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Co-occurrence Patterns of *Parkia biglobosa* with other tree Species for Agroforestry Plannings in North Eastern Nigeria Savanna Ecosystem

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Abstract

*Rapid deforestation, land degradation, and biodiversity loss are major threats to the savanna ecosystems of North Eastern Nigeria, reducing the sustainability of indigenous tree species important for agroforestry and rural livelihoods. *Parkia biglobosa* is an economically and ecologically valuable savanna species, yet limited information exists on its ecological association with other indigenous trees necessary for effective agroforestry planning. This study therefore investigated the co-occurrence patterns of *P. biglobosa* with other tree species in selected protected areas of North Eastern Nigeria. The study was conducted in Wawa-Zange Forest Reserve, Yankari Game Reserve, and Gashaka-Gumti National Park located in Gombe, Bauchi, Taraba, and Adamawa States. Sixty sample plots of 20 m × 20 m square were systematically established for vegetation assessment. Tree species with diameter greater than 10 cm were identified and analyzed using Chi-square (χ^2), Phi coefficient, and Cramér's V statistics. The results showed that *P. biglobosa* had significant positive associations with forty-three tree species belonging to eighteen families. Strong associations were observed with *Vitellaria paradoxa*, *Detarium macrocarpum*, and *Burkea africana*. The study concluded that these positive ecological relationships support biodiversity conservation, soil fertility improvement, and sustainable agroforestry development in the savanna ecosystem of North Eastern Nigeria. The study recommends the conservation and integration of compatible indigenous tree species into agroforestry programs and sustainable land management strategies to enhance ecosystem productivity and environmental sustainability in North Eastern Nigeria.*

INTRODUCTION

The savanna ecosystems of North Eastern Nigeria represent one of the most dynamic ecological zones in West Africa, characterized by seasonal rainfall, prolonged dry periods, and a mosaic of woody and herbaceous vegetation. Within these landscapes, agroforestry parklands have evolved as dominant land-use systems where farmers intentionally retain economically and ecologically valuable tree species within farmlands. Among these, *Parkia biglobosa* (African locust bean) is a keystone multipurpose species widely valued for its edible seeds, medicinal properties, fodder, and soil fertility enhancement potential. Its ecological importance is further amplified by its tendency to coexist with other indigenous tree species such as *Vitellaria paradoxa*, *Daniella oliveri*, and *Pterocarpus erinaceus*, forming complex spatial associations that influence ecosystem functioning and agricultural productivity (Teklehaimanot, 2004; Codjia *et al.*, 2003).

Understanding the co-occurrence patterns of *P. biglobosa* with other tree species is critical for designing sustainable agroforestry systems in the savanna. These patterns reflect underlying ecological processes such as competition for light, water, and nutrients, as well as facilitation mechanisms where certain species improve soil conditions or microclimates that benefit others. In many West African parklands, *P. biglobosa* is deliberately conserved due to its ability to improve soil nitrogen through litter decomposition and biological interactions, thereby enhancing crop yield in surrounding farmlands (Leakey, 2012). However, variations in species density, spatial distribution, and interspecific associations remain poorly documented in North Eastern Nigeria, limiting the development of evidence-based agroforestry planning frameworks.

Agroforestry planning requires detailed ecological knowledge of how tree species assemble and persist under human-

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managed landscapes. In savanna systems, spatial self-organization and resource partitioning often enable tree coexistence despite environmental constraints such as rainfall variability and fire disturbances (Sankaran *et al.*, 2005). Therefore, studying the co-occurrence of *P. biglobosa* with associated woody species can reveal patterns of compatibility or exclusion that are essential for optimizing tree spacing, species mixtures, and land productivity. Such insights are also important for biodiversity conservation, as savanna parklands serve as refuges for multiple plant and animal species while supporting rural livelihoods.

