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Research Article

Structural Characterisation of the *Afzelia africana Smith ex persoon* Stand in the Benoué National Park, North Cameroon

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Abstract

Assessing and monitoring forest species is essential for implementing effective conservation strategies that support biodiversity. This study investigates the structure and growth dynamics of the *Afzelia africana* (*A. africana*) stand along the periphery of Benoué National Park (BNP) in northern Cameroon. A forest inventory was carried out at 4 sites located at the four cardinal points of the Bénoué National Park (PNB). Twelve 3000 m x 50 m transects were used, with three transects per study site. Data were collected on density, height, diameter at breast height (Dhp), crown diameter, and biological and vegetative types. To compare *A. africana* populations between sites, an analysis of variance (ANOVA) was used. Results indicate that wood density is higher in the northern (120 ind. /ha) and southern (90 ind. /ha) peripheries compared to the eastern (54 ind. /ha) and western (28 ind. /ha) peripheries. The distributions of trunk and crown diameters, as well as height, exhibit a bell-shaped pattern, indicating a dominance of middle-class individuals and a scarcity of both regenerating and mature individuals. This distribution suggests that the *A. africana* stand is under pressure, particularly in the eastern and western peripheries of the BNP. Human activities such as gold panning, charcoal production, and branch pruning, which are most pronounced in the eastern periphery, as well as agriculture and urbanization in the western periphery are contributing to plant instability and the decline of key socio-economic species like *A. africana*, which is also facing threats of extinction. Raising awareness among local communities and stakeholders could significantly enhance the conservation efforts for this species, particularly by focusing on the protection of juvenile plants and the most disturbed areas.

Keywords

A. africana, Ecological Characterization, Sustainable Conservation, BNP, Northern Cameroon

1. Introduction

Tropical ecosystems, particularly African savannas, play a significant socio-economic role for local communities by providing vital natural resources. However, these ecosystems are currently facing severe degradation [1-3]. This degradation, which also affects associated protected areas, is occurring at an alarming rate, raising concerns among scientists and development stakeholders [4, 5]. Protected areas are primarily established to conserve biodiversity and maintain ecosystem

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services [6]. Nonetheless, the classification and protection levels of various protected areas in Africa remain inadequate for ensuring their long-term viability [7]. The existence of these areas often leads to significant changes in resource access for nearby communities [6].

The main drivers of these changes are human activities, including agriculture, illegal logging, and poorly managed animal husbandry practices [8, 9]. These activities are largely driven by population growth [10] and ineffective governance policies. Bénoué National Park (BNP), as a designated protected area, aims to preserve biodiversity while meeting local needs. However, it is currently facing increasing threats despite efforts from public authorities to protect it [11]. Resource management in and around the BNP often falls short of guaranteeing the park's long-term survival [12].

The BNP is experiencing widespread decline due to factors such as transhumance, overexploitation of forest resources, and rising urban demand for wood [13]. Additionally, climate change has exacerbated the situation, with declining rainfall and increasing temperatures since the 1960s. The degradation of the park can thus be attributed to socio-economic, political, and climatic factors, particularly chronic poverty and unemployment, alongside inadequate infrastructure. Illegal activities are on the rise and pose a significant threat to the park's biodiversity, impacting both animal and plant species, including socio-economically important species like *A. africana* [14].

A. africana is a vital species utilized for various purposes, including firewood, timber, medicine, and fodder [15, 16]. This has led to clandestine intrusions by local communities and transhumant herders into the BNP. The risk of extinction is already evident in the declining number of young plants in the region [16]. Given the pressing ecological challenges faced by *A. africana* stands in and around the BNP, there is an urgent need for a comprehensive action plan aimed at protecting and preserving this species, enabling it to fulfill its many roles for local populations.

Effective forest management requires a thorough understanding of forest stand conditions, utilizing structural analysis methods that assess species distribution and dendrometric characteristics such as individual volume, trunk diameter, and height [17-19]. This is equally applicable to individual species within any forest ecosystem, highlighting the relevance of this study. Limited research has focused on the threats to *A. africana* populations in the BNP's peripheral areas, with notable exceptions [16] on the current state of *A. africana* populations and pastoral practices in North Cameroon and [20] on the impact of human activities on *A. africana* populations in the region. The aim of this study is to examine the structure and growth dynamics of *A. africana* stands on the outskirts of the BNP, enabling a better understanding of their distribution and assessing their state of degradation to inform management strategies.

