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Effects of Ecological Factors on Population Status and Morphological Traits of *Faidherbia albida* (Del.) A. Chev. in Burkina Faso

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Abstract: *Faidherbia albida* (Del.) A. Chev. is a key agroforestry parklands species providing provisioning and regulating ecosystem services to people. Therefore, sustainable management and conservation of the species populations are great challenges on its distribution area. However, the species response to spatial variability of ecological conditions is poorly addressed, limiting its management and conservation. The objectives of this study were to: (i) assess the population status of *F. albida* along climate gradient in Burkina Faso and (ii) determine the effects of biotic and abiotic variables on population status and morphological traits of the species. Data were collected in 99 plots equally distributed in three climatic zones by focusing on biotic data in the plots (tree diversity and density, morphological traits of *F. albida* and all adult trees) and abiotic data (climate variables and elevation). The results showed that tree density and morphological traits of *F. albida* are significantly influenced ($P<0.05$) by climate zone. Tree density of the species increased from Sahelian to Sudanian zone while specific zone effects were observed for its morphological traits (tree diameter and height). Irrespective to climate zone, linear regressions based on diameter class distribution indicated that populations of *F. albida* are in degraded status exhibited by the dominance of largest trees. Tree diversity using Shannon index was negatively and significantly correlated to tree density of *F. albida* while opposite correlation was observed with tree height of the species. Specific and significant correlations were observed between abiotic variables considered in the study and morphological traits of *F. albida*. This study highlighted the instability of the population structure of *F. albida* and specific effects of biotic and abiotic variables on the species density and morphological traits. The results of this study could direct the management and conservation policies to ensure its sustainable use.

Keywords: Biotic and Abiotic Variables, Agroforestry Parkland, Population Structure, Climatic Zones

1. Introduction

Agroforestry parkland is a rational land use system developed by farmers during several generations. It is a sustainable land management system that increases production, combining agricultural crops, forest plants and/or animals simultaneously or in sequence [1]. Thus, woody species deliberately maintained in these farms allow people to have a diversity of use which includes food, fuelwood medicine and cultural practices [2]. In addition, agroforestry species contribute to microclimate regulation by combating water and wind erosion of soils and improving soil fertility for annual crops [3]. Agroforestry parkland represents a large part of agricultural landscapes in Burkina Faso with common species represented by *Faidherbia albida* (Delile) A. Chev., *Vitellaria paradoxa* C. F. Gaertn and *Parkia biglobosa* (Jacq.) R. Br. Ex G. Don [6] as well as many other local and exotic species. Among these several agroforestry species, *F. albida* is one of the most important species in agronomic, fodder and medicinal uses. Indeed, the species improves soil fertility in croplands from the decomposition of litter and propagation of roots to improve their physicochemical properties [7]. Furthermore, foliage shade of the species does not have any negative effect on annual crops due to its reversed phenology [8]. Its leafing and fruiting occur during the dry season after crop season and provides valuable fodder (leaves and fruits) for livestock feeding when fodder become scares in grassland pastures. In addition, its leaves and roots are rich in antioxidants that could help fight against many diseases [9]. *F. albida* has a high carbon absorption capacity [10, 3] and would significantly contribute to climate change adaptation. Regard to its importance, some studies have been conducted on the diversity of parks and populations structure of *F. albida* [11, 12]. The authors found that the populations of *F. albida* were in ageing status in Burkina Faso. However, these studies were carried out in restricted ecological zones with conclusions related to the local site effect. The species response to spatial variability of ecological conditions is highly needed to better understand the species ecology for identifying sustainable management policies. Furthermore, in some areas, *F. albida* parks ranged from a monospecific characteristic [13] to low mean diversity of species. The growth interest for invasive species planting in parklands, especially *Azadirachta indica* A. Juss. [cult.] [5] and *Eucalyptus camaldulensis* Dehnh. [cult.] could negatively impact the demography of *F. albida*. Indeed, biotic interaction such as interspecific competition related to tree diversity and density affect morphological trait of agroforestry species [14]. Therefore, assessing the effect of this interaction on populations and morphological trait of *F. albida* would help to improve the species management in parklands. Some abiotic ecological variables related to climate (temperature, rainfall, water vapour pression, wind), altitude and soil have significant influence on population structure of tree species [15-19]. Traoré et al. [20] found that juvenile density of *F. albida* was higher in humid zone than dry zone in Burkina Faso. Whether climate conditions are known to influence the population structure of *F. albida*, the specific effects of climate variables on the species were not yet determined. The objectives of this study were to: (i) assess the population status of *F. albida* along climatic gradient in Burkina Faso and (ii) determine the effect of biotic and abiotic variables on its tree density and morphological traits. The following research question was formulated: How abiotic and biotic variables affect the populations and morphological traits of *F. albida*?