Despite the ecological and socioeconomic importance of *P. biglobosa*, increasing land-use pressure, overexploitation, and climate variability are threatening its natural regeneration and distribution in many parts of the savanna zone (Boffa, 1999). Consequently, there is a growing need to integrate ecological data on species associations into agroforestry planning to ensure both conservation and sustainable agricultural production. This study therefore investigates the co-occurrence patterns of *P. biglobosa* with other tree species in the North Eastern Nigeria savanna ecosystem, with the aim of providing scientific guidance for improved agroforestry design, biodiversity conservation, and landscape management.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in the northeastern region of Nigeria, situated between latitudes 6° 26'–13° 45'N and longitudes 8° 42'–14° 39'E. This region includes the states of Borno, Yobe, Bauchi, Gombe, Adamawa, and Taraba. Covering an area of 262,578 km², the region is projected to have a population of approximately 26 million people, which constitutes around 12% of Nigeria's total population (National Population Commission [NPC], 2006). The climate is characterized by relatively high temperatures year-round, with average annual temperatures ranging from 28.32°C in Yola to 25.92°C in Bauchi. Rainfall varies across the region, from 467 mm in Nguru to 1,091 mm in Ibi (Hassan *et al.*, 2017). The study was carried out in a forest reserve, a game reserve, and a national park, located in the states of Gombe, Bauchi, and Taraba, respectively. The forest reserve was the Wawa-Zange Forest Reserve in Dukku Local Government Area of Gombe State. The game reserve was the Yankari Game Reserve in Alkaleri Local Government Area of Bauchi State. The national park was the Gashaka-Gumti National Park, spanning both Taraba and Adamawa States in northeastern Nigeria.

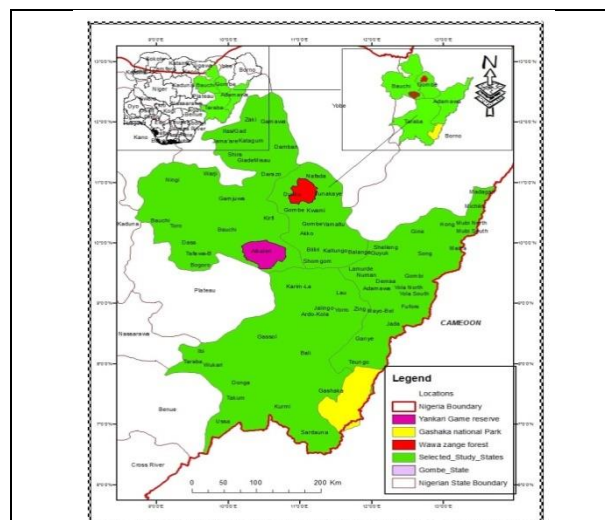


FIGURE 1: Map of Nigeria Showing North East States, Bauchi, Taraba, Adamawa and Gombe State, Wawa Zange, Yankari, and Gashaka Gumti National Park

Sources: Zin Geo partial (2024)

Sampling Method

Site Selection

There are six States in North eastern Nigeria; they include Borno, Bauchi, Adamawa, Taraba, Yobe, and Gombe. Gombe, Bauchi, Taraba and Adamawa State were purposively selected for this study based on the presence of functional protected areas, accessibility, vegetation type and the presence of target tree species. The following protected areas were randomly selected from the list of the reserves in this study; Wawa-Zange Forest Reserve in Dukku and Funakaye Local Government Areas of Gombe State, Yankari Game reserve in Alkaleri Local Government Area of Bauchi State and Gashaka Gumti National Park of Taraba and Adamawa State.

Choice of Trees Species

The choice of trees species for this study was based on the literature reviews that reported their multiple economic benefits drives from food, medicine, timber, fuel, and agroforestry (Saleh *et al.*, 2021). The *Parkia biglobosa*, is one of the most widespread and ecologically important plants species, with broad distribution across tropical and subtropical regions. The tree species belong to the Fabaceae family and is commonly found in savanna ecosystems, where it plays a significant ecological and socio-economics roles. The trees species have been reported to occur in almost all the natural protected reserves areas within the savannah region where the study was carried out as noted by Christenhusz and Byng, (2016).

Sample Plots

Three protected areas (natural forest) were used. In each of the protected area 2 transects lines of 2,000m were established. On each transect 2 clusters of 500 x 500m square were systematically located at 1,000m interval, this gave a total of 4 clusters per study protected area and 12 clusters for the entire three study protected areas. In each cluster, 5 plots of 20m x20m square were established, such that 4 plots were at the

vertex and 1 plot at the center as adopted by Soba *et al.* (2023). This gave a total of 20 plots per study location, 60 plots for the entire study.

