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Influence of *Parkia biglobosa* (Jacq.) R. Br. Ex G. Don on the Herbaceous Vegetation in the Katouré Valley of the Commune of Nyassia (Basse Casamance-Senegal)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Trees outside of protected areas play an important role in providing ecosystem services. They participate in the development of the mat by creating favorable conditions for the development of grasses. The influence of trees on the development and distribution of grasses is not well known.

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It is in this sense that this study was conducted to determine the effect of *Parkia biglobosa* cover on the composition, diversity, structure and spatial distribution of herbaceous vegetation.

Place and Duration of Study: The study was carried out in the commune of Nyassia in Lower Casamance on a site identified as a *Parkia biglobosa* park in the Katouré valley in August 2021.

Methodology: Floristic surveys were conducted under (R, R/2, R and 2R) and outside the control tree canopy.

Results: It was found that the number of species under the tree canopy ranged from 13 to 16 species and was greater than that observed outside the canopy (6 species). Species such as *Bracharia deflexa, Cyperus esculentus, Echinochloa colona, Indigofera heudelotii and Pentodon pentandrus were* the most frequently encountered in the surveys under the tree canopy (0R, R/2 and R). In contrast, *Andropogon gayanus* and *Bulbostylis capillaris* were the most abundant species in the noncanopy surveys. The canopy cover of *P. biglobosa*, which ranged from 70±17.6 (2R) to 83±19.4 (R/2), was higher than in the uncovered level (54±15.4). Diversity analysis revealed that the canopy surveys 0R (0.80±0.06), R/2 (0.81±0.04) and R (0.77±0.06) were the most diverse.

Conclusion: The presence of *Parkia biglobosa* influenced the presence of herbaceous species and improved habitat conditions.

Keywords: Parkia biglobosa; herbaceous; richness; diversity.

1. INTRODUCTION

Woody species outside the forest play a very important role in the proper functioning of agrarian and pastoral landscapes in sub-Saharan Africa and in Senegal in particular [1,2,3]. They provide multiple agronomic services by improving soil fertility and stability, and socioeconomic services by improving income and living conditions in rural areas, [4,5]. From an environmental point of view, these woody plants outside the forest also promote the restoration and conservation of herbaceous vegetation, which plays an important role in the supply (fodder and medicine) and proper functioning of ecosystems [5,6]. This herbaceous vegetation also provides a reservoir of novel and useful genes, and a considerable source of new diversity [7,8]. Despite their importance, these ecosystems are experiencing increasing degradation due to a variety of factors such as agricultural clearing, overexploitation of woody plants, and climate change [9,10,11]. This strong degradation results in a strong decrease in the diversity of woody species and a modification of the floristic composition of the herbaceous stratum becoming more fragile and very threatened [12,13]. Faced with these threats, various action plans associated with agricultural production are increasingly undertaken, particularly through the promotion of the advantages of agroforestry systems [14,15,16]. Thus, several research and development activities have been undertaken to determine the contribution of woody species to the improvement of agricultural production through their contribution to soil fertility and stability [17-21].

As with research conducted on non-forest species associated with agricultural production, little effort has been directed toward studying the influence of woody species on the phenology, productivity, and quality of herbaceous vegetation in a habitat [22,23,24]. The objective of our study is to determine the effect of *Parkia biglobosa* cover on the diversity, frequency and cover of herbaceous flora in the valley zone.

2. MATERIALS AND METHODS

2.1 Study Site

The study was conducted in the commune of Nyassia in Lower Casamance (Fig. 1) at a site identified as a *Parkia biglobosa* park in the Katouré valley (Fig. 2). This area is characterized by a coastal South Sudanese climate that is essentially dominated by two seasons: a dry season from October to May and a rainy season from June to mid-October [25]. The average annual rainfall is estimated at about 1200 mm and the average temperature is 27°C [25]. The vegetation encountered is essentially open forest and savannah with trees and shrubs [26].

