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Different densities of *Adansonia digitata* L. trees: Structure and impact on neighbouring flora in northern Ghana

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Abstract: The ecological significance of baobab trees in the Savanna ecosystem is yet to be recognized despite its numerous socio-economic importance in the area. This study was conducted at Doba to investigate the impact of basal area of baobab trees on associated plant species diversity and their aboveground biomass. Purposive sampling technique was used to identify the various baobab aggregation regimes categorized into highly-clumped, moderately-clumped and the isolated stands. A design consisting of concentric circles (zones) in addition to plot sizes of 100 m x 100 m was used. All woody species (height ≥ 1.5 m) within the 100 m x 100 m plots were enumerated and also the non-woody species within the concentric zones nested within the larger plots were enumerated using 1 m^2 quadrats. All trees/shrubs characteristics were measured. Also, the woody species biomass was determined by a non-destructive method while non-woody species biomass was determined by a destructive technique. The results showed that the mean height of the isolated, moderately-clumped and the highly-clumped baobab stands were 14.2 ± 2.20 m, 11.3 ± 1.06 m and 11.5 ± 0.81 m respectively. The results also indicated that the greatest mean woody species biomass was recorded at the highly-clumped baobab sites (4539.18±715.97 kg/ha) while the least was found at the isolated baobab stands (2497.36 ± 1088.87 kg/ha). Similarly, woody species diversity at the highly-clumped sites was the highest among the three sites. The mean biomass values of the non-woody species did not vary under the various baobab stands, however, their biomass under the various concentric zones differ significantly. Also, the non-woody species diversity showed that zone B (2.07 ± 0.36) under the highly-clumped stands was the most diverse area while zone C (1.24 ± 0.24) under the moderately-clumped stands was the least diverse zone. It is therefore recommended that baobabs are a potential nurse and/or facilitative plant for some species and should be managed and conserve on the parklands to realize its fullest potential.

Keywords: Aboveground biomass, Baobab, Doba, Highly-clumped, Isolated, Moderately-clumped

1. Introduction

Adasonia digitata L. (baobab) is acknowledged as an extraordinary tree in the Savanna ecosystem due to its large size and bizarre shape. Its odd shape has given rise to different common names describing the tree. For example, some called it an upside down tree because its branches look like roots. Others called it the monkey- bread tree because the fruit is a source of food for monkeys, cream of tartar tree due to the acidic taste of the fruits and bottle-tree because it resembles a bottle in shape (Sidibe and Williams, 2002). Baobab is resilient and bizarre in nature and can manifest a complete phenological cycle in a coppiced state. That is a cut-down baobab tree can shed its leaves completely, bear fresh leaves, flower and fruit in that state (Personal observation). The baobab has the largest trunk girth among all plant species in the Savanna ecosystem and in many situations shows unusual or strange shapes in nature. As a result, it appears to be the most prominent tree species and occurs naturally as both scattered and clumped together trees in the parklands with its crown shape ranging from depressed ovoid through globose to obovoid (Sidibe and Williams, 2002).

According to Munzbergova and Ward (2002), large scattered trees play key ecological and socio-economic roles in arid and semi-arid environments and thus the importance of a large tree like baobab in the Savanna ecosystem cannot be overemphasized. For example, the tree is a multipurpose plant, providing nutritional and medicinal benefits (Bonkoungou *et al.,* 1999*;* SCUC, 2006; Chadare, 2010; Affo and Akande, 2011). In ecological sense, the baobab tree provides shade to the soil beneath the canopy and the deciduous leaf drop acts as soil conditioner by providing a humus-rich top soil layer (SCUC, 2006). The tree litter also has positive effects on the under canopy soil such as improvement of microbial-biomass and activity, water infiltration and nitrogen content (Belsky *el al.,* 1989). In Sudan, Gebauer *et al.,* (2002) reported that the baobab tree spends only four months of the year in leaf and this is possible because some photosynthesis takes place in the trunk and branches during the eight-month leafless period. In northern Ghana, we observed that the tree spends more than six months of the year in leaf. Many researchers reported that in semi-arid areas, trees generally have favourable effects on associated flora by lengthening the period of the plant development and consequently increasing biomass production of the herbaceous undergrowth (Akpo, 1997; Grouzis and Akpo, 1997). Vetaas (1992) also reported that trees influence the diversity and productivity of herbaceous plants.

