although it is presented as a shrub [8], the species has a rather wide crown, ranging from 4.96 m to 6.55 m depending on the environment. This is comparable to that of arborescent species such as *Anogeissus leiocarpa*, whose crown in Burkina Faso has a diameter of between 5.9 m and 7.5 m [20].

By way of comparison and to put the parameters of the two species into perspective, the basal area of the baobab, considered the largest tree in African savannas [21], is of the order of 250-500 m^2/ha with a dbh of 150-240 cm at a density of 5-24 individuals/ha in Togo [17].

In contrast to the natural environment, the structure of *C. adansonii* in diameter classes in village terroirs suggests that old trees are being renewed and shows that the plant is well adapted to plantation conditions. The example of *C. adansonii* is a reminder that farmers can plant and maintain species that are both widespread and threatened, all of which contributes to a better understanding of the silviculture of these species. Protected areas do not provide sufficient protection for *C. adansonni* populations, confirming similar findings by Traoré et al. [22] in Burkina Faso for other highly exploited plants.

The vulnerability of *C. adansonii* individuals in agroforestry parks is the result of over-exploitation and the use of inappropriate pruning techniques that do not optimise leaf production throughout the year. The result is stunted trees and reduced leaf productivity. This is compounded by the lack of fruit production from these trees due to complete delimbing at very short intervals, which jeopardises the maintenance of good genetic variability within the population.

Observations in the wild, particularly along the banks of the Mouhoun River, clearly show that the plant is not suffering from a lack of young plants; it is their growth and emancipation from the juvenile stage that is not assured. Our results are in agreement with those of Sambaré et al. [23], who only reported individuals with dbh < 5 cm along rivers in the southern Sudanese area. The same authors made the same observations in the northern Sudan and southern Sahel zones, with the exception of the northern Sahel zone where plants with dbh ≥ 5 cm were reported. *C. adansonii* therefore remains a threatened plant in the natural ecosystems of several African countries, as highlighted by Attoh & Ahama [3]. In India, densities of the order of 8.6 adult individuals/ha have been reported [24].

In order to promote the development of abundant regeneration, the banks of watercourses in protected areas should be protected from development fires. Planting the species in natural formations is also a possibility and, given what has been observed in village areas, is likely to be successful.

The overall analysis of *S. latifolius* population shows that it is a species with low regeneration. This finding corroborates those of Tabuti et al. [5] and Stangeland et al. [25] for Uganda. Furthermore, Stangeland et al. noted [25] a lack of germination of exposed seeds under natural conditions, Protected areas are more favourable to a good population structure of *S. latifolius* and to a good health status of the plant. Authors such as Thiombiano et al. [6] and Tabuti [26] have reported the disappearance of the species in certain localities due to the cutting of roots for health care.

One of the causes of the vulnerability of *S. latifolius* in protected areas (between 26% and 45% of plants are vulnerable) is repeated bush fires. This slows down the emergence of seedlings. Fire also reduces the plants' potential for stress resistance and fruit production, as has been observed in *V. paradoxa* in natural formations [27]. In the current context of decreasing rainfall and the affinity of *S. latifolius* and *C. adansonii* for humid biotopes place them in a vulnerable position. The results showed greater woody diversity in the stands of the two species outside Bontioli, compared with those outside Koulbi. This can be explained by the fact that human settlement and the processes of anthropisation of environments are more significant around Bontioli than around Koulbi.

Conclusion

The results showed that protected areas play a positive role in maintaining a stable population structure for *S. latifolius* compared with *C. adansonii. C. adansonii* is in danger of becoming a threatened species in its natural habitat. Given that local populations, through the exploitation of species, influence the structure and dynamics of their populations, they must also be involved in actions to preserve these plants. The guiding principles of these actions should be the rational use of plants, the protection of habitats and the planting of species in high demand. The Bontioli Reserves and the Koulbi Classified Forest also deserve better protection.

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Conflict of interest: The authors declare no conflicts of interest.

