International Scholars Journals

International Journal of Agricultural Sciences ISSN: 2167-0447 Vol. 15 (4), pp. 001-013, April, 2025. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Forest Structure and Species Diversity in a Ghanaian Semi-Deciduous Tropical Forest

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Accepted 11 October 2024

The species composition of trees and the structure of plant flora of the Kakum National Park (KNP) were studied. A total of 73 species belonging to 63 genera and 28 families were identified in a 2.25 ha of the forest. The most significant families, in terms of the numbers of genera and species, were the Meliaceae, Sterculiaceae, Mimosaceae, Moraceae and Annonaceae. The importance value indices (IVIs) of the species were very low, ranging from 0.39 to 23.17. The Shannon-Weaver and Simpson diversity indices were high (averaging 3.43 and 0.95 respectively) and so was the average equitability (0.80). Most of the species (approximately 93%) were rare. The mean densities of trees and saplings were low with respective values of 257 and 15,043 individuals/ha. The mean density of seedling (50,250 individuals/ha) was high. The mean basal area of the trees was high, 33.76 m^2/ha. The high basal area was mainly due to the contributions of six families: Sterculiaceae, Meliaceae, Lecythidaceae, Sapindaceae, Ulmaceae and Mimosaceae in ascending order of importance. Estimated rates of recruitment and mortality of trees in the various size-classes were high.

Key words: Species composition, moist semi-deciduous, forest, diversity, Kakum

INTRODUCTION

Investigations into floristic composition and structure of forests are essential for providing information on species richness of the plants and the changes that they undergo that can potentially be useful for management purpose and assist in understanding forest ecology and ecosystem functions. The Kakum National Park is a priority conservation area as it is the home of several important species of flora (including mahogany, *Milicia excels* and ebony) and fauna (including the white breasted guinea fowl, the colobus monkey, chimpanzee, hippotamus, pangolius elephant, lion, leopard and the honey badger) (Wagner, Cobbinah and Bosu 2008). The Park may harbour globally significant species yet to be identified; for instance, in 1993, a new species of butterfly (*Diopetes kakumiú*), hitherto unknown to science was discovered in it (Wagner, Cobbinah and Bosu 2008). Tropical forests, with their myriad of species, benefit humans and other life-forms immensely, directly or indirectly. Food, medicine, timber and a number of non-timber forest products are obtained directly from the forest. Indirect ecosystem benefits of the biodiversity include protection of watershed and habitats of fauna, cycling of nutrients, carbon sequestration and regulation of local climate. The biological diversity of tropical forests is immense (Jordan, 1995; Swenson, 2009), not only at the genetic level but also at the species, community and ecosystem levels (Sandlund et. al., 1992; Lewis, 2009).

In a tropical forest community, there is a lack of species dominance (Townsend et. al., 2008), which coupled with the high species diversity makes it very vulnerable (Jacobs 1988), particularly for unmanaged or ill-managed forests where the forest is disturbed as a result of human activities. Pickett and White (1985) define disturbance as a relatively discrete event in time that disrupts ecosystems, community or population structure and changes resources, substrate availability or the physical environment. Forest disturbance will result in changes in the floristic composition and structure (Addo-Fordjour et. al., 2009). The lack of species dominance, with few individuals within a given species per hectare, implies that a forest disturbance can result in some plant species to dominate, while driving others to become extremely rare.

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Tropical forests are complex ecosystems (Gibbs *et. al.*, 2007) that are not fully understood (Richards, 1964). What may seem like unchanging climax vegetation actually undergoes subtle changes in floristic composition and structural attributes whereby continuous flux of different species of varying recruitment and mortality rates occur (Whitmore, 1992). Forest structure is a broad concept that relates to species distribution patterns, species quantities, species diversity (Schaberg et. al., 2008) and mapped patterns or mosaics of species associations (Lewis, 2009). However, there has not been much documentation on the floristic composition and structure of most of the forests in Ghana for the consumption of the scientific community; save for those of Vordzogbe et al. (2005), Anning et al. (2008) and Addo-Fordjour et al. (2009); and Hall and Swaine (1981), Hawthorne (1990), Hawthorne and Jongkind (2006) on diversity of plant species. There is the need, therefore, for regular survey of the forest to generate information on its compositional and structural attributes to update existing ones and thereby contribute knowledge to the understanding of the forest ecosystem for effective management. The aim of the study was to investigate the characteristics of the flora of the KNP to establish baseline information for future research projects. This park prohibits the exploitation of natural resources and instead serves scientific, educative, recreational, and aesthetic interests.