2. Methodology

2.1. Study Site

The study sites are located on the outskirts of the Bénoué National Park (BNP), which is 132 km from the town of Garoua, the capital of the Bénoué department (Figure 1). It lies between latitudes 7 °55' and 8 °55' North and longitudes 13 °34' and 14 °01' East. With a surface area of 180,000 ha, it is bounded to the north by the Mayo Ladé and Mayo Laindelaol rivers, to the south by the Mayo Dzoro river, to east by the Bénoué river and the west by National Road No. 1, from the bridge over Mayo Dzoro to Banda, along the old Ngaoundéré-Garoua road from Banda to ex-Djaba, along National Road No. 1 from ex-Djaba to the bridge over the Mayo-Sala and along the Mayo-Sala to its confluence with the Mayo-Ladé. The relief of the BNP comprises a system rocky massifs known as the "hossérés" mountains range in altitude from 220 m to over 700 m, separated by plains of varying size, found mainly in the northern part of the BNP [21]. The climate is Sudanian, with two sharply contrasting seasons: a rainy season from May to October and a dry season for the rest of the year. The average annual rainfall is 1500 mm/year, and the average annual temperature is 22 °C, decreasing from south to north. The vegetation is characterised by wooded/wooded savannahs or grassy savannahs [22]. The soil is ferruginous and hydromorphic at the bottom of the slope. The riparian population is estimated at more than 5,000 inhabitants living in 12 villages, with different ethnic groups predominantly Dii, originally from the hills, who have lived in the region for between 40 and 60 years [21]. The main activities around the BNP are agriculture, trade, livestock farming, fishing and gold panning.

Because of the activities of local people around the park, four study sites were selected on the periphery of the BNP: on the northern edge near Mayo Sala, to the south near Ngaouyanga, to the east at Ouro Mbao and finally on the western edge near Sakdje. These sites differ in terms of their biophysical characteristics and the human activities that take place there. The northern and southern peripheries are dominated respectively by wooded savannah and wooded savannah. Population density is low and logging is also low because of the eco- guards' patrols. On the other hand, to east and west of BNP, the population density is high there gallery forests and fallow land respectively. In the east, activities such as gold panning, poaching and cutting wood for charcoal are commonplace, unlike in the west, where there is significant agricultural activity and extensive urbanisation near BNP.