In the Upper East Region of Ghana, Blench (1999) reported that there was a notable elimination of almost all trees on farms which resulted in enhanced land degradation. Also, recent anthropogenic activities like excessive cutting of trees in general and baobab in particular for construction and/or farming purposes might have further affected tree cover and consequently affecting associated plant species. The negative change in baobab tree cover certainly reduces vegetation cover and enhances the exposure of soil surfaces which can threaten associated plant diversity in the area due to the fact that the land would be increasingly degraded. In general there is paucity of knowledge on the effects of baobab tree on food crops and indeed, there is no any reported case of the effects of the tree on its associated natural flora in literature so far. Hence, it is against this background that this study sought to examine the effects of basal area and structure of baobab tree on associated plant species diversity and aboveground biomass.

2. Materials and Methods

2.1. Study Area

The study was conducted at a village near Navrongo called Doba in the Kasena-Nankana East district of Upper East Region of Ghana. The district covers a total land area of 1657 square kilometre and within latitude 10º 54' N and longitude 01º 06' W.

The vegetation of the study area is Sudan Savanna with short grasses interspaced with common tree species like *Vitellaria paradoxa, Ceiba pentandra, Adansonia digitata,* and *Parkia biglobosa* (Tailor, 1960).

The climate of the area is linked with the prevailing general air circulation affecting the West African sub region. A clear-cut rainy season from May to October with a monomodal pattern and a dry season from November to April are the main features of the climate, but the onset of the rains is highly unpredictable. The mean annual rainfall is between 750 mm to 1100 mm with high temperatures throughout the year. Also, the area experiences abundant sunshine throughout the year with mean relative humidity values ranging between 35 % to 95% measured at 0600 GMT. A climatic diagram of Navrongo, the nearest weather station is shown in Figure 1.

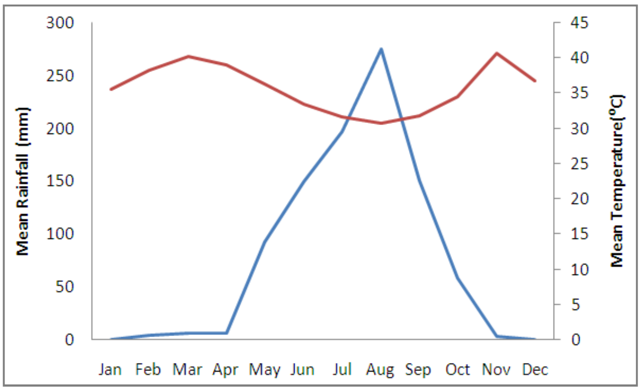

Fig 1: *A climatic diagram of Navrongo showing mean monthly rainfall and temperature patterns (from 2001 to 2011). Source of data: Ghana Meteorological Service.*

2.2. Selection of Experimental Subjects, Plots Layout and Design

Purposive sampling technique was used to select baobab trees in the natural stands based on three aggregation regimes of the stands into highly-clumped trees, moderately-clumped trees and isolated trees. The reason for arriving at such classification was based on the results of the tree inventory and reconnaissance survey carried out in the study area.

Thus, for the highly-clumped baobab trees, it consists of six trees and all of them situated within 20 m x 20 m land area. Also, the moderately-clumped trees were made up of three baobab trees and they all situated within 20 m x 20 m land area while isolated baobab tree has no additional baobab tree within an area of 20 m x 20 m of land area. Additional criterion used in selecting the clumped baobab trees was that trees species form more or less close canopies. The highly-clumped baobab tree stands were identified at three different sites and same was done for both the moderately-clumped and isolated baobab stands. Thus, the stands were replicated three times each. At each highly-clumped baobab trees site, the shortest tree was given the first label, (ie 01) and labeling order increases with increasing height until the tallest tree received the last label (ie 06). The same labeling order was done for moderately-clumped and isolated stands.

Also, plot sizes of 100 m x 100 m each was constructed, leaving the selected baobab trees at the centre of the plots.

In addition, three 100 m x 100 m plots were marked out in the natural vegetation in which no tree was found to serve as controls. Thus, a total of twelve 1-hectare plots were constructed in which nine contained the various baobab regimes and three as controls.