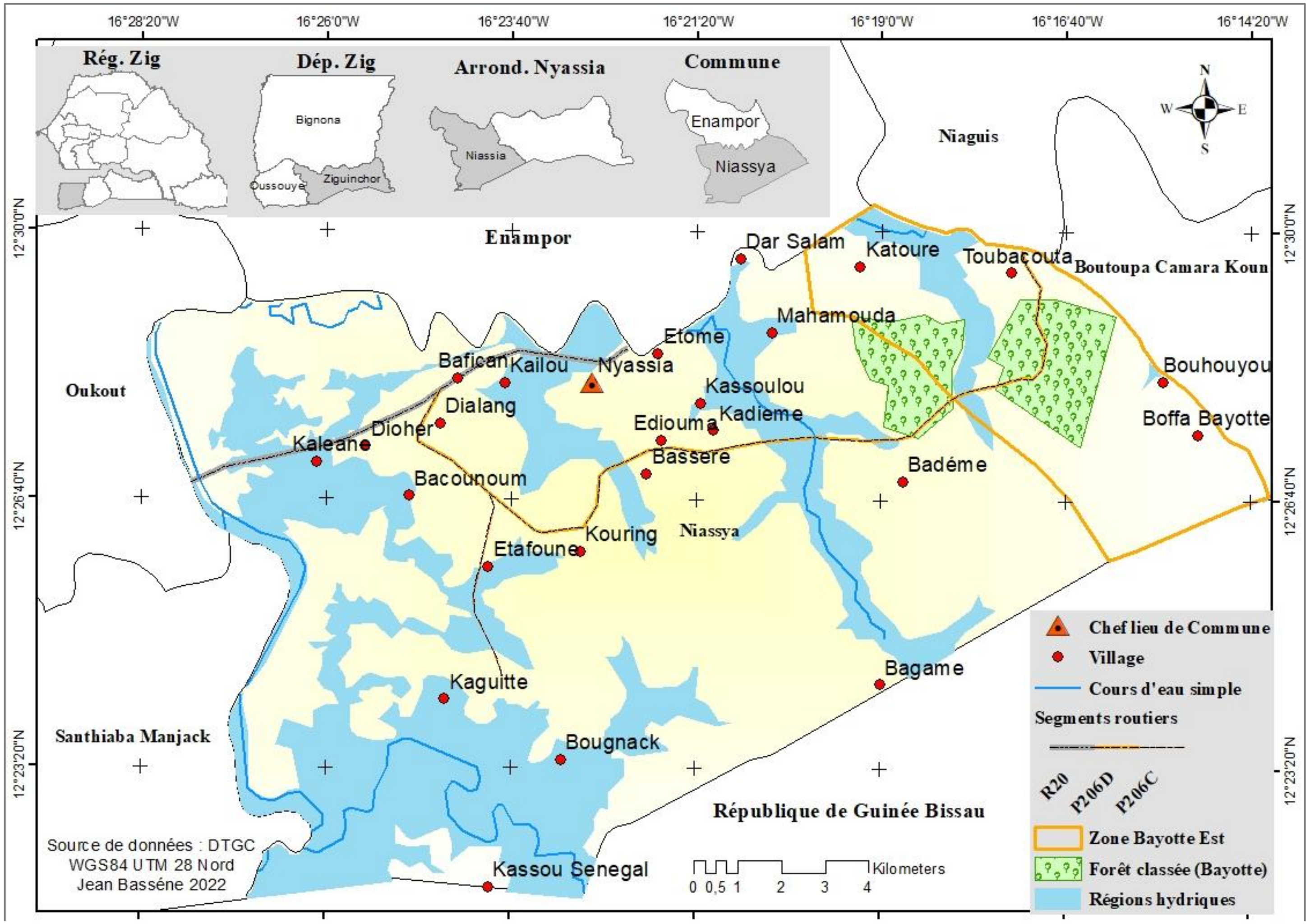

Fig. 1. Location of the study area

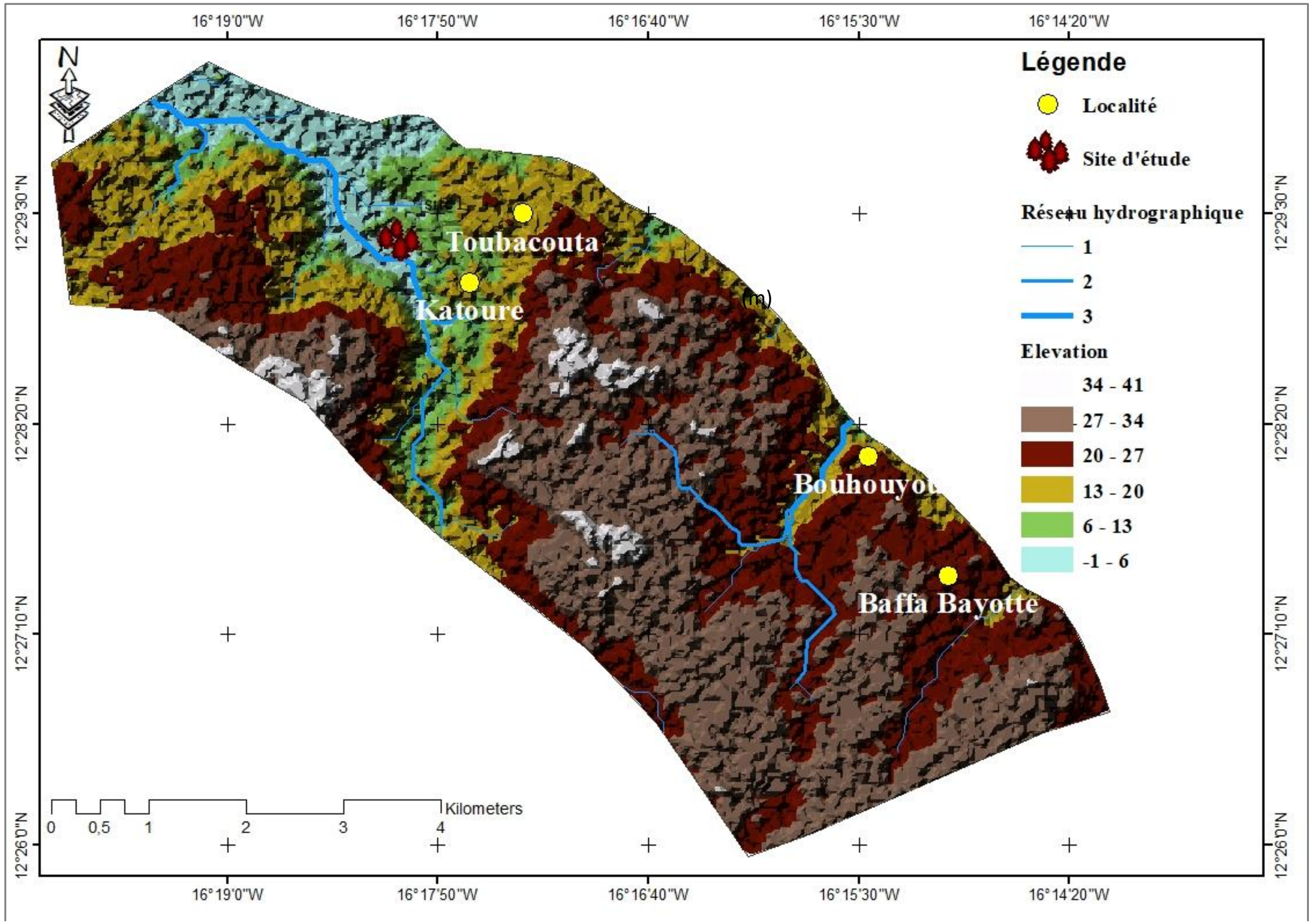

Fig 2. Hydrographic Network and Topography of the East Bayotte Area

2.2 Sampling

An inventory of woody species was conducted in the Katouré valley followed by criterion sampling on all individuals of the species *Parkia biglobosa,* retaining only isolated individuals with a height ≥ 5 m. From the set of isolated individuals, a random selection of 15 individuals was made to determine the effect of *P. biglobosa* on the herbaceous mat. From each individual, two zones were defined: under and outside the *P. biglobosa* canopy. The zone outside the canopy is characterized by the absence of influence of any other tree. The under-top zone was stratified into transects marked with ropes starting from the foot of the tree to a certain distance: 0R (at the foot of the tree), R/2 (half the radius of the tree crown), R (radius of the tree) and 2R (twice the radius of the tree). The inventory was conducted systematically on each transect using a 1 m^2 quadrat containing 100 squares (Fig. 3). A total of 60 quadrats or floristic surveys were conducted, with 15 for each distance (0R, R/2, R, and 2R). In the non-tree canopy area, ten 9 m^2 (3m x 3m) plots were delineated at a minimum distance of 50 m from any tree. In each of these plots, 5 quadrats of 1m side containing 100 tiles were made (Fig. 3). A total of 50 quadrats for floristic surveys were conducted in the non-tree canopy area. For each floristic survey, the entire herbaceous stratum was inventoried.