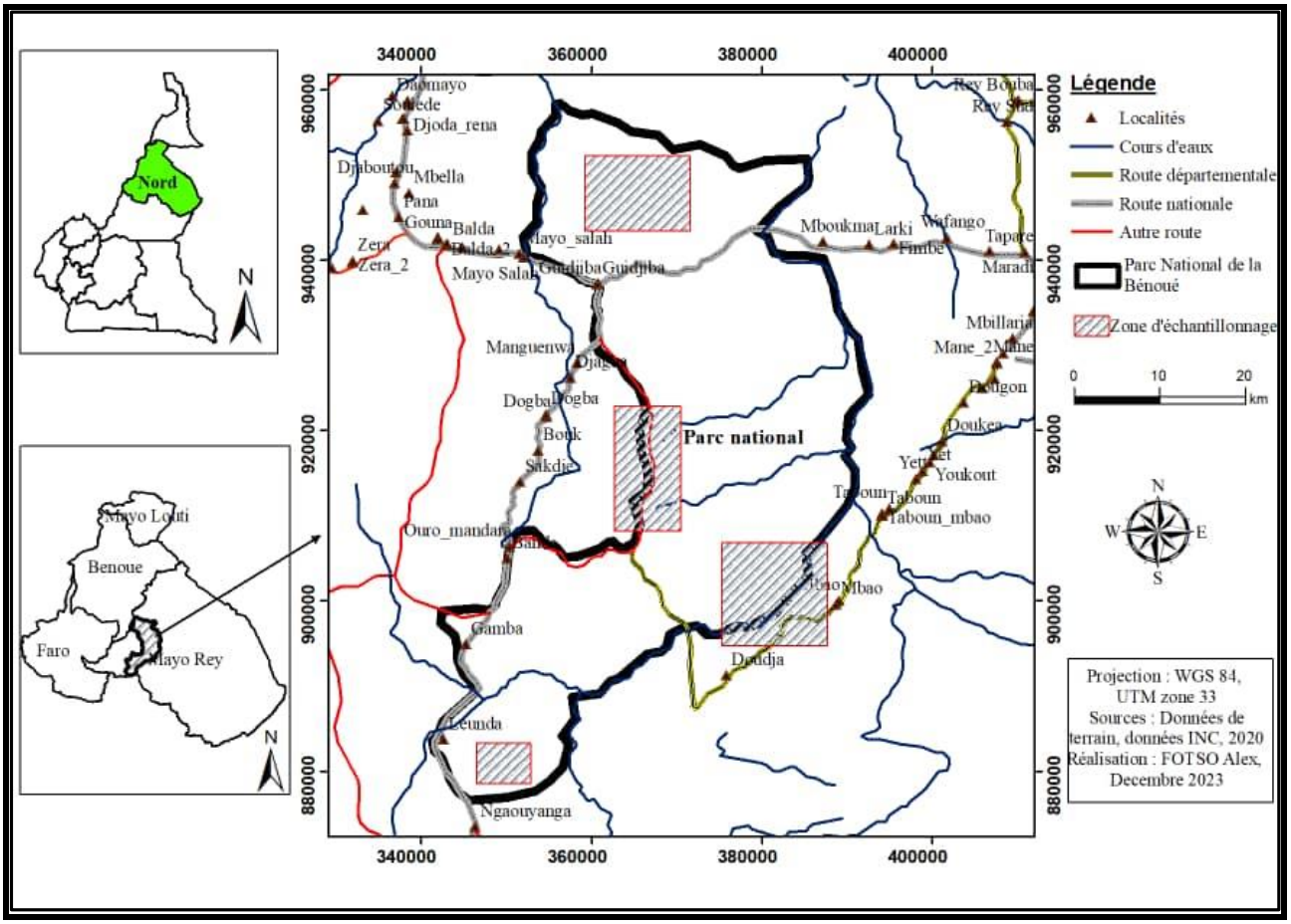


Figure 1. *Map of the study area.*

2.2. Data Collection Method

The floristic inventory was conducted using the transect method, based on modified approaches by [23, 24] Due to the scarcity of *A. africana* plants, the transects were adjusted to 3000 meters in length and 50 meters in width to effectively assess the distribution of this species. A total of 12 transects, three for each of the four study sites (representing cardinal points), were randomly established to capture the diversity and ecology of *A. africana*. The experimental design employed a randomized block layout with three replications, with each study site representing a treatment and the number of plots serving as replications.

During the floristic inventory, the height of shrubs, including *A. africana*, was measured using a graduated pole, while larger trees were measured with a Blume-Leiss device. The circumference at breast height was recorded with a tape measure and converted to diameter at breast height using the formula$D = C/\pi$, where D is the diameter, C is the circumference, and π is approximately 3.14. The crown diameter of each tree was estimated using a decameter by averaging two perpendicular measurements: the larger, measured along the north-south axis, and the smaller, along the east-west axis, according to the formula $DH = (d1 + d2)/2$, where DH is the crown diameter, d1 is the larger diameter, and d2 is the smaller diameter. Density was calculated with the formula D=NS, where N is the number of species in the study area and S is the total sampled area for each site, totaling 45 hectares (3000 m x 50 m x 3). Most woody species accompanying *A. africana* were identified and recorded directly in the field using local or scientific names. Specimens of unidentified species were collected and compared with existing floras [25].

2.3. Ecological Characterization

To assess the ecological characteristics of the companion species of *A. africana*, a phytogeographical analysis was conducted. This involved grouping species based on biological types, modes of diasporic dissemination, and geographical distribution. Based on past research [26], Biological types were classified and adapted for tropical species [27]. All species studied were identified as phanerophytes, characterized by dormant aerial buds located more than 50 cm above the soil surface. The determination of types and modes of diasporic dissemination followed the methodologies of [28] and the classifications proposed by [29], Schnell [27] and Mandango [30]. Phytogeographical distribution types were established based on the major chorological subdivisions recognized for Africa by [31].

2.4. Statistical Analysis

All collected data were entered into Excel 2013, allowing for the generation of graphs to effectively describe vegetation characteristics and determine floristic indices. An analysis of variance (ANOVA) was employed to compare the parameters of *A. africana* stands across different sites. Statistical analyses were conducted using XLSTAT and SPSS.

3. Results

3.1. Stand Density of *A. africana*

The density of *A. africana* stands varies significantly across the study sites (Figure 2). The highest density was observed in the northern region, with 120 individuals per hectare (ind./ha), consisting of 9 ind./ha for *A. africana* and 111 ind./ha for other ligneous species. In contrast, the lowest density is recorded in the southern region, with 28 ind./ha, including 3 ind./ha for *A. africana* and 25 ind./ha for other woody species.

The eastern (54 ind./ha) and western (28 ind./ha) peripheries exhibit lower total stand densities compared to the northern (120 ind./ha) and southern (90 ind./ha) peripheries. This trend is consistent for both *A. africana* and its accompanying woody species.

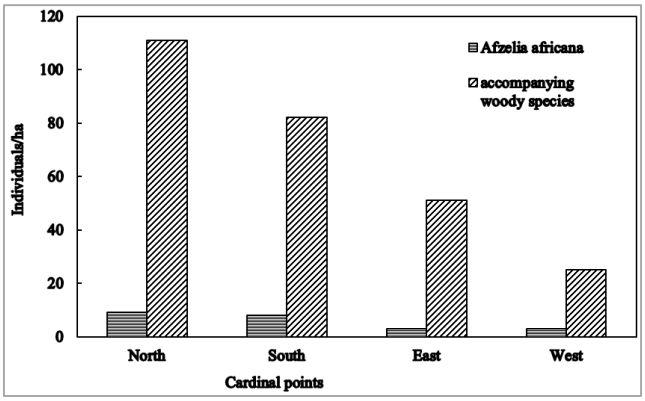


Figure 2. *Density of A. africana stands across cardinal points.*

3.2. Demographic Structure of the *A. africana* Population

3.2.1. Diameter Structure

The distribution of the diameter classes at breast height for all tree species in shown as Figure 3 while, diameter classes for *A. africana* is shown on figure 4. Overall, these distributions exhibit a bell-shaped curve, both for the entire vegetation in the BNP (Figure 3) and for *A. africana* across the four study sites (Figure 4). Based on the distribution of diameter classes for *A. africana*, two distinct groups of sites can be identified.