In order to investigate the different areas under the baobab tree canopy especially with reference to the gradient of the tree effects from the trunk's base to the periphery of the canopy on the non-woody vegetation. An experimental design with concentric zones was used to reduce directional biases and also to separate the different influence zones of trees as suggested and used by (Rao *et al*., 1998; Boffa, 1999; Bayala *et al.,* 2002; Sanou *et al.,* 2011) with modification. The area around each isolated baobab tree and the clumped baobab trees was then subdivided into three concentric zones as follows:

Zone A (Completely inside canopy), from the trunk of each isolated tree up to half of the radius of the tree crown/ for the clumped baobab trees, from the trunks up to half the radius of periphery tree crowns;

Zone B (Mid to edge canopy), from half of the radius of each isolated tree crown up to the edge of the crown/ for the clumped baobab trees, from half of the radius of the tree crowns (periphery trees) up to the edges of the crowns of those trees;

Zone C (Outside canopy), from the edge of each isolated tree crown up to 3 m away/ for the clumped baobab trees, from the edges of the periphery trees crowns up to 3 m away.

2.3. Determination of Tree Parameters

Tree/shrub heights were determined by the use of a clinometer while their bole heights were measured with a height pole. Trunk girth and diameter at breast height were measured with a diameter tape. Crown diameter was measured by determining the average diameters of canopies vertical projections in North-South and East-West directions (Peiler, 1994) using surveyor's tape. The basal area of each tree/ shrub was calculated.

2.4. Sampling Flora in the Plots

For the woody species (height ≥ 1.5 m), they were all identified and enumerated in each hectare plot while with the non-woody species especially grasses and forbs, a 1-m^2 quadrat was used to sample them at senescence stage in each of the zones in all the plots. The quadrat was randomly distributed ten times in each of the zones and species enclosed by the quadrat were identified and enumerated (in case of density; for frequency, the presence or otherwise of a species in a quadrat) but those species that could not be easily identified in the field, sample specimens were taken to a trained taxonomist and/or herbarium for identification. Thus the abundance of the species was determined by frequency and density techniques.

2.5. Determination of Aboveground Biomass

The aboveground biomass of the non-woody species was determined by a destructive technique. The species enclosed in any three 1-m^2 quadrat in each zone were clipped to the ground level and put in separate labeled envelopes, sent to the laboratory and oven dried at 80^0C to a constant weight for 48 hours.

The aboveground biomass of the woody species, especially trees and shrubs found in the plots was estimated using revised allometric technique by Anderson and Ingram (1998). The appropriate regression equation was however, calibrated before using to determine the biomass of the woody species. This is a non-destructive method of estimating woody species biomass.

2.6. Determination of Species Diversity

Species diversity for both the woody and the non-woody species was determined using Shannon diversity index (Cox, 2002).

2.7. Data Analysis

Results of baobab tree data are expressed as means ± standard error. Data on various baobab characteristics, woody and non-woody species biomass were analyzed using a one-way analysis of variance (ANOVA). Data on other woody species abundance were analyzed using chi-square analysis. Species diversity was calculated using the formula: $H' = -\sum_{i=1}^{s} pi ln pi$ (Cox, 2002), where pi is the proportion of the ith species, In pi is natural log of pi, s is the species richness and H' is the Shannon diversity index. Species richness was calculated using Menhinick's index, $d = S/\sqrt{N}$, where s is the total number of species and N is the total number of individuals. We also computed the individual tree basal area by converting diameter data to basal area using the formula $BA = \pi(d/2)^2$, where BA is the basal area of the tree stem/bole expressed in meter square per hectare, d is the tree diameter at breast height in metre and π is 3.142.

3. Results and Discussion

3.1. Structural Characteristics of Various Baobab Stands

The mean heights of the three different baobab stands were similar ($F = 0.90$, $df = 30$, $P = 0.418$) (Table 1).
Baum, (1995) reported that the baobab tree is characterized by its massive size reaching to a height of 18-25 m. Also, Gebauer *et al.,* (2002) posited that baobab is a massive and majestic tree which attains a maximum height of 25 m. The mean heights of the three different stands obtained in this study did not match up to the height range of earlier work done by Baum, (1995) and Gebauer *et al.,* (2002).