2.3 Data Collection

Prior to the herbaceous layer inventory, the height, diameter at breast height (DBH), and cross- sectional diameters (Dmin and Dmax) of the canopy of the trees selected for the study were measured. The average canopy diameter was calculated to determine the canopy area (S houp). Within each quadrat, the various grass species encountered were identified and listed on pre-made collection sheets and their abundance estimated. The percentage of ground cover by the entire grass layer was also visually estimated within each quadrat.

2.4 Data Processing and Analysis

Taxonomic richness in each 0R, R/2, R, and 2R transect was determined; species accumulation curves as a function of sampling effort were plotted for. From these samples, the number of species in the area was estimated using the "Chao" estimator [27]: $\text{Schao} = Sobs + \frac{f1^2}{2f2}$ Sobs = the number of species in the sample, F1 = the number of observed species represented by a single individual (singletons) and F2 = the number of observed species represented by two individuals (duplicates).

The specific frequency for each species was calculated per transect. Diversity was calculated using Simpson's index (D) [27]: $D' = 1 - \sum P_i^2$; P_i : relative abundance.

However, Jaccard's ecological distance was adopted for this [28]:

$D = 1 - \frac{S1,1}{S1,1+S1,0+S0,1}$ [S1.1 being the species observed in the two communities, S1.0 those observed only in the first community, S0.1 those observed only in the second community].