The site to the east of the park is similar to the one to the west in that both are representative of almost all *A. africana* diameter classes but contain relatively few individuals. The western site has a maximum of 13 individuals in the 40-50 cm class, while the eastern site peaks at 13 individuals in the 60-70 cm class. On the other hand, the site to the north shares similarities with the southern site in terms of a high number of individuals: 48 individuals in the 30-40 cm class in the north and 66 individuals in the same class in the south. Although both the northern and southern sites have a higher number of *A. africana* individuals, they differ in the representativeness of diameter classes. At the southern site, no individuals were found in the first five diameter classes 10-60 cm, while at the northern site, only the 10-20 cm class was absent.

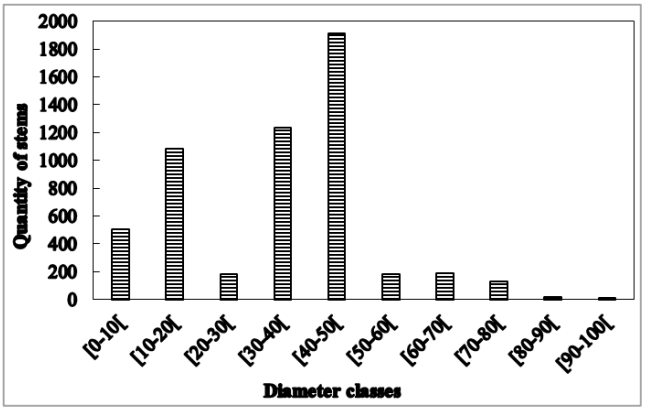


Figure 3. *Distribution of diameter classes of vegetation in the PNB.*

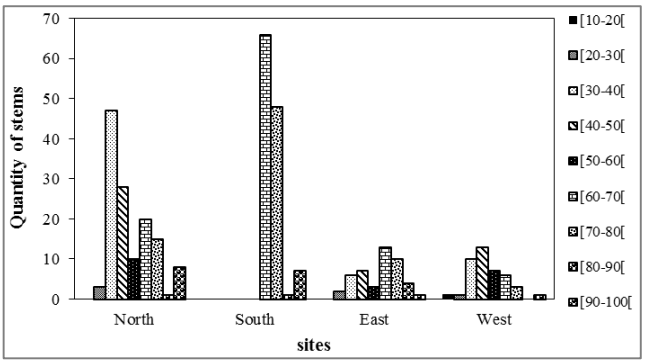


Figure 4. *Distribution of A. africana diameter classes according to study sites.*

3.2.2. Structure of Crown Diameter Classes

Figure 5 illustrates the distribution of *A. africana* crown diameter classes for the entire BNP (A) and by site (B), respectively. In general, these distributions are bell-shaped, with medium-diameter individuals (4–8 m) being the most numerous, while small-diameter (0–2 m) and large-diameter individuals (8–14 m) are less abundant (Figure 5).

The shape of the crown diameter distribution varies across sites (Figure 5B). Sites located to the north and west of the

park exhibit bell-shaped distributions, with few small- and large-diameter trees, and in the case of the western site, an absence of both small- and large-diameter individuals. On the other hand, sites to the south and east of the park display inverted J-shaped distributions, characterized by many small-diameter trees and fewer large-diameter trees, with the eastern site lacking large-diameter trees entirely.

It is also noteworthy that the sites to the north and south of the park are characterized by the presence of all crown diameter classes, from small-diameter to large-diameter trees, while sites to the east and west are distinguished by the absence of medium- and large-diameter trees.

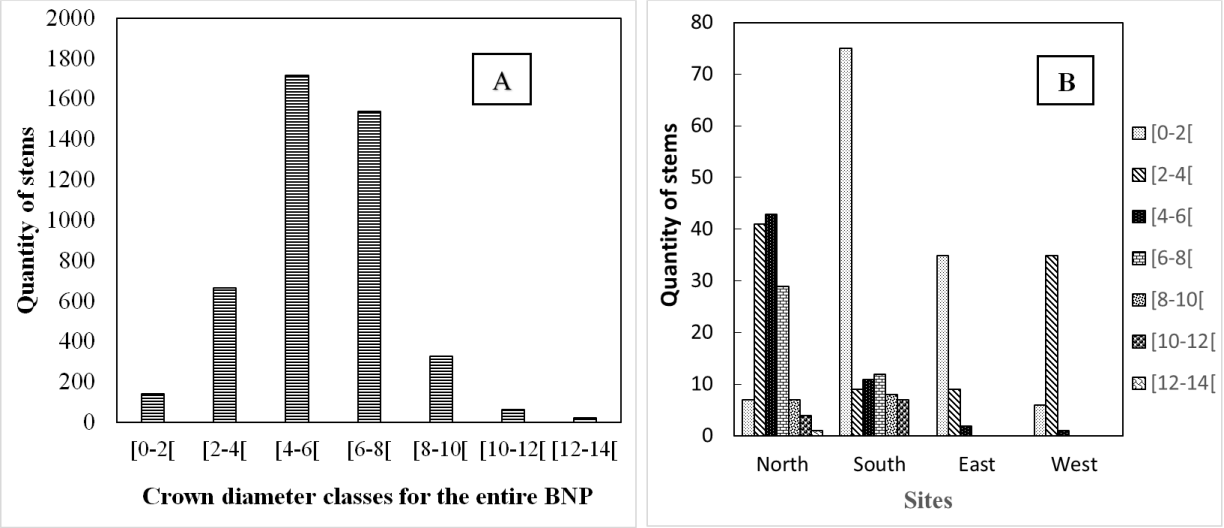


Figure 5. *Distribution of crown diameter classes for PNB vegetation (A) and by study site (B).*