Table 1: *Structural characteristics of various baobab stands*

Stands regime	Height (m)	Bole height (m)	Girth (m)	Diameter at breast height (m)	Crown diameter (m)
Isolated stands	14.2 ± 2.20	3.6 ± 0.83	8.2 ± 1.42	2.6 ± 0.46	22.3 ± 2.47
Moderately-clumped stands	11.3 ± 1.06	3.4 ± 0.30	5.8 ± 0.92	1.5 ± 0.20	15.5 ± 2.19
Highly-clumped stands	11.5 ± 0.81	3.5 ± 0.26	4.5 ± 0.44	2.1 ± 0.14	17.4 ± 1.19

This could probably be due to the fact that the studies were conducted at different ecological areas or the earlier works might have dealt with very old trees. The present finding however, conforms to earlier study by Sanou *et al.,* (2011) who reported a mean height of baobab trees as 15.5 ± 1.10 m in Burkina Faso and this could be possible because of the relative proximity of the two study sites. That is Doba in Ghana and Nobere in Burkina Faso.

Similarly, the mean girths of the various baobab stands did not vary (F = 1.310, df = 30, P = 0.286) (Table 1). Baum, (1995) reported that the trunk of baobab tree is swollen and giant individuals can reach a girth of 28 m. Also, according to Gebauer *et al.,* (2002) the baobab tree has a short and a stout trunk which attains 10 m to 14 m or more in girth. The present findings showed that the girth of baobab trees at the three different stand regimes did not agree with the earlier studies conducted by Baum, (1995) and Gebauer *et al.,* (2002) in Sudan. The lower girth values obtained in the present study as compared to earlier ones may be attributable to differences in site factors such as soil and microclimate.

The mean crown diameter also followed the trend of the mean girth (F = 1.734, df = 30, P = 0.196) (Table 1). Sanou *et al.,* (2011) also reported a mean crown diameter of baobab stands as 16.52 ± 0.82 m in their study in Burkina Faso. However, the range of crown diameter in this study exceeds that reported earlier by Sanou *et al.,* (2011) and this may be possible because the current study occurred in a relatively humid area than that of Sanou *et al.,* (2011). In general, wide crowns cast larger shade than smaller crowns and since the people in the study area were observed to cultivate their food crops close to baobab trees, it may have implications because of its shading effects.

3.2. Abundance of Neighbouring Tree/Shrub Species

In general, average of 5.5 associated woody species were recorded in each baobab stand category (Table 2).

However, there were no significant differences among the relative abundance of associated woody species located at the various baobab sites (X^2 = 11.00, df = 8, P = 0.202). Indeed, *Vitellaria paradoxa*, *Diospyrus mespiliformis* and *Fadherbia albida* were found in all the three baobab sites (Table 2). According to Baum (1995) and Purseglove, (1982) baobab is frequently associated with similar habitats of *Tamarindus indica*, *Vitellaria paradoxa, Parkia spp, Balanites aegyptiaca* or *Fadherbia albida.* Surprisingly, no *Parkia biglobosa* tree was found in this study, as has been widely reported to be one of the commonest species in the Savanna parklands. The absence of the species could be attributed to unfavourable soil factors. Also, the destruction of the parklands by seasonal fires, grazing and cultivation might have affected the natural regeneration and probably the population of mature species of *Parkia biglobosa* in the area.

Contrary to all the above measured parameters, there were differences among the basal areas of the woody species found at the three baobab sites (F= 25.541, df = 6, P= 0.037). The basal area of other woody species located at the highly-clumped sites (2.1099 m^2/ha) was higher than those at the moderately-clumped sites (1.4319 m^2/ha) and those at the isolated baobab sites (1.1925 m^2/ha). Thierry *et al*., (2012) reported woody species basal areas in protected and unprotected Savanna vegetation as 19.2 m^2/ha and 16.6 m^2/ha respectively. Also study conducted by Kangbeni *et al*., (2014) in Savanna vegetation reported basal areas of woody species in shrub-land Savanna, woodland Savanna and tree Savanna as 40.63 ± 20.63 m^2/ha, 25.90 ± 11.3 m^2/ha and 22.76 ± 9.1 m^2/ha respectively. Thus, the lower basal area values obtained in the current study could be attributable to a disturbance effect on woody species which may be linked to the cutting of trees for fuel wood and other domestic uses and consequently degrading the ecosystem of the area.