2. Material and Methods

2.1. Study Area

This study was conducted in Burkina Faso along climatic gradient (Figure 1). Nine (09) study sites were selected and distributed in the three climatic zones of the country. The Sahelian zone is the driest climate zone characterized by annual rainfall ranging from 300 to 600 mm and high temperature from 15°C to 45°C [21] with two alternating seasons. A short rainy season from June to September and a long dry season from September to May. Natural vegetation is dominated by tree and shrub steppes and tiger bushes [22]. Common woody species observed in the zone are *Balanites aegyptiaca* (L.) Del., *Vachellia tortilis* (Forssk) Hayne, *Pterocarpus lucens* Guill. & Perr., *Combretum micranthum* G. Don, *Grewia flavescens*, Juss., *Commiphora africana* (A. Rich.) Engl., and *Dalbergia melanoxylon* Guill. & Perr. [22]. The Sudano-Sahelian zone, located in central part of the country is the transition zone between dry and humid parts. The annual rainfall is ranging from 600 to 900 mm with temperatures varying from 20 to 30°C [21]. This zone is also characterized by two seasons, a rainy season from May to October and a dry season from November to April. Natural vegetation is dominated by tree and shrub savannas [23]. Common woody species observed in this zone are *Antiaris africana* Engl., *Carapa procera* DC, *Dialium guineense* Willd., *Milicia excelsa* (Welw.) CCBerg, *Voacanga africana* Stapf, *Pterocarpus santalinoides* L. Hér. ex DC., *Syzygium guineense* DC., *Cola laurifolia* Mast., *Diospyros mespiliformis* Hochst. ex A. Rich. [23, 24]. Agroforestry parklands are dominated by *Vitellaria paradoxa*, *Bombax costatum* Pellegr. & Vuillet, *Tamarindus indica* L., *Parkia biglobosa*, *Adansonia digitata*, *Piliostigma reticulatum* and *F. albida* [22, 25]. The Sudanian zone which is the most humid zone records an average annual rainfall over 1100 mm and thermal amplitudes of 20-25°C [21]. This zone is characterized by two alternating seasons: a dry season lasting 6 months from October to March and a rainy season lasting 5 to 6 months from April to October [26]. The common tree species observed in the zone are represented by *Antiaris africana*, *Carapa procera*, *Dialium guineense*, *Milicia excelsa, Voacanga africana, Pterocarpus santalinoides*, *Syzyguim guineense*, *Cola laurifolia, Anogeissus leiocarpa* (DC) Guill. & Perr., *Celtis toka* (Forsst.) Hepper & J. R. I. Wood, *Diospyros mespiliformis* Hochst. Ex A. DC. and *Pterocarpus erinaceus* Poir. [22, 24]. Agroforestry parklands are dominated by *Vitellaria paradoxa* and *F. albida* are also encountered and other fruit species [13].