3.2.3. Height Structure

The distribution of height classes of woody vegetation in the BNP (A) and that of the *A. africana* (B) in the four study sites are illustrated in Figure 6. The distribution of height classes of woody vegetation in the BNP (Figure 6A) is generally bell-shaped, with the majority of individuals concentrated in the middle class between 5 and 10 m.

The number of individuals in the small and large height classes of woody vegetation is low wiith the exception of the site located to the west of the BNP, the distribution of the height classes of *A. africana* in the three sites is bell-shaped, with a dominance of the middle classes located between 5 and 10 m for the site located to the north of the BNP and between 10 and 15 for the sites located the south and east of the BNP. To the west, on the other hand, the height class distribution of *A. africana* is inverted J, with the majority of individuals being small. This site also differs of the other study sites by the absence of tall individuals (Figure 6B).

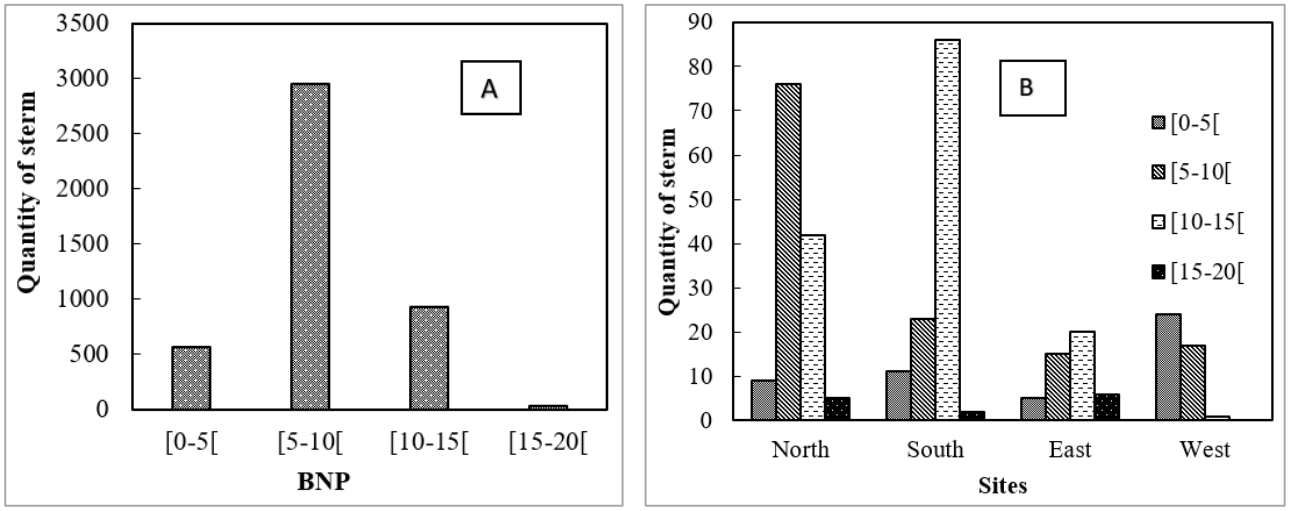


Figure 6. *Height class distributions of woody vegetation in the BNP (A) and of A. africana according to cardinal points (B).*

3.2.4. Correlation Between Dendrometric Parameters of *A. africana* at Different Sites in the BNP Study

The correlations between the three dendrometric parameters of A. africana vary across the study sites in the BNP (Table 1). To the north of the BNP, all three dendrometric parameters show positive and significant correlations ($P < 0.05$), with some correlations being highly significant ($P < 0.01$). In the eastern part of the park, DBH is correlated with both height and crown diameter, with Pearson correlation coefficients of 0.238 and 0.360, respectively. For the entire BNP, DBH is positively and significantly correlated with height (r = 0.534), and height is also positively and significantly correlated with crown diameter (r = 0.175).

In contrast, to the south and west of the BNP, only DBH is significantly correlated with height, with Pearson correlation coefficients of 0.484 and 0.435, respectively.