Data Collection

All the tree species (> 10cm in diameter) found within the sample plots were generally identified, counted and documented for the study locations as adopted by Nurochman *et al.*, (2018).



Plate 1: Picture of the Researcher taking from the field

$$\chi^2 = \frac{(ad-bc)^2 x N}{(a+b)(c+d)(a+c)(b+d)} \dots \dots \dots \text{eqn1}$$

Where:

χ^2 = Chi-square

a = Number of plots containing both species A and B

b = Number of plots containing species A only

c = Number of plots containing species B only

d = Number of plots that does not contain both species A and B

N = Number of plots

The calculated Chi-Square was compared to the Chi-Square table (χ^2 table) at free degrees (df) of 1 at the level of 1 % and 5%, to determine the association between the species. If the calculated χ^2 is greater than or equal to the χ^2 table at a 1% level means that the association is very significant. If the calculated χ^2 is greater or equal to the χ^2 table at the 5% level means the association significant. Finally, if the calculated table is less than the χ^2 table at a 5% level means no association or the association is not significant.

Furthermore, the Phi and Cramér’s V values was used to determine the strength and direction of the association:

Cramér’s V values between 0 and 1:

- 0.00 to 0.10: Very weak or no association.
- 0.10 to 0.30: Weak association.
- 0.30 to 0.50: Moderate association.

- 0.50 and above: Strong association.

If the Phi value is Positive or negative from the calculation, the results indicate positive or negative associations between the two species.

Statistical Analysis

Association between the study tree species and other tree species found in the study plots were analyzed using Chi-Square (χ^2) as modified by Denny *et al.*, (2021).

RESULTS AND DISCUSSION

The result of the association between *Parkia biglobosa* and other forty-three (43) tree species found in the study area is presented in Table 1. The result of the association revealed that *P. biglobosa* was found in association with forty three (43) different tree species belonging to eighteen (18) families. Among the 43 tree species, twelve (12) were from the Fabaceae family, which were; *Uraria chamae*, *Tamarindus indica*, *Cassia singuena*, *Piliostigma thonningii*, *Dichrostachys cinerea*, *Daniellia oliveri*, *Detarium macrocarpum*, *Prosopis africana*, *Azelia africana*, *Isobertina doka*, *Burkea africana* and *Pterocarpus erinaceus*. Five species belonging to the Combretaceae family *Combretum glutinosum*, *Anogeissus leiocarpus*, *Guiera senegalensis*, *Combretum lamprocarpum*, and *Terminalia microptera* were also found in association with *P. biglobosa*. Also, the Anacardiaceae family had five (05) tree species, namely; *Spondias pinnata*, *Crosperteric fenifoga*, *K. senegalensis*, *Searsia lancea*, and *Lannea acida*. Moraceae, three (03) tree species; *Ficus religiosa*, *Ficus zycopus*, and *Myrianthus serratus*., Sapotaceae, three (03) tree species; *Haemotostolopis barteri*, *Vitellaria paradoxa*, *Nuclia latifolia*, and *Lofera alata*.

The Sterculiaceae family was represented by two (02) tree species in the association, they were; *Sterculia kunthianum*, and *Sterculia setigera*. Also, represented by two (02) tree species in the association was Rubiaceae family, they included; *Mitragyna inermis* and *Tricalysia cherelieri*. About eleven families were represented by one (01) tree species in the association, these were; Zygophyllaceae (*Balanites aegyptiaca*), Apocynaceae (*Perinari excelcia*), Hymenocardiaceae (*Hymenocardia acida*), Burseraceae (*Commiphora africana*), Verbenaceae (*Vitex doniana*), Meliaceae (*Ekebergia capensis*), Rutaceae (*Limonia acidissima*), Chrysobalanaceae (*Parinari excelcia*), Annonaceae (*Anonna senegalensis*), Malvaceae (*Grewia molle*) and Bignoniaceae (*Nucariya macroptera*).