2.2. Sampling Design and Data Collection

Study sites were selected based on climate zones and the presence of *F. albida* parks with three (03) sites per zone. In total, 33 plots were installed in each climate zone for biotic and abiotic data collection with at least 10 plots per sites. Individual circular plots of 10,000 m² (1 ha) with a radius of 56.42 m were used for data collection. Biotic data collected in each plot were woody species richness, total number of adult tree species and morphological traits of all tree species including *F. albida*. Individuals with Diameter at Breast Height at 1.30 m (DBH) upper than 5 cm were considered as adult trees [27]. Morphological traits measured on each individual tree were DBH and total height. For species richness, all tree species in each plot were directly recorded with their scientific name. For species unidentified on the field, samples consisting of leafy branches were collected and brought to the Laboratory of Plant Biology and Ecology of Université Joseph KI-ZERBO for determination. All species recorded were listed in the appendix using the nomenclatures of APG III [28] and Kyalangalilwa et al. [29]. Circular plots were used because they do not have any preferred directions, reducing considerably the border effect during data collection [30] and were also easy to install in agroforestry parklands [31]. Regarding plot size, a similar plot with 1 ha was adopted in study of Shea tree parks in Burkina Faso [32].

Abiotic data collected in each plot were: mean annual temperature (°C), mean annual rainfall (mm), water vapour pression (kPa) and elevation (m). Due to the fact that local climate data of each plot are not available, global climate data were downloaded from WorldClim version 2 [33] with a spatial resolution of 30 s (i.e. 1 km). Climate variables of each plot were extracted using raster values in ArcGIS software 10.4.1 based on their geographical coordinates. To account for climate data variability in each site, a minimum distance of 1 km was observed from one plot to another.

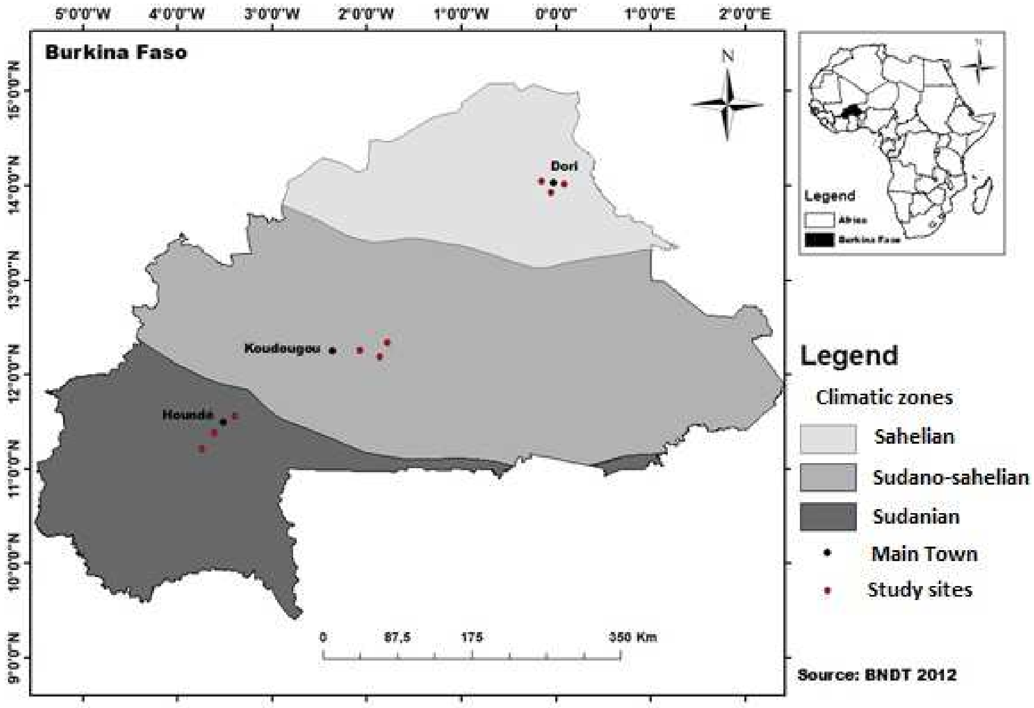

Figure 1. *Map of study area.*

2.3. Data Analysis

The floristic and morphological parameters calculated to characterize *F. albida* parks are: Shannon diversity index (H), Tree density (N) and basal area of the stand (G):

$H = -\sum_{i=1}^{S}(p_i \ln p_i)$, S is the species richness in the plot and pi is the relative abundance of the i-th species in a plot. Given that H account for species richness and abundance within the plot, it could probably indicate the intensity of interspecific competition in the plot.