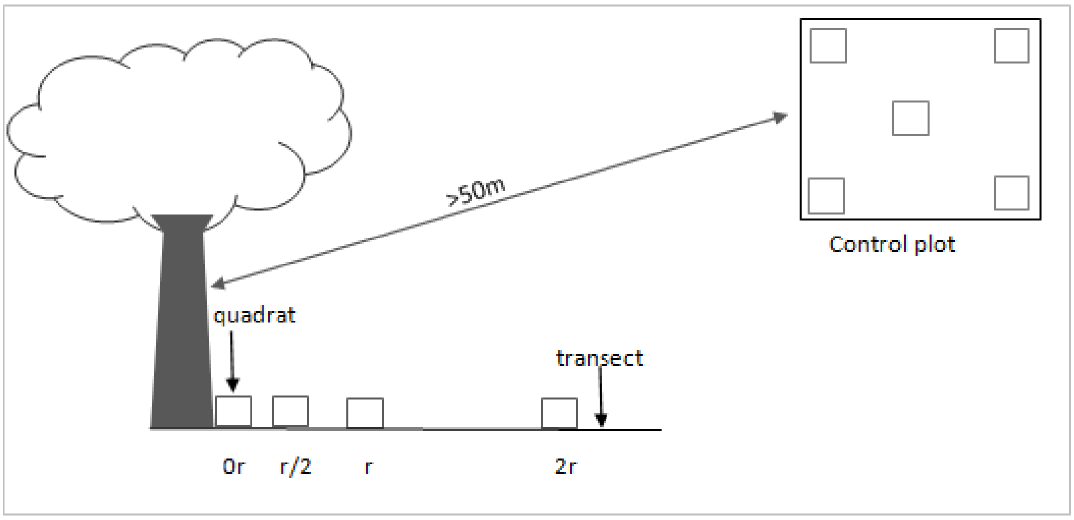

Fig. 3. Sampling method in the under- and out-of-top zone

Jaccard's ecological distance was also adopted in the clustering analysis for grouping based on floristic compositions. Principal component analysis was performed to characterize the groups. All data were processed and analyzed with Excel and R-4.2.2 software. Analyses of variance (ANOVA) were performed to compare means between treatments. When significant differences existed between treatments, the Newman-Keuls test, at the 5% threshold, was used to discriminate the means [29].

3. RESULTS

3.1 Structural Characteristics of *P. diglobosa* Individuals

The trees selected for the study of the herbaceous stratum are characterized by an average height of 10m ± 0.35, an average diameter of 28 cm ± 2.47 and an average canopy area of 56 m2 ± 24.74. The height, diameter, and canopy area of *P. biglobosa* trees ranged from 5.5 to 13.5m, 15 to 70 cm, and 16 to 154 m^2, respectively (Table 1).

3.2 Floristic Composition

3.2.1 Richness, overlap and diversity

The inventory of the herbaceous flora conducted during this study resulted in the identification of 20 species grouped into 18 genera and 11 families. The taxonomic richness observed in the different surveys of each transect revealed that the number of species, genera and families increases when approaching the foot of the tree (0R to 2R) (Table 2).

Species richness (species and families) is relatively the same for the different transects. The sampling effort is estimated at 98% for species and 100% for families (Table 2). However, this sampling effort is confirmed by the evolution of the species accumulation curve, which begins to reach the asymptotic stage around 8ième in the condition with tree influence and around 35ième in the condition without tree influence (Fig. 4).

The analysis of variance of the cover rate of the herbaceous layer showed a highly significant difference (*P* = 2.9e-09) between the different transects 0R, R/2, R and 2R (Table 2). The cover rate did not vary significantly at the under tree canopy surveys. However, under tree canopy cover rates were significantly higher than out of tree canopy cover (54% ± 15.4, *P* = 2.9e-09).

ANOVA showed a significant difference in diversity (*P* = 1.55e-12) between the 0R, R/2, R and 2R transects (Table 2). Under tree canopies, diversity at 0R (0.80 ± 0.06), R/2 (0.81 ± 0.04) and R (0.77 ± 0.06) was significantly higher than at 2R (0.61 ± 0.26). Thus, diversity decreases with increasing distance from the canopy area. Also, the diversity under the canopy is significantly higher than that outside the canopy (0.58 ± 0.1).