The objectives of the study were to: 1. determine the species composition of the trees, 2. investigate the diameter–class distribution of the trees, 3. determine the abundance of the trees, saplings and seedlings and the ecological importance of the trees, 4. estimate the regeneration potential and mortality of the trees and 5. to assess the distribution of climbers (lianas together with vines) in relation to the trees.

Study area

The KNP occupies an area of 213 km^2 and is located between longitudes 1^o 16' W and 1^o 27' W and latitudes 5^o 20^1 N and 5^o 30' N. The KNP lies about 25 km north of Cape Coast in the Central Region of Ghana (Twumasi, 2001) and harbors the headwaters of several rivers of which the most important is the Kakum River from which the Park derives its name (Figure. 1).

The forest was demarcated between 1925 and 1926 and was designated a Reserve in 1933. The forest has had a long history of exploitation selective logging

(Paijmans and Jack, 1960), ranging from subsistence farming, mining of clay to timber extraction (Agyare, 1985); enrichment planting had also been practiced in the past (Paijmans and Jack, 1960) prior to its conversion into a national park in 1989 (Eggert, et. al., 2003).

The KNP receives two periods of rainfall – from late March to July and from September to mid November with a mean annual rainfall of 1328 mm and a high relative humidity of about 90 % (Twumasi, 2001). The geology comprises intrusive granite gneiss of the Cape Coast Granite Complex outcrops (Paijmans and Jack, 1960). The soils are Gleyic Acrisols belonging to the Kakum Series (Owusu-Bennoah et al, 2000).

The forest of the KNP is Moist Semi-Deciduous: South East Subtype (Figure. 2) with two types of plant associations that have been identified: these are *Lophira-Triplochiton* Association to the north and *Celtis-Triplochiton* Association to the south (Paijmans and Jack, 1960, Hall and Swaine 1981). Some of the genera in this association include *Celtis*, *Lophira* and *Tarrietia*. Also present in this forest are species of the following genera, *Cola, Pterygota, Sterculia, Nesogordonia, Entandrophragma, Khaya* and *Lovoa.* The most frequent members of the Moraceae are *Antiaris, Bosqueia* and *Milicia.* The *Celtis-Triplochiton* Association, which is a climatic climax vegetation of the Moist Semi-Deciduous forest, contains species of the genera, *Celtis, Triplochiton, Piptadeniastrum* and *Khaya. Tarrietia* is absent while *Lovoa* and *Parkia* is rare in this Association (Taylor, 1960).

MATERIALS AND METHODS

Sampling of Trees

A total of 100 plots, each measuring 15 m x 15 m was randomly selected in each of four forest stands. By stand, it is meant any part of the forest that is selected for a study (Mueller-Dombois and Ellenberg, 1974). Within each of these plots, all trees ≥ 31 cm girth at breast height were measured using a surveyor’s tape. Girth height was taken to be 1.3 m above the forest floor. In the event where a tree had more than a single stem, the main trunk was measured at the narrowest point below the branches. Trees that were very huge or had high buttresses were measured at about 30 cm above the convergence of the protrusions of the buttresses on the bole. The girth at breast height values were converted into diameter at breast height (dbh) values.

Most of the trees were identified in the field by slashing the bark and then looking for diagnostic features like color, smell, and exudates among others. Specimens of the bark, leaves, flowers and fruits, where available, of those species that could not be identified were collected and identified using standard reference textbooks (Hutchinson and Dalziel, 1958; Irvine, 1961; Hawthorne, 1993; Hawthorne and Jongkind, 2006).

Sampling of Saplings and Seedlings

Within each 15 m x 15 m plot, a 4 m x 4 m subplot was demarcated in the middle. The total number of saplings (individual plants ≥ 2.5cm < 10 cm dbh by inspection) was counted and recorded. A 2 m x 2 m subplot was nested, in a similar manner, within each of the 4 m x 4 m subplots for determining the number of seedlings (individual plants >1.5 m high).