$N = n/s$, n is the total number of trees in the plot, and s the area of plot (1 ha)

$G = \frac{\pi}{4s}\sum_{i=1}^{n} 10^{-4} DBH_i$, DBH_i being the diameter (in cm) of the i-th tree of the plot and s the unit area of the plot (s= 1 ha). Given that G account for tree size (DBH) and their abundance within the plot, it could be a good indicator of inter specific competition in the plot.

The status of *F. albida* populations at plot and climate zone levels were assessed using the method of Condit et al. [34]. Thus, ten (10) diameter classes were used as follow: 5-10, 10-15, 15-20, 20-25, 25-30, 30-35, 35-40, 40-45, 45-50 and ≥ 50 cm. A linear regression was performed with the median class and the density of individuals per diameter class. The resulting parameters, especially slope, r^2 (coefficient of determination) and regression probability were considered as indicators of distribution status [35]. A negative slope indicates that small-diameter individuals are abundant, while a positive slope indicates an abundance of large-diameter individuals. In addition, values of the coefficient of determination (r^2) and their p-values make it possible to observe whether there is a stable transition between number of individuals and diameter classes.

2.4. Statistical Analyses of the Data

For selecting appropriate statistical tests, the normality of floristic and morphological data was tested using Shapiro Wilk test. Based on the non-normal distribution of data, non-parametric tests were applied for comparison between climate zones. Therefore, we applied Kruskal-Wallis test followed by Mann Whitney-Wilcoxon pairwise post-hoc test at 5% to compare biotic variables between climate zones. Generalized Linear Model (family = binomial, link = logit) was performed to assess the effect of biotic and abiotic variables on the structure of *F. albida* at plot level. To do that, regression parameters (slope, r² and p-value) from each plot were used to determine the structure status of the populations. Information on structure status were coded using two scale points: 0 = unstable population and 1 = stable population. Correlation matrix tests with Spearman method were performed to assess the effect of biotic and abiotic variables on density and morphological traits of *F. albida* [15]. All analyses were performed using R 4.0.4 software [36].

3. Results and Discussion

3.1. Results

3.1.1. Effect of Climate Zone on Density and Morphological Traits of F. albida

The results indicated that climate zone has significant effect ($p<0.05$) on tree density, DBH and height of *F. albida* (Table 1). The highest tree density (25.33 ± 19.60 ind. ha^{-1}) was recorded in Sudanian zone while the lowest density (13.27 ± 5.50 ind. ha^{-1}) was observed in the Sahelian zone. Regarding DBH, the highest mean value was recorded in Sudano-Sahelian zone and the lowest in the Sudanian zone (Table 1). For tree height, highest mean value was observed in Sudano-Sahelian (13.51 ± 3.08 m) zone and the lowest in the Sahelian zone (10.97 ± 2.53 m). Biotic variables of the parks represented by Shannon diversity index and basal area of plots were illustrated in table 1. Shannon index differed significantly from one zone to another and decreased along the climatic gradient in which the high value (1.17 ± 0.36 bits) was observed in Sahelian zone and the low (0.71 ± 0,43 bits) in Sudanian zone. For basal area, the lowest value was found in Sahelian zone (0.69 ± 0.51 m². ha^{-1}) and the highest in Sudano-Sahelian zone (4.33 ± 3.64b m². ha^{-1}). Slopes, r² and p values from linear regressions on size class distribution showed that populations of *F. albida* are unstable in all of the three climatic zones with dominance of large trees (Figure 2).