Table 1. *Pearson correlation coefficients (r) between DBH, height, and crown diameter of A. africana at the BNP study sites.*

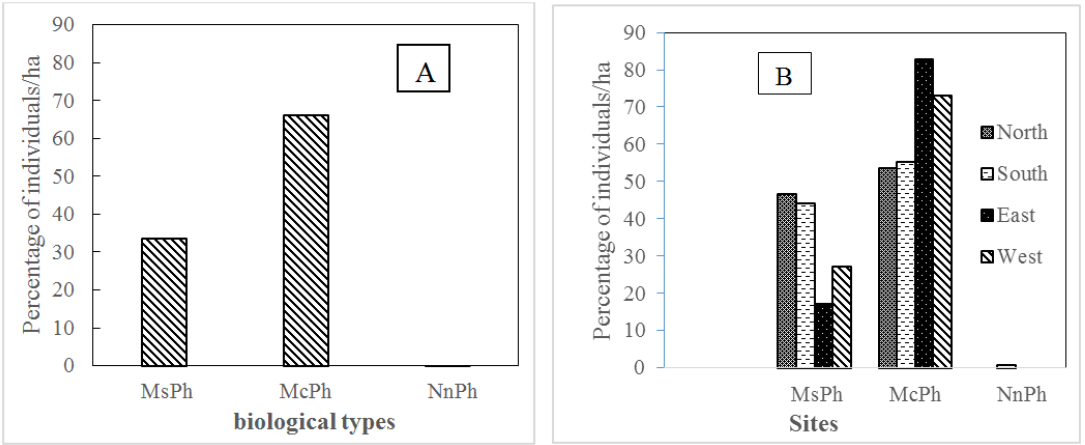
Sites	Parameters	DBHp	Height	crown-diameter
	DBH	1		
North	Height	0.560**	1	
	Tree crown	0.174*	0.466*	1
	DBH	1		
South	Height	0.484*	1	
	Tree crown	0.062 ns	0.026ns	1
	DBH	1		
East	Height	0.238*	1	
	Tree crown	0.360*	0.125ns	1
	DBH	1		
West	Height	0.435**	1	
	Tree crown	-0.026 ns	0.074 ns	1
	DBH	1		
BNP	Height	0.534**	1	
	Tree crown	0.007ns	0.175*	1

3.3. Biological and Phytogeographical Characteristics of Sites in the BNP

3.3.1. Biological Types of Woody Plants

In this study, three biological types of woody plants were identified: Micro-Phanerophytes, Meso-Phanerophytes, and Nano-Phanerophytes (Figure 7). A quantitative analysis of these biological types in BNP reveals the dominance of micro-phanerophytes, which make up more than half of the BNP flora (66.11%), while nano-phanerophytes are virtually absent, comprising only 0.16% of the flora (Figure 7A). Meso-Phanerophytes occupy an intermediate position, accounting for 33.73%.

The spectra of biological types of woody vegetation across the four sites are similar, although they differ in numerical significance (Figure 7B). Micro-Phanerophytes dominate the woody vegetation at all four sites, with 82.71% of the flora in the east, 72.93% in the west, 55.35% in the south, and 53.45% in the north. Meso-Phanerophytes (MsPh), which range in height from 10 to 30 meters above ground level, occupy second place, representing 46.55% of the vegetation in the north, 44.02% in the south, 27.07% in the west, and 17.29% in the east of the BNP. Nano-Phanerophytes (Nn-Ph), are only found in the south of the BNP (0.63%) and are absent from the other sites.



Ms-Ph= Mésophanérophytes; Mc-Ph= Microphanérophytes; Nn-Ph=Nanophanérophytes.

Figure 7. *Biological spectrum of woody species in the BNP (A) and in the study sites (B).*

3.3.2. Phytogeographical Types

The phytochory of woody species enabled the identification of ten distribution types, which were categorized into three main groups: species with a distribution limited to the African continent (53.85%), basic species (39.02%), and species with a wide distribution, though poorly represented (7.12%) in the BNP flora (Table 2).

Sudanian species (S), which are widely distributed in the Sudanian regional center of endemism, are the most numerous, comprising 39.02% of the BNP flora. Next, the Sudano-Zambézian (SZ) species, found in both the Sudanian and Zambézian regional centers of endemism, account for 35.61% of the flora. Species from other distribution types are either poorly or very poorly represented in the BNP flora, with percentages ranging from 0.59% for African multi-regional species (PRA) to 8.20% for Afro-tropical species (AT).

Table 2. *Phytogeographical Distribution Types of the Woody Flora in the BNP.*

	Phyto-geographical types	Number of species	Percentages (%)
ELD	PAN	27	2.63
	PAL	7	0.68
	AA	39	3.80
	Total	73	7.12
EDLA	AT	84	8.20
	PA	39	3.80
	SZ	365	35.61
	GC	43	4.20
	PRA	6	0.59
	SG	15	1.46
	Total	552	53.85
EB	S	400	39.02
	Total	400	39.02

ELD: species with a wide distribution; EDLA: species with a distribution limited to the African continent; EB: basic species. Afro-American (AA), Afro-tropical (AT), Palaeo-tropical (PAL), Pantropical (PAN), African multi-regional (PRA), Sudanian (S), Sudano-Guinean (SG), Sudano-Zambézian (SZ), Guineo-Congolese (GC), multi-regional (PA).