Table 1. Structural characteristics of *Parkia biglobosa* plants

Tree number	**Height (m)**	**DHP (cm)**	**Dmin (m)**	**Dmax (m)**	**S houp (m2)**
1	15	70	10	14	113
2	10,5	23	7	9	50
3	6,5	19	4	6	20
4	13,5	45	11	13	113
5	9,5	27	9	11	79
6	12,5	32	9	10,5	75
7	13	37,5	13	15	154
8	9,5	32	5	7	28
9	6,5	15	4	5	16
10	6,5	15	4	5	16
11	6,5	16,5	4	6	20
12	5,5	14,5	4	5	16
13	10,5	27,3	4	5	16
14	11	23,5	9	11	79
15	10,5	27	7	8	44
Average	**10**	**28**	**7**	**9**	**56**

Table 2. Observed and estimated taxonomic richness, cover and diversity as a function of distance from the canopy

Distance	Species			Families			Recovery (%)	Simpson's Index
	SObs	SEst	Rate (%)	SObs	SEst	Rate (%)		
0R	16	17	94	10	10	100	76±15,1**a**	0,80±0,06**a**
R/2	15	15	100	9	9	100	83±19,4**a**	0,81±0,04**a**
R	15	16	94	8	8	100	76±15,3**a**	0,77±0,06**a**
2R	13	13	100	7	7	100	70±17,6**a**	0,61±0,26**b**
Witness	6	6	100	5	5	100	54±15,4**b**	0,58±0,1**b**

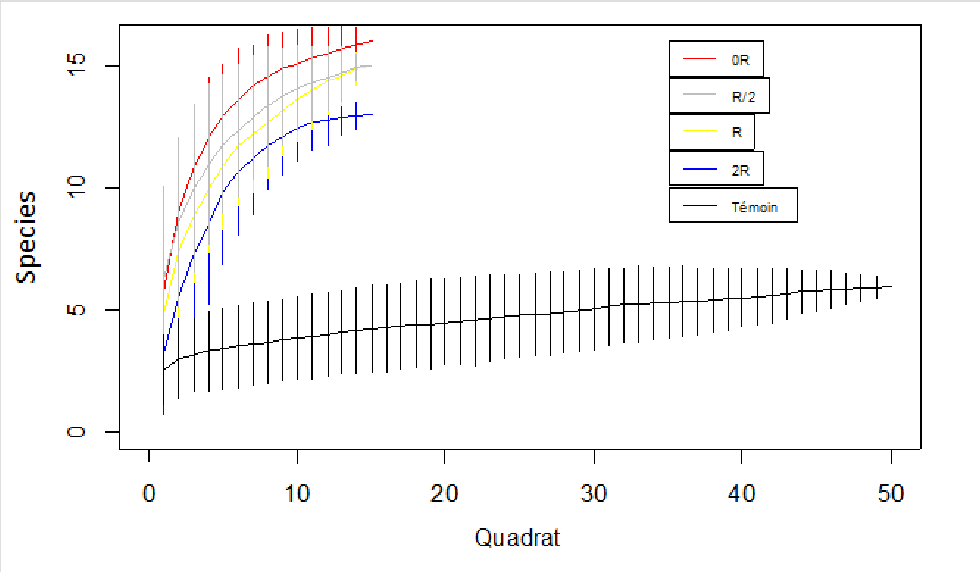

Fig. 4. Species accumulation curves

3.2.2 Distribution

Among the species inventoried, some had a continuous, some semi-continuous and some disjunct distribution (Table 3). *Crinum latifolium, Bulbostylis capillaris, Indigofera heudelotii, Andropogon gayanus* remain, however, the most spatially distributed species that are encountered in all observation distances from the tree canopy. Among the most exclusive species, *Ipomoea asarifolia* and *Sesbania bispinosa* are the species that are only present outside the canopy. The species *Hyptis suaveolens* and *Hedychium flavescens* are present only at the under-top surveys at distance R and 0R, respectively.

3.2.3 Frequency

Of the species surveyed in this study, *B. deflexa, C. esculentus, E. colona, I. heudelotii,* and *P. pentandrus* were most frequently encountered in the under tree canopy surveys (0R, R/2, and R), with frequencies of occurrence of more than 50% (Table 4). *A. gayanus* and *B. capillaris* are more frequently encountered in the out-of-top surveys with an occurrence frequency equal to 100%. *H. flavescens, H. asper, H. suaveolens, I. asarifolia, I. eriocarpa* and *S. bispinosa* are the least frequent species with an occurrence frequency that varies between 4 and 13%.

3.2.4 Abundance

Analysis showed variation in abundance with species and distance from the canopy (Table 5). *A. conyzoides, A. gayanus, B. deflexa, B. capillaris, C. esculentus,* and *E. colona* were the most abundant species in 0R and/or R/2 surveys. *A. gayanus* (31%), *B. deflexa* (32%), and *E. colona* (60%) are most abundant in the R distance surveys. *B. deflexa, E. colona, A. conyzoides,* and *A. gayanus* were most abundant in surveys at distance 2R with 76%, 66%, 51%, and 46% respectively. *B. capillaris* (74%) and *A. gayanus* (40%) were most abundant in the out-of-top surveys.