Table 1. *Structural parameters of F. albida and biotic variables of its parks according to climate zones.*

	Sahelian	Sudano-sahelian	Sudanian	P-value
Structural parameters of *F. albida*				
Density (Tree.ha^{-1})	13.27 ± 5.50a	21.15 ± 18.37a	25.33 ± 19.60ab	0.006
Height (m)	10.97 ± 2.53a	13.51 ± 3.08 b	11.10 ± 2.86ac	<0.001
DBH (cm)	38.51 ± 13.54a	42.13 ± 16.02b	36.55 ± 18.18ac	0.005
Biotic variables of parks				
G (m². ha^{-1})	0.69 ± 0.51a	4.33 ± 3.64b	1.30 ± 2.66a	<0.001
H (bits)	1.17 ± 0.36 a	1.12 ± 0,39 a	0.71 ± 0,43 b	<0.001

H: Shannon index; G: Basal area (m^2. ha^{-1}); DBH: diameter at breast height (1.30m); Values in mean ± standard deviation. Values with the same letters are not significantly different (p>0.05)

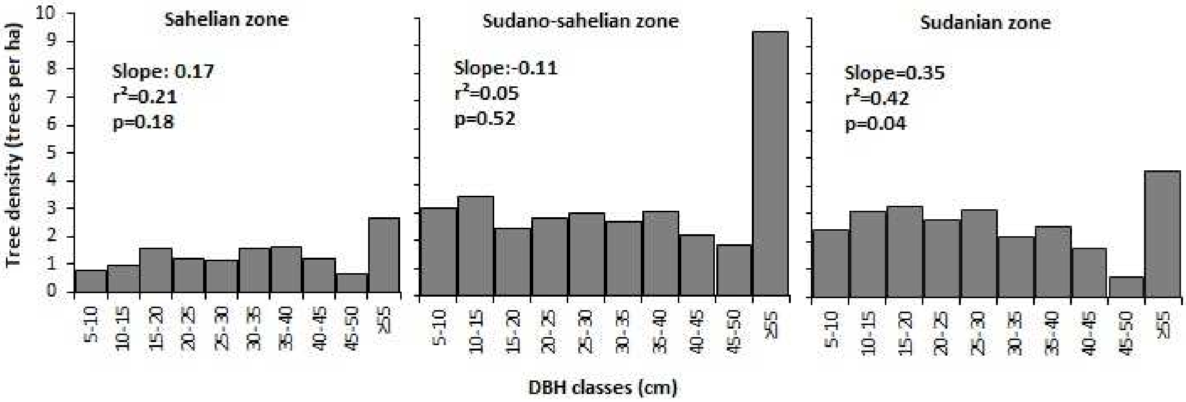

Figure 2. *Diameter class distribution of F. albida populations in tree climatic zones of Burkina Faso.*

3.1.2. Effect of Biotic and Abiotic Variables on F. albida Density and Morphological Traits

For biotic variables, Spearman correlations indicated that H has negative and significant correlation ($p<0,05$) with tree density and positive and significant correlation with tree height of *F. albida* (Table 2). Basal area of the plot has positive and significant correlation with DBH and height of the species. In contrast, basal area has negative and significant correlation with tree density. The remain correlations were not significants (Table 2). For abiotic variables, rainfall and elevation have respectively positives and significant correlations with tree density and height while negatives correlations were observed with DBH (Table 3). Temperature was negatively and significantly correlated with tree density and two morphological traits. Regarding vapour pressure, it was negatively and positively correlated with DBH and tree density respectively with significant p-values (Table 3). The results from Generalized Linear Model showed that biotic variables do not have any significant effect on populations structure of the species (Table 4). Only annual rainfall was the abiotic variable having significant effect on populations structure of the species (Table 5).