References

1. Nikiema A, Ouédraogo SJ, Boussim J. Situation des ressources génétiques forestières du Burkina Faso. In: Atelier sous-régional FAO/IPGRI/ICRAF sur la conservation, la gestion, l'utilisation durable et la mise en valeur des ressources génétiques forestières de la zone sahélienne, Ouagadougou (2001).
2. Sangli G, Ouattara B, Ouedraogo M, et al. Des pratiques agricoles aux activités minières. Revue de Géographie de l'Université de Ouagadougou 2(11) (2022): 45-62.
3. Attoh AQM, Ahama KYS. Multiplication generative de *Crataeva adansonii* DC. Journal de la Recherche Scientifique de l'Université de Lomé 20 (2018): 103-116.
4. Dimobe K, Ouédraogo K, Annighöfer P, et al. Climate change aggravates anthropogenic threats of the endangered savanna tree Pterocarpus erinaceus (Fabaceae) in Burkina Faso. J Nat Conserv 70 (2022).
5. Tabuti JRS, Lye KA, Dhillion SS. Traditional herbal drugs of Bulamogi, Uganda: plants, use and administration. Journal of Ethnopharmacology 88 (2003): 19-44.
6. Thiombiano A, Schmidt M, Da S, et al. Vascular plants: flowering plants. In: Thiombiano A, Kampmann D, eds. Biodiversity atlas of West Africa. Volume II, Ouagadougou and Frankfurt/main, Burkina Faso and Germany (2010): 184-192.
7. Tyagi P, Sharma PK, Kothari SL. Micropropagation of *Crataeva adansonii* DC Prodr: an ornamental avenue tree. Protocols for In Vitro Propagation of Ornamental Plants (2010): 39-46.
8. Arbonier M. Arbres, arbustes et lianes d'Afrique de l'Ouest. 4th ed. Montpelier, France; Edition Quae (2019).
9. Kaboré SA, Hien M, Ouédraogo D, et al. Use of ecosystem services and induced effect of human pressure on the species in the Southwestern Region of Burkina Faso. Ethnobotany Research and Applications 12 (2014): 561-570.
10. Sahoo S, Davidar P. Effect of harvesting pressure on plant diversity and vegetation structure of Sal forests of Similipal Tiger Reserve, Odisha. Trop Ecol 54 (2013): 97-107.
11. Sharma PK, Tyagi P, Sharma KC, et al. Clonal micropropagation of *Crataeva adansonii* (DC.): a multipurpose tree. In Vitro Cellular & Developmental Biology-Plant 39 (2003): 156-160.
12. Cunningham AB. Applied ethnobotany, people, wild plant use and conservation. London, United Kingdom; Earthscan Publications (2001).
13. Nacoulma BMI, Traoré S, Hahn K, et al. Impact of land use types on population structure and extent of bark and foliage harvest of *Afzelia africana* and *Pterocarpus erinaceus* in Eastern Burkina Faso. Int J Biodivers Conserv 3 (2011): 62-72.
14. Ouédraogo O. Phytosociologie, dynamique et productivité de la végétation du parc national d'Arly. (Sud-Est du Burkina Faso). PhD Thesis: University of Ouagadougou, Burkina Faso (2009).
15. Jaccard P. Distribution de la flore alpine dans le bassin des Dranes et dans quelques régions voisines. Bull Soc Vaudoise Sci Nat 37 (1901): 241-272.
16. Niwattanakul S, Singthongchai J, Naenudorn E, et al. Using of Jaccard coefficient for keywords similarity. In: Editors: Ao SI, Castillo O, Douglas C, Feng DD, Lee J-A eds. Proceedings of the International MultiConference of Engineers and Computer Scientists Vol I, Hong Kong, China (2013): 380-384.
17. Kebenzikato AB, Wala K, Dourma M, et al. Distribution et structure des parcs à Adansonia digitata L. (baobab) au Togo (Afrique de l'Ouest). Afrique Science 10 (2014): 434-449.
18. Rondeux J. La mesure des arbres et des peuplements forestiers. Gembloux, Belgique; Presses agronomiques de Gembloux (2021).
19. SAS Institute Inc. JMP 9 Discovering JMP. Cary, NC, USA, SAS Institute (2010).
20. Ouédraogo A, Glèlè Kakaï R, Thiombiano A. Population structure of the widespread species, *Anogeissus leiocarpa* (DC.) Guill. & Perr. across the climatic gradient in West Africa semi-arid area. S Afr J Bot 88 (2013): 286-295.
21. Gebauer J, El-Siddig K, Ebert G. Baobab (Adansonia digitata L.): a review on a multipurpose tree with promising future in the Sudan. Gartenbauwissenschaft 67 (2002): 155-160,
22. Traoré L, Sop TK, Dayamba SD, et al. Do protected areas really work to conserve species? A case study of three vulnerable woody species in the Sudanian zone of Burkina Faso. Environ Dev Sustain 15 (2012): 663-686.
23. Sambaré O, Bognounou F, Wittig R, et al. Woody species composition, diversity and structure of riparian forests of four watercourses types in Burkina Faso. J Forestry Res 22 (2011): 145-158.
24. Sharma N, Kant S. Vegetation structure, floristic composition and species diversity of woody plant communities in sub-tropical Kandi Siwaliks of Jammu,

J & K, India. International Journal of Basic and Applied Sciences 3 (2014): 382-391.

25. Stangeland T, Tabuti JRS, Lye KA. The influence of light and temperature on the germination of two Ugandan medicinal trees. Afr J Ecol 46 (2007): 565-571.

26. Tabuti JRS. The uses, local perceptions and ecological status of 16 woody species of Gadumire Sub-County, Uganda. Biodivers Conserv 16 (2007): 1901-1915.

27. Lamien N, Tigabu M, Guinko S, et al. Variations in dendrometric and fruiting characters of Vitellaria paradoxa populations and multivariate models for estimation of fruit yield. Agroforest. Syst 69 (2007): 1-11.