Table 3. Distribution of species by distance from the canopy

Families	Species	Code	0R	R/2	R	2R	Witness
Amaryllidaceae	*Crinum latifolium*	*Cl*	+	+	+	+	+
Asteraceae	*Ageratum conyzoides*	*Ac*	+	+	+	+	
Commelinaceae	*Commelina benghalensis*	*Cb*	+	+			
Convolvulaceae	*Ipomoea asarifolia*	*Ia*					+
Convolvulaceae	*Ipomoea eriocarpa*	*Ie*	+	+			
Cyperaceae	*Bulbostylis capillaris*	*Bc*	+	+	+	+	+
Cyperaceae	*Cyperus esculentus*	*Ce*	+	+	+	+	
Fabaceae	*Crotalaria hyssopifolia*	*Ch*	+	+	+	+	
Fabaceae	*Indigofera heudelotii*	*Ih*	+	+	+	+	+
Fabaceae	*Sesbania bispinosa*	*Sb*					+
Fabaceae	*Sesbania sesban*	*Ss*	+	+	+		
Fabaceae	*Tephrosia bracteolata*	*Tb*	+	+	+	+	
Lamiaceae	*Hyptis suaveolens*	*Hs*			+		
Malvaceae	*Corchorus olitorius*	*Co*	+	+	+	+	
Malvaceae	*Hibiscus asper*	*Ha*			+	+	
Poaceae	*Andropogon gayanus*	*Ag*	+	+	+	+	+
Poaceae	*Bracharia deflexa*	*Bd*	+	+	+	+	
Poaceae	*Echinochloa colona*	*Ec*	+	+	+	+	
Rubiaceae	*Pentodon pentandrus*	*Pp*	+	+	+	+	
Zingiberaceae	*Hedychium flavescens*	*Hf*	+				

Table 4. Occurrence of species as a function of distance from the canopy

Family	Species	0R	R/2	R	2R	Witness
Asteraceae	*Ageratum conyzoides*	27	20	20	13	
Poaceae	*Andropogon gayanus*	20	20	13	27	100
Poaceae	*Bracharia deflexa*	73	87	67	40	
Cyperaceae	*Bulbostylis capillaris*	27	7	7	13	100
Commelinaceae	*Commelina benghalensis*	33	13			
Malvaceae	*Corchorus olitorius*	53	53	27	27	
Amaryllidaceae	*Crinum latifolium*	40	33	33	20	40
Fabaceae	*Crotalaria hyssopifolia*	27	27	13	20	
Cyperaceae	*Cyperus esculentus*	53	53	53	20	
Poaceae	*Echinochloa colona*	53	53	73	60	
Zingiberaceae	*Hedychium flavescens*	7				
Malvaceae	*Hibiscus asper*			7	13	
Lamiaceae	*Hyptis suaveolens*			7		
Fabaceae	*Indigofera heudelotii*	60	93	73	53	4
Convolvulaceae	*Ipomoea asarifolia*					4
Convolvulaceae	*Ipomoea eriocarpa*	7	7			
Rubiaceae	*Pentodon pentandrus*	53	100	60	33	
Fabaceae	*Sesbania bispinosa*					4
Fabaceae	*Sesbania sesban*	13	13	13		
Fabaceae	*Tephrosia bracteolata*	20	13	13	7	

3.3 Dissimilarity

High floristic dissimilarity ranging from 93 to 95% was noted between under- and out-of-top zones (Table 6). However, under the canopy, dissimilarity was low between the pairs 0R and R/2 (0.22) and R/2 and R (0.27), ranging from 41 to 51%.

3.4 Relationship between Distances and Floristic Composition

Clustering analysis revealed 4 distinct groups at more than 75% (Fig. 5). Thus the 1er group concerns transects 0R and R/2 with an abundance of *B. deflexa, C. olitorius, C. esculentus, I. heudelotii, P. pentandrus, A.*

conyzoides, C. hyssopifolia, S. sesban, T. bracteolata, H. flavescens and *C. benghalensis*. The 2nd group encompasses transect R and is distinguished by a dominance of *E. colona* and *I. heudelotii* species. The 3eme group includes transect 2R and is characterized by a greater presence of *H. asper* and H. *suaveolens*. The 4eme group, corresponding to the area outside the canopy, is characterized by the presence of *I. asarifolia, S. bispinosa, A. gayanus, B. capillaris* and *C. latifolium* (Fig. 6).