There was no significant difference among the species richness of the associated woody species found at the three baobab stands (X^2 = 12.00, df = 12, P = 0.446). However, there were significant differences (F = 161.19, df = 6, P = 0.006) among the associated woody species diversity at the various baobab stands. The results thus showed that woody species diversity at the highly-clumped baobab sites was the highest (1.09 ± 0.12) among the three sites (Table 2). Brookman-Amissah *et al.,* (1980) earlier reported woody species diversity in the Savanna vegetation as 6.17, 6.75 and 5.47 respectively for protected plots, early burnt plots and late burnt plots. Thus, the woody species diversity indices obtained in this study did not agree with the earlier work and might probably due to the fact that the current study was carried out in the open parkland as opposed to the earlier work which was conducted in a forest reserve, where logging is completely prohibited leading to richer diversity than the open parkland. The result on the contrary is consistent with that (0.55 and 1.26) of Mwase *et al.,* (2007) reported in miombo woodland in Malawi.

Table 2: *Abundance of other woody species situated at various baobab sites*

Stands regime	Species	Total counts	Rel. abundance (%)	Basal area (m^2/ha)	Species richness	Species diversity
Highly-	*Vitellaria paradoxa*	5	24	0.8501	1.43±0.23	1.09±0.12
clumped	*Balanites aegyptiaca*	3	14	0.2178		
	Azadirachta indica	1	9	0.0201		
	Anogeissus leiocarpus	1	9	0.1810		
	Diospyros mespiliformis	1	10	0.1320		
	Fadherbia albida	1	10	0.2552		
	Spondias monbin	1	10	0.4537		
Mod'ly-	*Vitellaria paradoxa*	3	50	0.8063	1.10±0.34	0.83±0.21
clumped	*Balanites aegyptiaca*	1	17	0.1134		
	Azadirachta indica	1	17	0.0380		
	Diospyros mespiliformis	1	17	0.1320		
	Fadherbia albida	1	25	0.3422		
Isolated	*Vitellaria paradoxa*	1	33	0.1320	1.19±0.12	0.94±0.13
Stands	*Diospyros mespiliformis*	2	50	0.3061		
	Fadherbia albida	1	25	0.2923		
	Acacia hockii	1	50	0.0661		
	Tamarindus indica	1	33	0.3960		

3.3. Effects of Various Baobab Stands on Aboveground Biomass of Associated Woody Plants

There were differences among the aboveground biomass of the various woody species located at the three different baobab stand sites (F = 29.636, df = 6, P = 0.032). Like the trend of the basal area of the woody species, the greatest mean aboveground biomass (4539.18±715.97 kg/ha) of the woody species was recorded at the highly-clumped sites with the least found at the isolated stands (2497.36±1088.87 kg/ha) (Table 3).

The differences in the aboveground biomass of associated woody species at the various baobab regimes could be attributed to relatively larger sizes of those plants at the highly-clumped sites. Stijn *et al*., (2000) reported aboveground biomass of woody trees/shrubs in 12 plots of their study to range between 760 kg /ha and 3490 kg/ha. The results obtained in this study suggest that there was a higher woody biomass at the highly-clumped baobab sites in the study area and this could probably arise from the fact that those sites were relatively remote from homesteads and might have been minimal affected by bushfires and other anthropogenic consequences that affect woody species. In the Savannas in general, the spatial pattern of woody plants is driven by climate, topography, soils, competition, herbivory and fire over a wide range of scales (Skarpe, 1992; Scholes and Archer, 1997).

Table 3: *Aboveground biomass of woody species situated at various baobab sites*

Stands type	Associated woody species	Species biomass (kg/ha)	Mean biomass (kg/ha)
Highly-clumped stands	*Vitellaria paradoxa*	5234.72	4539.18±715.97
	Balanites aegyptiaca	1677.06	
	Azadirachta indica	83.37	
	Anogeissus leiocarpus	1066.98	
	Diospyros mespiliformis	752.11	
	Fadherbia albida	1628.29	
Moderately-clumped stands	*Spondias monbin*	3174.40	
	Vitellaria paradoxa	5178.35	2996.23±1108.10
	Balanites aegyptiaca	635.73	
	Azadirachta indica	182.10	
	Diospyros mespiliformis	765.35	
	Fadherbia albida	2227.16	
Isolated stands	*Vitellaria paradoxa*	765.35	2497.36±1088.87
	Diospyros mespiliformis	1803.56	
	Fadherbia albida	1892.03	
	Acacia hockii	326.08	
	Tamarindus indica	2705.05	