Table 1: *Parkia biglobosa* is Association with other Tree Species in the Study Area

Tree Species	Chi-Square (χ^2)	Df	p-value	Cramér’s V	Phi	Strength of Association	Direction of Association
<i>Terminalia microptera</i>	62.300 ^a	4	.000**	.715	+1.011	Strong association	Positive
<i>Sterculia</i>	61.504 ^a	4	.000**	.710	+1.004	Strong association	Positive

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<i>setigera</i>							
<i>Combretum glutinosum</i>	61.010 ^a	4	.000**	.707	+1.000	Strong association	Positive
<i>Pterocarpus erinaceus</i>	61.009 ^a	4	.000**	.707	+1.000	Strong association	Positive
<i>Anageisus leiocarpus</i>	61.000 ^a	4	.000**	1.000	+1.000	Strong association	Positive
<i>Guiera senegalensis</i>	64.211 ^a	4	.000**	.725	+1.026	Strong association	Positive
<i>Isobalinia doka</i>	62.775 ^a	4	.000**	.717	+1.014	Strong association	Positive
<i>Balamites aegyptiaca</i>	62.230 ^a	4	.000**	.714	+1.010	Strong association	Positive
<i>Burkea Africana</i>	63.773 ^a	4	.000**	.723	+1.022	Strong association	Positive
<i>Perinary excelcia</i>	61.627 ^a	4	.000**	.711	+1.005	Strong association	Positive
<i>Prosopis africana</i>	61.504 ^a	4	.000**	.710	+1.004	Strong association	Positive
<i>Afzelia Africana</i>	61.111 ^a	4	.000**	.708	+1.001	Strong association	Positive
<i>Combretum lamprocarpum</i>	61.178 ^a	4	.000**	.708	+1.001	Strong association	Positive

Table 1 Cont'd: *Parkia biglobosa* is Association with other Tree Species in the Study Area

Tree Species	Chi-Square (χ^2)	Df	p-value	Cramér's V	Phi	Strength of Association	Direction of Association
<i>Hymenocardia acida</i>	63.570 ^a	4	.000**	.722	+1.021	Strong association	Positive
<i>Strerospermum kunthinum</i>	61.111 ^a	4	.000**	.708	+1.001	Strong association	Positive
<i>Commiphora africana</i>	61.665 ^a	4	.000**	.711	+1.005	Strong association	Positive
<i>Detarium macrocarpum</i>	64.447 ^a	4	.000**	.727	+1.028	Strong association	Positive
<i>Spondias pinnata</i>	62.109 ^a	4	.000**	.714	+1.009	Strong association	Positive
<i>Croseteric fenifoga</i>	62.534 ^a	4	.000**	.716	+1.012	Strong association	Positive
<i>Myrianthus serratus</i>	63.745 ^a	4	.000**	.723	+1.022	Strong association	Positive
<i>Vitelaria paradoxa</i>	63.017 ^a	4	.000**	.719	+1.016	Strong association	Positive
<i>Tricalysia cherelieri</i>	62.775 ^a	4	.000**	.717	+1.014	Strong association	Positive
<i>Daniellia oliveri</i>	61.034 ^a	4	.000**	.707	+1.000	Strong association	Positive
<i>Nuclia latifolia</i>	63.773 ^a	4	.000**	.723	+1.022	Strong association	Positive
<i>K. senegalensis</i>	61.264 ^a	4	.000**	.709	+1.002	Strong association	Positive

<i>Dichrostochiya cinera</i>	63.986 ^a	4	.000**	.724	+1.024	Strong association	Positive
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Table 1 Cont'd: *Parkia biglobosa* is Association with other Tree Species in the Study Area

Tree Species	Chi-Square (χ^2)	Df	p-value	Cramér's V	Phi	Strength of Association	Direction of Association
<i>Vitex doniana</i>	62.783 ^a	4	.000**	.717	+1.015	Strong association	Positive
<i>Searsia lancea</i>	61.178 ^a	4	.000**	.708	+1.001	Strong association	Positive
<i>Cassia singuena</i>	63.773 ^a	4	.000**	.723	+1.022	Strong association	Positive
<i>Piliostagma thonigii</i>	61.044 ^a	4	.000**	.707	+1.000	Strong association	Positive
<i>Ekebergia capensis</i>	62.775 ^a	4	.000**	.717	+1.014	Strong association	Positive
<i>Haemotostolopis barteri</i>	62.775 ^a	4	.000**	.717	+1.014	Strong association	Positive
<i>Limonia acidissima</i>	63.718 ^a	4	.000**	.723	+1.022	Strong association	Positive
<i>Parinari excelcia</i>	63.773 ^a	4	.000**	.723	+1.022	Strong association	Positive
<i>A.senegalensis</i>	63.773 ^a	4	.000**	.723	+1.022	Strong association	Positive
<i>Linear acida</i>	63.773 ^a	4	.000**	.723	+1.022	Strong association	Positive
<i>Grewol molle</i>	63.773 ^a	4	.000**	.723	+1.022	Strong association	Positive
<i>Nucariya macroptera</i>	63.570 ^a	4	.000**	.722	+1.021	Strong association	Positive
<i>Lofera alata</i>	63.773 ^a	4	.000**	.723	+1.022	Strong association	Positive