The distribution of phytogeographical types varies across the study sites (Figure 8). The woody vegetation at all four study sites is predominantly dominated by Sudanian (S) and Sudano-Zambian (SZ) species, with contribution values reaching 47.52% in the north for Sudanian species and 44.27% in the west for Sudano-Zambian species. Species from other distribution types are either only marginally present across the study sites or completely absent, such as Palaeo-tropical (PAL) species, which are absent at the northern site, and Plurire-gional African (PRA) species, which are absent at the eastern and western sites of the BNP. The high proportion of species with a distribution limited to the African continent (EDLA) suggests a certain degree of stability in the study area.

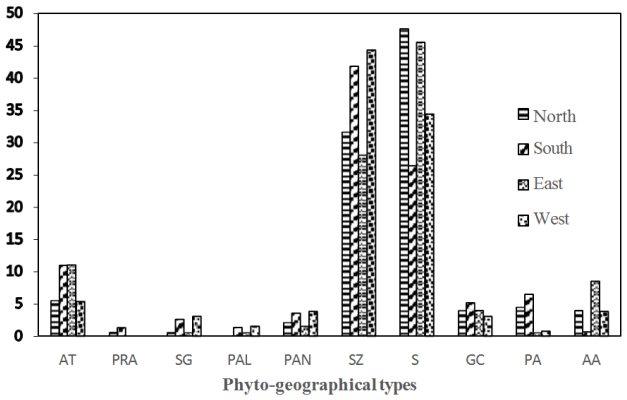


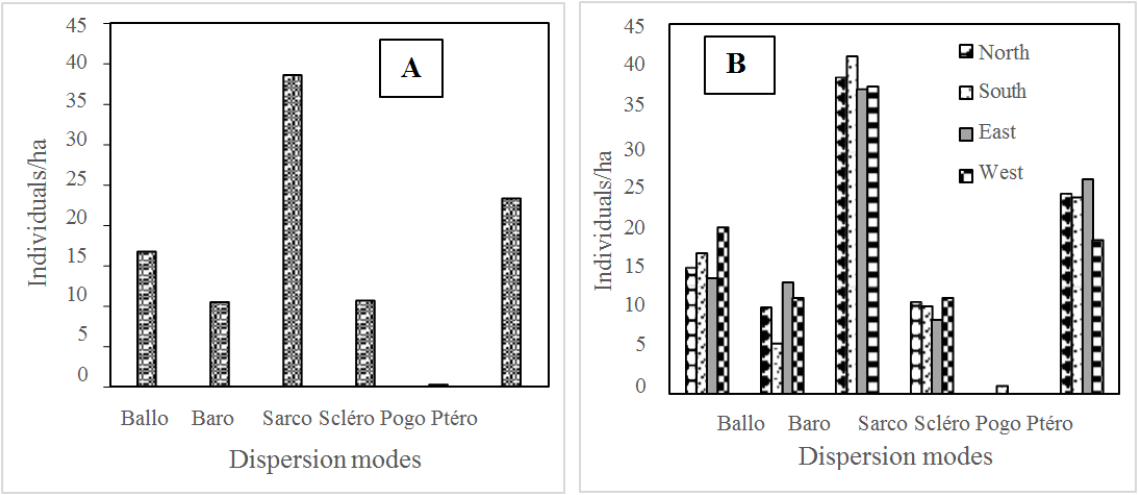
Figure 8. *Phytogeographical Type Spectrum by Cardinal Directions.*

Afro-American (AA), Afro-tropical (AT), Paleo-tropical (PAL), Pantropical (PAN), African multi-regional (PRA), Sahelian (S), Sudano-Guinean (SG), Sudano-Zambézian (SZ), Guineo-Congolese (GC) and multi-regional (PA).

3.3.3. Distribution of Diaspore Types

Across the BNP, woody vegetation is dispersed by various types of diaspores, with the Sarcochore type being the most predominant, followed by the Pterochore type, contributing 38.58% and 23.31% of the total species, respectively (Figure 9A). The Pogonochore type is very poorly represented, accounting for only 0.24% of the flora. Other diaspore types are moderately represented, with contributions ranging from 10.48% to 16.72%.

At the study sites, the distribution of diaspore types mirrors the overall trend observed throughout the park, with the Sarcochore type dominating numerically at all four sites (37.18% in the east and 41.10% in the south). The Pogonochore type is virtually absent, except at the southern site (0.97%) (Figure 9B). The remaining diaspore types are moderately represented at each of the four study sites.



Ballochore (Ballo), Barochores (Baro), Sarcochores (Sarco), Sclerorochore (Scléro), Pogonochore (Pogo), Ptérochore (Ptéro).

Figure 9. *Distribution of Diaspore Types Across the BNP (A) and Study Sites (B).*

4. Discussion

Human pressure around the BNP varies by site, and these differences are reflected in the similarity between the northern and southern sites, in contrast to the eastern and western sites. These differences can be attributed to the density and distribution of diameters and heights of woody plants, including *A. africana*. Densities of woody species are higher in the northern and southern sites compared to the eastern and western sites, for *A. africana* stands. Similarly, the number of individuals in the dominant diameter classes is higher at the northern and southern sites compared to the eastern and western sites.