Table 5. Relative abundance of species as a function of distance from the canopy

Species	0R	R/2	R	2R	Witness
Ageratum conyzoides	30	6	12	51	
Andropogon gayanus	13	47	31	46	40
Bracharia deflexa	57	43	32	76	
Bulbostylis capillaris	35	30	20	35	74
Commelina benghalensis	7	11			
Corchorus olitorius	17	27	10	34	
Crinum latifolium	**3**	14	4	32	8
Crotalaria hyssopifolia	10	7	5	9	
Cyperus esculentus	38	40	22	33	
Echinochloa colona	31	32	60	66	
Hedychium flavescens	3				
Hibiscus asper			1	4	
Hyptis suaveolens			10		
Indigofera heudelotii	15	22	21	12	1
Ipomoea asarifolia					9
Ipomoea eriocarpa	10	5			
Pentodon pentandrus	7	8	4	7	
sesbania bispinosa					1
Sesbania sesban	4	3	3		
Tephrosia bracteolata	8	3	3	1	

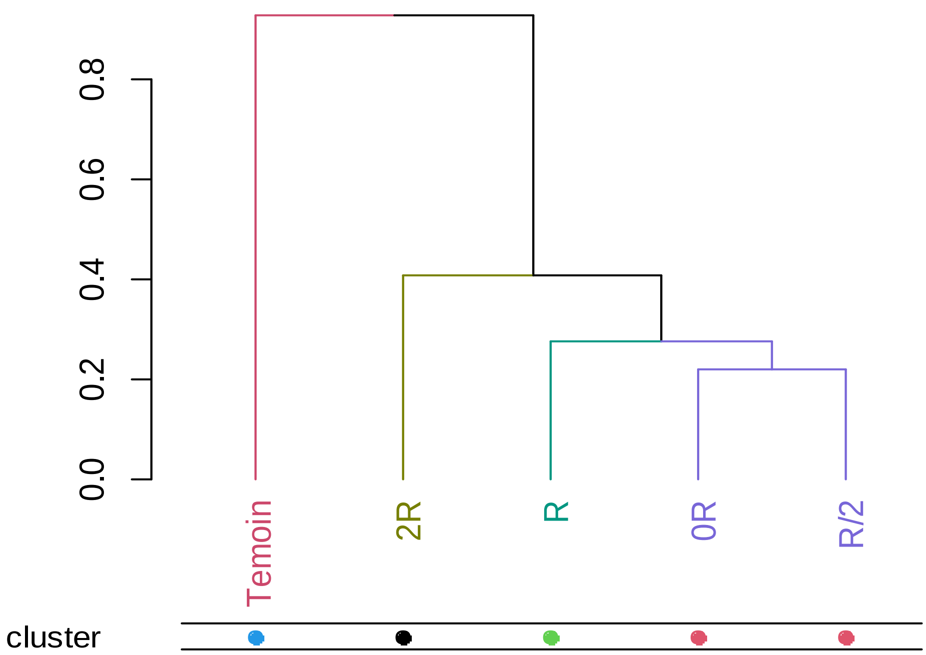

Fig. 5. Grouping of distances according to jaccard dissimilarity

Table 6. Jaccard's distance matrix of distances to the canopy

	2R	0R	R	R/2
0R	0,47			
R	0,41	0,31		
R/2	0,51	0,22	0,27	
Witness	0,94	0,93	0,95	0,95