3.4. Effects of various baobab stands on Aboveground Biomass of Associated non-woody Plants

There were no significant differences among the non-woody species biomass at the various baobab stands as well as in the control plots (F = 1.838, df = 27, P = 0.134) (Table 4abc). However, the results showed that there were significant differences (F = 94.383, df = 15, P = 0.012) among the non-woody species biomass in the concentric zones under the various baobab stands. The mean biomass values of the non-woody species in the concentric zones under the three baobab stands are in the order: zone C > zone B > zone A. Similarly, the species biomass followed the same trend under the isolated stands. However, the biomass order changes to zone B > zone C > zone A under the moderately-clumped stands while the order is: zone C > zone A > zone B under the highly-clumped stands, The biomass values of the non-woody plants differ significantly under the various concentric zones probably because of the gradient of the trees effect especially in relation to shading. For instance, Medina (1982) reported in the Savannas of South and Central America that C_3 grasses grow only under tree canopies and never grow in the open grassland usually dominated by C_4 grasses. Normally, plant species differ in the degree of their tolerance to shade and might probably cause the variation in their distribution around the baobab trees and consequently biomass yield in the various concentric zones.

The biomass values of *Acalypha fimbriata* in zones A under the isolated, moderately-clumped and highly-clumped stands were 24.69 ± 4.88 g/m^2, 79.69 ± 1.59 g/m^2 and 271.53 ± 50.69 g/m^2 respectively (Tables 4abc) but the biomass values of *Pennisetum purpureum* in zones A under the corresponding stands regimes was 0 g/m^2 throughout. The non-woody species which are typically grasses (Poceae) notable *Pennisetum purpureum*, *Sporobolus jacquemonti* and *Tephrosia pedicellata* have recorded no biomass values in the completely shaded area (zone A) under the various baobab stands. These species have not been present under the canopies presumably because they are C_4 grasses and thus are intolerant of shade. In a study conducted by Stijn *et al*., (2000) in a Savanna vegetation, the biomass yield of a non-woody species (*Hyperhenia hirta*) mean value in an enclosure was 1.11 ton/ha while its mean value in an unprotected area, where cattle were allowed to graze was 0.16 ton/ha.

Table 4a: *Biomass of non-woody species in the neighbourhood of highly-clumped baobab stands*

Species	**Zone A**	**Biomass (g/m²)** **Zone B**	**Zone C**	**Contr.**
Acalypha fimbriata	271.53±50.69	28.89±5.31	0	0
Ageratum conyzoides	0	0	3.2±0.61	17.98±2.99
Bidens pilosa	14.18±3.80	99.81±4.33	101.2±20.27	99.21±11.08
Cassia obtusifolia	12.23±2.21	26.94±1.08	49.08±4.27	50.01±10.51
Commelina sp.	3.1±0.95	24.98±0.69	28.03±2.08	0
Cynodon dactylon	0	0	25.70±0.94	18.60±0.82
Cyperus rotundus	0	44.36±4.22	0	28.17±3.75
Digitaria gayana	0	0	24.46±2.17	0
Dioscorea lecardii	13.42±1.95	0	0	0
Entada africana	0	0	30.71±2.52	0
Heptis pectinata	163.41±10.44	28.89±1.94	6.1±1.00	2.07±1.69
Loudetia annua	0	116.61±13.01	0	24.28±2.90
Mucuna pruriens	0	10.70±1.31	0	0
Pennisetum pedicellatum	5.6±1.55	20.01±3.28	54.2±4.33	93.41±4.61
Pennisetum purpureum	0	0	12.88±1.23	108.55±7.21
Sida acuta	42.46±5.77	205.6±10.47	15.12±1.50	0
Sorghastrum bipennatum	0	0	32.71±3.32	0
Spilanthes filicaulis	0	28.1±1.51	0	0
Sporobolus jacquemonti	0	0	56.78±10.44	69.72±1.80
Stylochiton hypgaeus	10.04±3.74	18.8±1.34	5.9±0.47	12.68±0.53
Tephrosia linearis	0	0	22.10±3.02	0
Tephrosia pedicellata	0	60.46±4.46	77.74±19.91	62.03±4.20
Tridax procumbens	44.21±3.39	17.8±2.53	36.7±2.36	0
Triumfetta rhomboidea	187.35±24.09	0	0	0
Zornia latifolia	0	0	23.30±1.16	0
Means per zone	396.81±135.56	347.64±110.63	449.50±96.37	0