Table 2. *Spearman correlations between structural parameters of F. albida (tree density, DBH and height) and biotic variables (basal area of other species and Shannon index).*

	DBH	Density	H	Height	G-Os
DBH	1				
Density	-0.325	1			
H	0.2243	-0.5672***	1		
Height	0.7973	-0.0512	0.0926***	1	
G-Os	0.4909***	-0.0846***	0.2248	0.3839***	1

H: Shannon index; G-Os: Basal area of other species (m^2. ha^{-1}); DBH: diameter at breast height (1.30m); Significant levels: * P<0.05; **. P<0.01; *** P<0.001.

Table 3. *Spearman correlations between structural parameters of F. albida (tree density, DBH and height) and abiotic variables (environmental parameters).*

	T°M	RfM	DBH	Density	Elevation	Height	VP
T°M	1						
RfM	-0.6068	1					
DBH	-0.0418***	-0.0846***	1				
Density	-0.3827***	0.3559***	-0.0935	1			
Elevation	-0.7170	0.6344	-0.0456*	0.3986***	1		
Height	-0.0800***	0.0760***	0.7303	0.0661	0.1317***	1	
VP	-0.2346	0.9191	-0.1078***	0.3249***	0.4426	0.0371	1

VP: Water Vapour Pressure; H: Shannon index; G: Basal area (m^2. ha^{-1}); DBH: diameter at breast (1.30m); T°M: Mean Temperature degree; RfM: Mean Rainfall; Significant levels: * P<0.05; **. P<0.01; *** P<0.001.

Table 4. *Results of GLM presenting the effects of biotic variables on F. albida's size class distribution.*

	Estimate	Std. Error	Z value	Pr(>|z|)
(Intercept)	-1.53703	0.67000	-2.294	0.0218 *
H	-0.63508	0.72327	-0.878	0.3799
G-Os	-0.04537	0.14086	-0.322	0.7474

H: Shannon index; G-Os: Basal area of other species (m^2. ha^{-1}); DBH: diameter at breast height (1.30m); Significant levels: * P<0.05; **. P<0.01; *** P<0.001.

Table 5. *Results of GLM presenting the effects of abiotic variables on F. albida's size class distribution.*

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	347.91103	242.65397	1.434	0.1516
T°M	-0.60378	0.51622	-1.170	0.2422
RfM	0.08700	0.04348	2.001	0.0454 *
Elevation	-0.11831	0.07188	-1.646	0.0998
VP	-118.54598	63.85063	-1.857	0.0634

VP: Water Vapour Pressure; T°M: Mean Temperature degree; RfM: Mean Rainfall; Std. Error: Standard Error; Pr (>|z|): Probability; Significant levels: * P<0.05; **. P<0.01; *** P<0.001.

3.2. Discussion

3.2.1. Effect of Climate Zone on Tree Density and Morphological Traits of F. albida

F. albida tree density and morphological traits varied significantly among climatic zones. The low density and height observed in Sahelian zone is probably related to the aridity in that zone. In West Africa, aridity is one of the main factors responsible for tree populations decline [37, 38]. Indeed, the Sahelian character of this zone with low rainfall is nevertheless suitable to livestock farming, which subjects trees and shrubs to overgrazing and pruning for fodder. This leads to a slow development of the morphological parameters of the woody species on this zone, especially *F. albida* which is highly fodder species. Drought and anthropogenic pressures such as tree mutilation, tree cutting and harvesting could contribute to reduce tree density and slow down the tree growth [38, 17]. The instability of the species populations observed in the three climate zones was generally characterized by a low number of small diameter individuals and an irregularity of the transition in their size class distribution. This indicates an ageing state of the populations, which could be related to the illegal harvesting and pruning of individuals, although the species is protected by the Burkina Faso forestry code [39]. This situation is farmer's logic of resource management oriented towards satisfying current needs, rather than towards concern for sustainability [40]. Indeed, over-exploitation of the forest products in parklands without fallow implementation do not give opportunity to rebuilding and revitalizing their rejuvenation [41]. Similar results indicating the degradation of tree populations were reported on agroforestry parks of *Parkia biglobosa*, *Vitellaria paradoxa* and *Lannea microcarpa* in Burkina Faso [25, 42, 43]. Agroforestry parklands constitute the highest level of ecosystem disturbance [44]. *F. albida* parks being in proximity to habitations and farming hamlets, although the species has a special protection status, is one of the main sources of fuelwood, timber, fodder (fruits and leaves) as well as medicine to treat some diseases. Harvesting for fodder and medicine through partial to total pruning and intensive debarking could be responsible for low seed availability in parklands and disturbance of the species' development cycle [45-47]. These uncontrolled practices combined to the difficulties of juveniles growth in parks [19] can be presented as factors contributing to the unstable structure of the species.