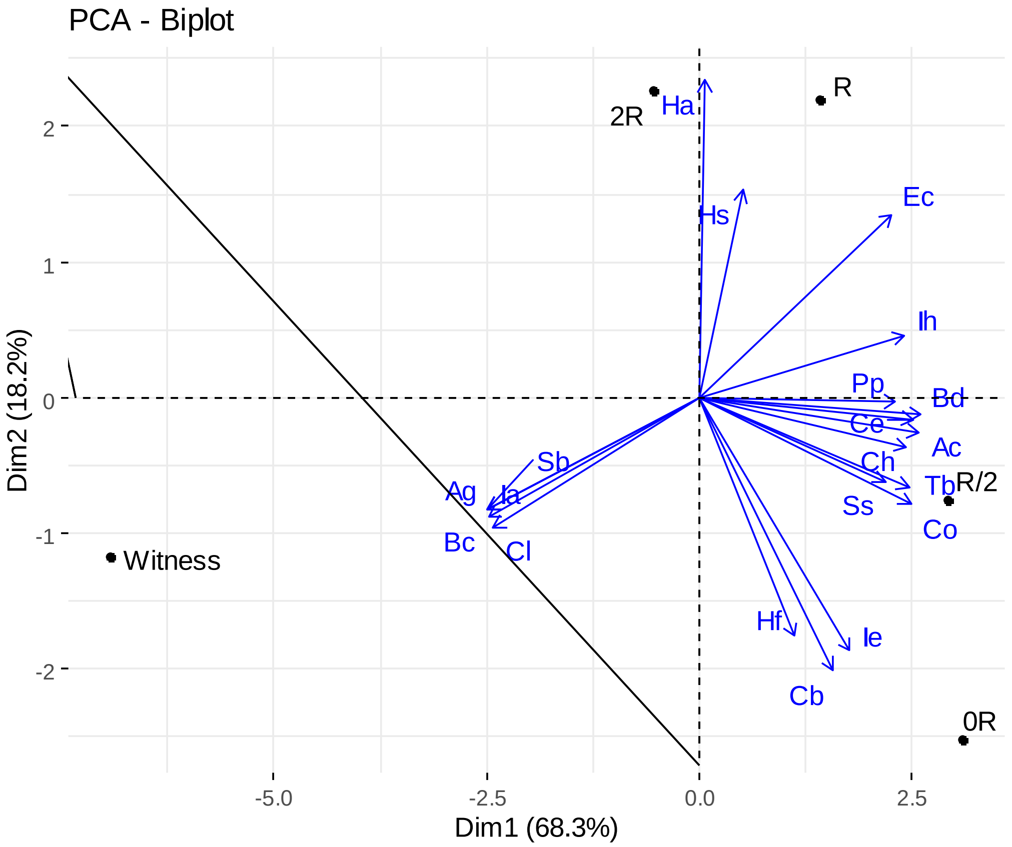

Fig. 6. Projection of distances and species by principal component analysis

4. DISCUSSION

Herbaceous plants are mostly used by farmers as medicinal plants, fodder or for cultural purposes. These plants also contribute to soil stabilization, erosion control and groundwater regulation [30,31]. Therefore, in situ biodiversity conservation should not only focus on trees, but also encompass grasses, as they are also very sensitive to habitat change [32]. It has been found, however, that the microenvironment created by the tree located outside of protected areas, tends to influence either positively or negatively the floristic composition, frequency, abundance and cover of the herbaceous stratum [23, 33, 34, 35].

Indeed, at the end of this study, analysis of the herbaceous plant groupings showed that the numbers of species, genera, and families observed in the surveys under the influence of the *Parkia biglobosa* tree were far greater than those observed in the surveys without the influence of any tree (control). This may suggest, however, that the presence of the Parkia tree would strongly contribute to the occurrence and maintenance of herbaceous biodiversity in a habitat. Authors such as Sanou et al. (2017) have indeed obtained similar results by assessing weeds around the *Parkia biglobosa* trunk in association with some crops and compared to field plots. Factors underlying this high diversity observed under and around the *Parkia biglobosa* tree are thought to be related to wind and animals (birds, ruminants, and rodents), among others. It has been reported that the trapping of grass seeds carried by the wind in the tree canopy and released under the canopy contributed to the species fill under and around the tree [36,37,38]. This is in the same way that some birds parasitize *Parkia biglobosa* by dispersing some grass seeds into it [39]. Also, some rodents and ruminants, while sheltering under the tree canopy, leave some seeds there through their droppings [40, 41, 42].

In addition to its impact on enhancing herbaceous biodiversity in the habitat, the study also showed that *P. biglobosa* influenced the frequency, abundance and cover of some herbaceous species under and around the tree. However, this could be related to the edapho-climatic conditions that prevail under the canopy of the species, as *P. biglobosa* due to its canopy architecture and the fact that it is a deciduous legume, would substantially improve soil fertility as well as its moisture content by reducing the temperature under its canopy [43,44,45,46]. It is mainly in this sense that some authors justify the argument that "the effects of temperature and soil fertility may outweigh the negative effect of tree shade" [45].

Shade from the *Parkia biglobosa* tree influenced the distribution and frequency of the herbaceous layer in this study. This suggests that in some way, herbaceous species respond individually to environmental variables and therefore to the influences of tree shading [47,48].

Indeed, more than 70% of the herbaceous species were influenced by the presence of *P. biglobosa.* Among these species *B. deflexa, C. olitorius, C. esculentus, E. colona, I. hirsuta* and *P. pentandrus* were strongly influenced by the presence of *P. biglobosa* as they were very frequent and specifically found in the surveys under and around the tree. Species such as *A. conyzoides, C. benghalensis, C. hyssopifolia, S. sesban, T. bracteolata, H. flavescens, I. eriocarpa,* although infrequent, were also specifically found in the surveys under and around the tree. This could be explained by the fact that most of these species prefer humus soils in the lowlands and/or seek light shade and/or are thermo-cosmopolitan [49,50]. On the other hand, the specificity of these herbaceous species under and around the tree and consequently their absence in the completely uncovered area could be related to the high abundance of *A. gayanus* in the said area. Indeed, according to Rossiter- Rachor et al. (2009) *A. gayanus* tends to stimulate ammonification and inhibit nitrification, and this inhibition would lead to a change in soil nitrogen relationships and reinforce its competitive superiority and persistence in the completely uncovered area outside the canopy.

5. CONCLUSION

This study showed that the presence of *P. biglobosa* trees influenced the floristic composition, distribution, frequency and abundance of herbaceous vegetation. The taxonomic richness inventoried under *P. biglobosa* trees was greater than that inventoried outside the tree canopy. Diversity was greater under the *Parkia* canopy and high floristic dissimilarity existed between the under and out of tree canopy areas. The presence of *P. biglobosa* influenced the appearance of herbaceous species under its canopy through improved habitat conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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