Table 1 Cont'd: *Parkia biglobosa* is Association with other Tree Species in the Study Area

Tree Species	Chi-Square (χ^2)	Df	p-value	Cramér's V	Phi	Strength of Association	Direction of Association
<i>Ficus zycopus</i>	63.570 ^a	4	.000**	.722	+1.021	Strong association	Positive
<i>Uraria chamae</i>	61.074 ^a	4	.000**	.708	+1.001	Strong association	Positive
<i>Ficus religiosa</i>	66.545 ^a	4	.000**	.739	+1.044	Strong association	Positive
<i>Mitragyna inermis</i>	64.623 ^a	4	.000**	.728	+1.029	Strong association	Positive
<i>Tamarindus indica</i>	61.190 ^a	4	.000**	.708	+1.002	Strong association	Positive

Source: Field Survey, 2024

The results revealed significant and positive ecological links between *P. biglobosa* and each of the forty-three (43) tree species found in the study plots, indicating that these relations were unlikely to be random. Instead, the uniform pattern of significance points towards an ordered ecological interaction that could be due to common environmental preferences, mutualistic relationships, or co-evolutionary histories. Moreover, the effect sizes calculated using Cramér's V invariably ranged above 0.7, indicating high strengths of association. The occurrence of these values, together with Phi coefficients not exceeding 1.000, speaks of a more or less simultaneous presence or association of these species in the

same habitat patches or ecological niches. The positivity consistency for these associations indicates that where *P. biglobosa* is found, there is a high likelihood of these associated species also being found, thus reflecting overlapping or complementary life-history traits. This is consistent with research conducted by Buba (2015), who reported that beneficial interactions between the species are likely to take place where plants share ecological requirements, for example, types of soil preferred and tolerance to environmental conditions.

Species such as *Guiera senegalensis*, *Burkea africana*, *Detarium macrocarpum*, and *Vitellaria paradoxa* had high values of association, indicating their position as co-dominant species or key elements in the same complex of vegetation.

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Ecologically, such a significant positive correlation could reflect synergistic benefits, for instance, the promotion of nitrogen fixation by legume partners increasing soil fertility or the complementary root architecture minimizing interspecific competition for nutrients and water. In addition, synchronized phenological events, like concurrent flowering or fruiting, would promote mutualistic animal interactions, like seed dispersal or pollination, further embedding these species together in ecological webs. The results of this study are consistent with existing literature on the facilitation of functions by trees in savanna ecosystems, where positive interspecific associations tend to be typified by species that occupy complementary ecological niches. For example, Razavie *et al.* (2012). reported that two species with positive associations share similar ecological requirements, and this consequently results in decreased competition and enhanced efficiency of resource use. This is a representation of the interactions observed between *P. biglobosa* and its partner species, which can reduce interspecific competition by encouraging complementary root architecture and improving water and nutrient acquisition in shared habitats.

Conclusion

The study concluded that *P. biglobosa* has strong and positive associations with many indigenous tree species in the savanna ecosystem of North Eastern Nigeria. The findings showed that the species coexists well with several economically and ecologically important trees, indicating that these species share similar environmental conditions and support ecosystem stability, biodiversity conservation, and soil fertility improvement. The strong ecological relationships observed suggest that *P. biglobosa* plays an important role in sustainable agroforestry systems and landscape management within the savanna region.

Recommendation

The study recommends that farmers, forest managers, and conservation agencies should encourage the conservation and integration of *P. biglobosa* alongside its associated indigenous tree species in agroforestry systems to improve soil fertility, biodiversity, and ecosystem sustainability. There is also a need for sustainable management practices, public awareness, and further research on the ecological and economic benefits of these species associations for effective agroforestry planning in North Eastern Nigeria.

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