3.2.2. Effect of Ecological Variables on F. albida Tree Density and Morphological Traits

High Shannon index (H) has a negative impact on tree density of *F. albida*, indicating that higher richness and abundance of tree in parklands reduce tree density of *F. albida*. This could be explained by the fact that a very high density of tree species in the parks leads to high competition for water and soil. Highest species diversity is the farmer's management strategy to diversify income and services from parks [25], which compromises the recruitment of juveniles of *F. albida*. Positive correlations between biotic variables (H and G) and morphological traits of the species (height and diameter) could indicate that adult trees of *F. albida* have more competitive capacity for light and nutrients compared to other species in parklands. For abiotic variables, positives correlations were respectively observed between rainfall and elevation and tree density and height of *F. albida* while negative correlation was observed with DBH. At high elevation, trees could put more emphasis on their stability in order to be not uprooted. In addition, leaching due to water logging and the depth of the groundwater could also have a negative impact on the development of tree diameter. According to Noulekoun et al. [17], high density of *F. albida* at high altitude increase the competition between species individuals for resources leading to smaller trees compared to low altitude. However, the negative impact of rainfall on DBH could be related to the fact that *F. albida* is a sahelian species which is being adapting to humid conditions. Variation in the morphological traits of a plant along an environmental gradient reflects variation in the relative importance of adaptation mechanism of that plant along this gradient [48]. The negative impact of temperature on tree density and morphological traits of *F. albida* indicates that this climate variable has adverse influence on the recruitment and growth of young individuals of the species. Indeed, more the temperature is higher, more biological and physiological functions of the species are disturbed [49]. High temperature can cause the fall of flowers, abortion of fertilized flowers, cessation of photosynthesis, loss of seed germination capacity, cessation of plant growth and the loss of many fewer resistant individuals [49]. Temperature was also found as the main factor influencing *F. albida* distribution [50]. Concerning population structure, rainfall is the main abiotic variable affecting the species population status. This indicates that good rainfall provides suitable conditions for a better recruitment of young individuals, with a better survival rate, giving a stable structure to the species. In contrary, a high dryness could negatively impact the recruitment capacity and growth of the species [15, 51].

4. Conclusion

This study revealed that tree density and morphological traits of *F. albida* were related to climate gradient. In general, low tree density and morphological traits were observed in sahelian zone. However, population structure in the three climate zones were degraded probably due to miss-management and over-exploitation of the species. Specific effects of biotic and abiotic variables were observed on tree density and morphological traits of the species, indicating the complexity of the relationship between *F. albida* and ecological conditions. Therefore, the findings of the study indicate that for sustainable management and conservation policies, it is essential to address multiple specific ecological aspects in *F. albida* parks management. This study provides information on the trends of *F. albida* populations along climate gradient that will be helpful for farmers and forest managers to design sustainable management policies.

5. Recommendation

In this study, the status of *F. albida* populations was appreciated based on biotic and abiotic variables. However, it would be useful to include human pressure variables (pruning, debarking, tree cutting and grazing) and management strategies in the parks in order to appreciate the contribution of human actions on the status of the species' populations.

Conflicts of Interest

The authors declare no conflict of interest.