Table 4b: *Biomass of non-woody species in the neighbourhood of moderately-clumped baobab stands.*

Species	Biomass (g/m^2) Zone A	Zone B	Zone C	Contr.
Acalypha fimbriata	79.69±1.59	87.55±2.23	0	0
Ageratum conyzoides	46.95±3.29	12.56±1.40	0	17.98±2.99
Aristida kersingii	0	0	31.44±3.99	41.20±2.28
Brachiaria deflexa	0	17.36±1.28	0	0
Cassia obtusifolia	41.39±2.28	26.98±2.02	0	50.01±10.61
Cymbopogon giganteus	0	0	259.33±25.66	71.22±14.91
Cynodon dactylon	0	26.27±3.69	22.94±1.64	18.60±0.82
Desmodium toruosum	0	20.73±0.71	0	0
Hackelochloa granularis	24.91±1.51	0	0	0
Heptis pectinata	36.27±2.06	43.42±7.09	0	2.07±1.69
Hyperthelia dissolute	0	0	137.95±7.90	0
Hypoestes cancellata	0	160.51±6.51	0	0
Indigofera sp	27.15±4.16	16.17±3.54	0	0
Loudetia annua	0	87.48±1.48	0	24.28±2.90
Ludwigia decurrens	0	0	8.92±1.39	0
Melanthera scandens	12.97±1.60	68.9±5.72	0	0
Monechma ciliatum	20.87±1.49	33.61±4.19	0	0
Pennisetum pedicellatum	0	33.28±0.94	69.88±8.92	93.41±4.61
Pennisetum purpureum	0	0	20.73±2.97	108.55±7.21
Schizachyrium exile	0	346.47±23.40	0	0
Setaria pallidafusa	0	0	68.92±4.42	0
Sida acuta	56.38±3.63	89.60±11.22	64.49±2.76	0
Tephrosia pedicellata	0	23.10±1.12	0	62.03±4.20
Waltheria indica	0	0	35.44±5.46	0
Means per zone	352.38±158.34	601.94±137.22	513.14±147.38	0

Table 4c: *Biomass of non-woody species in the neighbourhood of isolated baobab stands.*

Species	Biomass (g/m^2) Zone A	Zone B	Zone C	Contr.
Acalypha fimbriata	24.69±4.88	22.31±2.58	0	0
Acanthospermum hispidium	0	12.36±1.67	17.85±0.72	0
Ageratum conyzoides	42.15±3.15	14.78±1.28	71.22±5.16	17.98±2.99
Andropogon gayanus	0	0	67.43±2.33	0
Anthephora ampulacea	0	45.83±0.87	33.63±1.34	0
Aristida kersingii	0	0	42.68±13.61	41.20±2.28
Brachiaria deflexa	0	35.14±3.05	35.21±2.16	0
Cassia obtusifolia	0	41.2±5.06	23.56±1.22	50.01±10.61
Chloris pilosa	0	26.68±0.73	22.71±2.05	0
Commelina sp.	21.23±1.44	0	0	0
Cymbopogon giganteus	0	2.01±0.60	98.52±5.32	71.22±14.91
Cyperus articulatus	41.56±0.73	54.11±3.36	36.71±4.92	0
Desmodium toruosum	26.51±0.84	0	0	0
Dioscorea lecardii	30.41±6.51	21.64±4.97	0	0
Heptis lanceolata	0	7.47±1.13	0	0
Heptis pectinata	14.57±2.39	11.67±0.39	4.68±1.01	2.07±1.69