The structural analysis of *A. africana* woody stands was conducted through floristic inventories at four sites surrounding the Benou é National Park (BNP) to assess the status of this stand and inform strategies for its sustainable conservation. Overall, the results concerning the structural traits, biological types, and species distribution patterns reflect a stand under anthropogenic pressures, consistent with Sudano-Sahelian ecological conditions [32-37].

The disturbance factors, evident in the bell-shaped structure of *A. africana* stands around the BNP, are reflected in the dominance of individuals with intermediate diameters and heights and the low representation of both young (0–10 cm) and old (60–100 cm) individuals, with the absence of very large individuals (≥ 80 cm). This distribution pattern [33-36], indicates an unstable stand structure. [16], in another study on *A. africana* and Pterocarpus erinaceus stand structures in agroforests in eastern Burkina Faso, observed a similar trend, which was also linked to instability [39]. This instability in *A. africana* stands is primarily driven by human activities, such as land clearing for agriculture, harvesting of fodder and medicinal products, urbanization, and bushfires. Consequently, the absence of effective protective measures threatens the survival of these stands on the outskirts of the BNP.

The low number of young shoots and large individuals can be attributed to pressures from herbivores and humans, as reported in other studies. For example, the study of *A. africana* seed fate in a wooded savannah in Burkina Faso [16], showed that bushfires and seed predators (such as large birds and rodents) are the main factors responsible for the unavailability of seeds during the optimal germination period. Furthermore, a study on the population status of *A. africana* in northern Cameroon, highlighted the trapping of seeds by herbivores as another limiting factor for the regeneration of this species in that region [16].

At all four study sites, the biological spectra are dominated by micro-phanerophytes, with rates ranging from. This dominance can be explained by the geographical location of the BNP within the Sudan-Sahelian zone, which is characterized by the predominance of shrub-like vegetation. These findings align with those of [40], who also observed a dominance of micro-phanerophytes, followed by nano-phanerophytes, and meso-phanerophytes in Massenya, Chad. According to Thiombiano [41] and [42], the prevalence of micro-phanerophytes suggests the dominance of shrub or low forest formations in such environments.

The differences between the northern-southern and eastern-western sites can largely be explained by the type of plant formation, the sites' proximity to the park, the density of riparian populations, and the intensity and type of anthropogenic pressures. The northern and southern sites are characterized by savannah vegetation and low riparian population density. Anthropogenic pressures here are relatively low, aided by the presence of patrol teams that discourage unauthorized entry by local populations and livestock. This helps limit or significantly reduce human pressure on these areas.

In contrast, the eastern and western peripheries are closer to the BNP and are characterized by gallery forests and fallow lands, respectively. These sites are marked by higher local

population densities, and patrol teams are rarely present due to the inaccessibility of their vehicles. This situation has led to intensified human activities, such as gold panning, poaching, charcoal production, and the pruning of *A. africana* branches for fodder in the east of the BNP, as well as urbanization and agriculture to the west. Anthropogenic pressures on natural resources, especially on socio-economically important species like *A. africana*, are much more intense at the eastern and western peripheries than at the northern and southern ones. [42] demonstrated that *A. africana* is under significant pressure for fodder production in many countries, including Mali, Burkina Faso, Nigeria, and Cameroon [43, 44]. In fact, it is considered an endangered species in several regions, particularly in Benin, where it is becoming increasingly rare [45, 46].

Additionally, the high proportion of species with a distribution restricted to the African continent (EDLA) at the study sites further indicates the instability of the vegetation in this area. Tchobsala [38] noted that a high proportion of species limited to Africa is a sign of disturbance and the loss of vegetation specificity. Similar observation was made when same phytogeographical zone was studied concluding that the BNP area is experiencing biodiversity instability, likely due to human activity and overgrazing.

5. Conclusion

The structural characterization of *A. africana* stands around the BNP in northern Cameroon revealed that the species' density is notably lower compared to other species in the surrounding vegetation. However, its density is higher in the northern and southern peripheries than in the eastern and western peripheries. The diameter distribution, both overall and at the various study sites, follows a bell-shaped curve, with very few individuals having small diameters or large diameters. The populations of *A. africana* are in sharp decline, primarily due to their limited regeneration potential and low seedling survival rates.

Raising awareness about the conservation of the remaining populations is crucial for their protection, sustainable management, and the potential restoration of new populations. Furthermore, in-depth studies on both sexual regeneration and vegetative propagation are essential for developing effective strategies for the long-term conservation and eventual domestication of *A. africana*.

Abbreviations

A.africana	*Afzelia africana*
BPN	Benoue National Park
DBH	Diameter at Chest Height
Ind	Individual
ha	Hectare

Author Contributions

Koudtou Njanga Jean Calvin: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing

Tchobsala: Methodology, Resources, Supervision, Validation

Ibrahima Adamou: Formal Analysis, Methodology, Resources, Supervision, Validation

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Field

Koudtou Njanga Jean Calvin: Plant Ecology, Agroforestry, Plant Biology, Sustainable Development, Conservation vegetable, Carbon Credit Estimation

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