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Appendix

Table 6. *Species and family repartition according to climatic zones.*

Species	Family	Climatic Zones		
		Sahelian	Sudano-sahelian	Sudanian
Adansonia digitata L.	Malvaceae	x	x	x
Afzelia africana Sm. ex Pers.	Fabaceae		x	
Anacardium occidentale L. [cult.]	Anacardiaceae			x
Azadirachta indica A. Juss. [cult.]	Meliacea	x	x	x
Balanites aegyptiaca (L.) Del.	Zygophyllaceae	x	x	
Bauhinia rufescens Lam.	Fabaceae	x		
Borassus aethiopum Mart.	Arecaceae		x	
Calotropis procera (Aiton) R. Br.	Apocynaceae	x	x	x
Senna siamea (Lam.) H. S. Irwin & Barneby	Fabaceae			x
Senna sieberiana DC.	Fabaceae		x	
Ceiba pentandra (L.) Gaertn.	Malvaceae		x	x
Citrus limon (L.) Burm. f. [cult.]	Rutaceae		x	
Combretum glutinosum Perr. ex DC.	Combretaceae	x		
Combretum micranthum G. Don	Combretaceae		x	
Combretum paniculatum Vent.	Combretaceae			x
Crescentia cujete L. [cult.]	Bignoniaceae		x	
Diospyros mespiliformis Hochst. ex A. DC.	Ebenaceae		x	
Eucalyptus camaldulensis Dehnh. [cult.]	Myrtaceae		x	x
Euphorbia balsamifera Aiton	Euphorbiaceae	x		
Faidherbia albida (Delile) A. Chev	Fabaceae	x	x	x
Feretia apodanthera Delile	Rubiaceae		x	x
Ficus ingens (Miq.) Miq.	Moraceae			x
Ficus sur Forssk.	Moraceae		x	x
Ficus sycomorus L.	Moraceae		x	x
Gmelina arborea Roxb	Lamiaceae			x
Guiera senegalensis J. F. Gmel.	Combretaceae		x	
Hyphaene thebaica (L.) Mart.	Arecaceae	x		
Jatropha curcas L. [cult.]	Euphorbiaceae		x	x
Khaya senegalensis (Desr.) A. Juss.	Meliaceae		x	x
Lannea microcarpa Engl. & K. Krause	Anacardiaceae		x	x
Leptadenia lanceolata (Poir.) Goyder	Apocynaceae	x	x	
Maerua crassifolia Forssk.	Capparaceae	x		
Mangifera indica L. [cult.]	Anacardiaceae		x	x
Mitragyna inermis (Willd.) Kuntze	Rubiaceae			x
Moringa oleifera L.	Moringaceae			x
Parkia biglobosa (Jacq.) R. Br. ex G. Don	Fabaceae		x	x
Piliostigma reticulatum (DC.) Hochst.	Fabaceae		x	
Piliostigma thonningii (Schumach.) Milne-Redh.	Fabacea		x	x
Prosopis juliflora (Sw.) DC.	Fabaceae	x		
Saba senegalensis (A. DC.) Pichon	Apocynaceae		x	x
Sarcocephalus latifolius (Sm.) E. A. Bruce	Rubiaceae			x
Sclerocarya birrea (A. Rich.) Hochst.	Anacardiaceae		x	
Senegalia senegal (L.) Britton	Fabaceae	x		
Sterculia setigera Delile	Malvaceae		x	
Stereospermum kunthianum Cham.	Bignoniaceae	x		
Tamarindus indica L.	Fabaceae		x	x
Terminalia macroptera Guill. & Perr.	Combretaceae			x
Terminalia mantaly H. Perrier [cult.]	Combretaceae			x
Vachellia nilotica (L.) P. J. H. Hurter & Mabb	Fabaceae	x	x	x
Vachellia seyal (Delile) P. J. H. Hurter	Fabaceae	x	x	x
Vachellia tortilis (Forssk.) Hayne	Fabaceae	x		x
Vitellaria paradoxa C. F. Gaertn.	Sapotaceae		x	x
Ziziphus mauritiana Lam.	Rhamnaceae	x	x	x

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