Species	Zone A	Biomass (g/m^2) Zone B	Zone C	Contr.
Leucas martinicensis	0	16.24±2.69	0	0
Malvastrum sp.	0	0	38.65±2.28	0
Melanthera scandens	0	6.01±0.60	0	0
Monechma ciliatum	0	0	20.44±2.31	0
Panicum repens	0	0	23.73±1.92	0
Pennisetum pedicellatum	27.76±2.05	67.21±4.59	89.90±16.21	93.41±4.61
Sida acuta	79.52±2.82	12.54±1.62	59.76±4.01	0
Sida cordiafolia	0	118.73±13.01	0	0
Sorghastrum bipennatum	0	0	27.16±1.50	0
Stylochiton hypogaeus	56.12±3.71	23.8±2.25	0	12.68±0.53
Tephrosia pedicellata	0	0	29.30±1.97	62.03±4.20
Tridax procumbens	12.90±1.51	7.88±1.42	21.67±1.92	0
Triumfetta rhomboidea	7.02±0.60	0	0	0
Waltheria indica	25.12±2.02	0	0	0
Means per zone	154.93±80.12	230.25±80.80	329.70±78.66	0

3.5. Non-woody Species Diversity at the Various Baobab Stands

There were significant differences (F = 234.397, df = 15, P = 0.005) among the non-woody species diversity at the various baobab stands. The results indicated that zone B (2.07 ± 0.36) under the highly-clumped stands was the most diverse than any other zone in all the three different stands while zone C (1.24 ± 0.24) under the moderately-clumped stands was the least diverse (Fig. 2). Vetaas (1992) reported that trees influence the diversity and productivity of associated herbaceous plants. In the study area in general, the environmental factors can be extreme in most cases and thus the higher diversity in zone B under the highly-clumped stands suggests better microclimate amelioration in the stands.

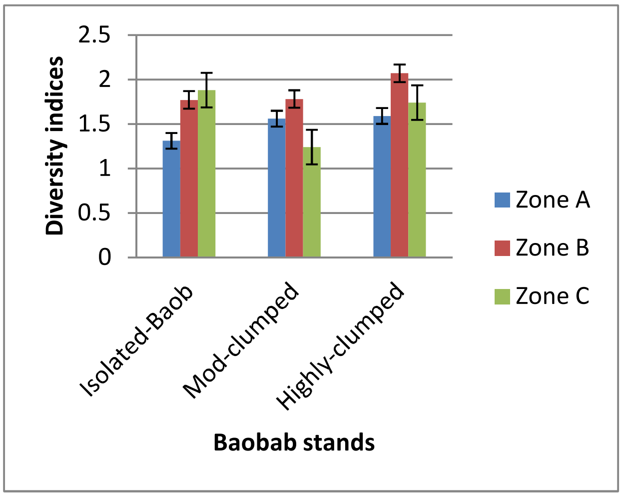

Fig. 2: *Diversity indices of non-woody species at the various baobab stands*

4. Conclusion

The mean heights and the mean girths of the baobab trees at Doba in the Kasena-Nankana East district of Ghana did not vary among the various baobab stands. Similarly, the crown diameters did not show any variation among the various baobab stands Also, there was no difference among the relative abundance of the associated woody species at the various baobab stands. However, *Vitellaria paradoxa, Diospyrus mespiliformis* and *Fadherbia albida* were found in all the three baobab sites. Contrary to all the above, there were differences among the basal areas of the woody species found at the three baobab sites. The basal area of associated woody species located at the highly-clumped sites was higher than those at the other two baobab sites. Also, there was no difference among the species richness of the woody species at the three baobab stands. However, there were differences among the associated woody species diversity at the various baobab stands. Thus, the woody species diversity at the highly-clumped baobab sites was the highest among the three sites. Furthermore, the greatest mean aboveground biomass of the woody species was recorded at the highly-clumped sites with the least found at the isolated stands.

The mean biomass values of the non-woody species did not vary under the various baobab stands but rather vary in the concentric zones under the various stands. The non-woody species diversity pointed out that zone B under the highly-clumped stands was the most diverse than any other zone while zone C under the moderately-clumped stands was the least diverse. Although, the biomass of the various non-woody species was not significantly different under the various baobab regimes, *Heptis pectinata* and *Acalypha fimbriata* biomasses decreased consistently from the canopies of both the clumped and the isolated baobab stands into the open fields. It is therefore, recommended that farm-managed regeneration of woody species in general and baobab trees in particular should be encouraged because the tree has the potential of serving as nurse and/or facilitative plant for some other species in the study area.

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