Climber Distribution

The presence of climbers on trees affects their growth and

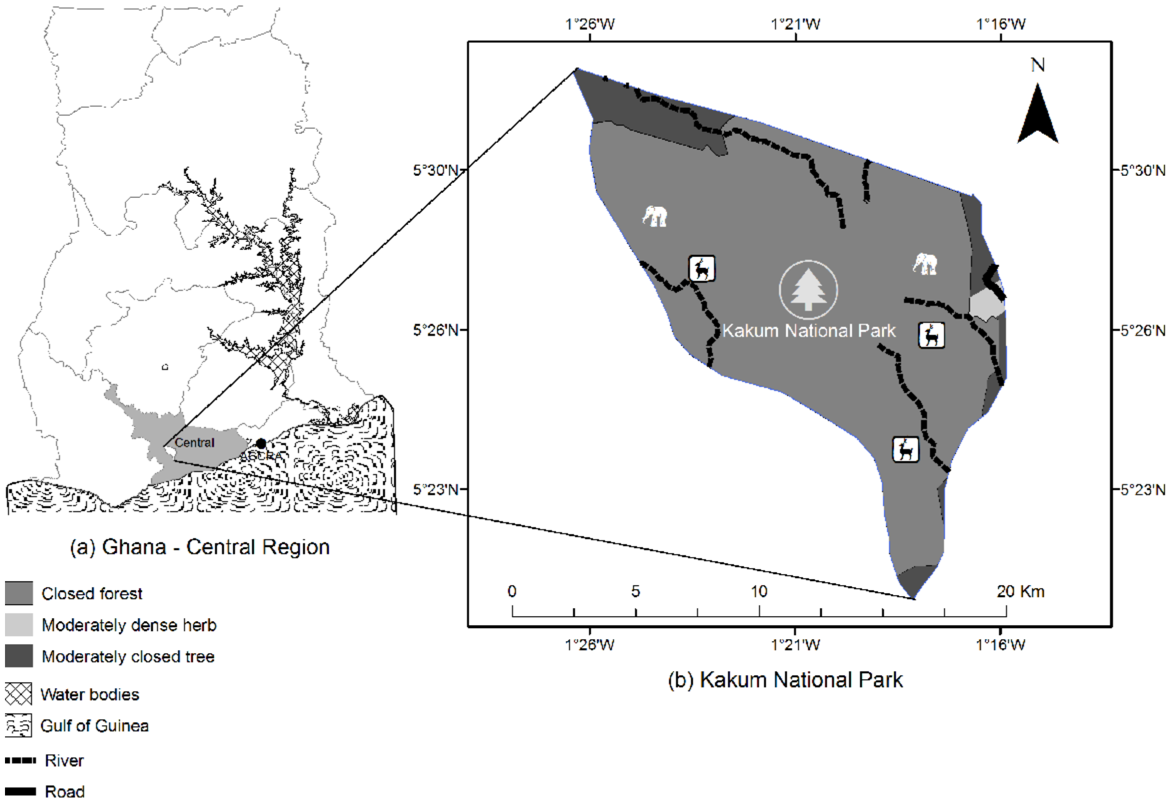

Figure 1. Location of the Kakum National Park

development. They have been noted to suppress natural regeneration and delay forest recovery (Babweteera et. al., 2001). The presence or absence of climbers on the trees was scored on a 5-point scale (Alder and Synnott, 1992) whereby 0, 1, 2, 3 and 4 represented trees that were: free of climbers; climbers on the stem only; climbers in the crown only; climbers on the stem and crown; and trees that were smothered by climbers respectively.

Community Analyses

The ecological status of the tree species was determined by calculating the importance value index (IVI) for each species. The IVI was obtained by summation of the relative percentage values of frequency, density and dominance (Oyun, et. al., 2009). The Law of Frequency or valence analysis (Raunkaier, 1934) was used to assess the rarity or commonness of the tree species (Hewit and Kellman, 2002; Pirie et. al., 2000). In this classification the percentage frequency of the species was classed as A, B, C, D and E; where A represents rare (0–20%), B is low frequency (20–40%), C is intermediate frequency (40–60%), D is moderately high frequency (60–80%) and E is high frequency or common (80– 100%). With this classification, the expected distribution of the species is A>B>C≤ ≥D<E. The diversity of trees (individuals ≥10 cm dbh or ≥ 31 cm gbh) was determined for each stand using Simpson's and Shannon-Weaver diversity indices (Vasanthraj and Chandrashekar, 2006).

Ecological guild and star rating of the tree species were determined (Hawthorne, 1993; Hawthorne and Gyakari, 2006). Ecological guild of the species were classified as: pioneer, non-pioneer light-demanding and shade-bearing. The species were star rated as: Black Star, species rare internationally and at least uncommon in Ghana; urgent attention to conservation of populations needed; Blue Star, widespread internationally but rare in Ghana or vice-versa; Scarlet Star, common, but under serious pressure from heavy exploitation; Red Star, common, but under pressure from exploitation; Pink Star, common and moderately exploited, also non-abundant species of high potential value; and Green Star species, no particular conservation concern, common in Ghana.

Stand Basal Area and Density Determinations

Basal area and densities were determined on per hectare basis (Mishra et al., 2005; Addo-Fordjour et al., 2009). The basal areas of the trees in each stand were summed up and converted to basal area per hectare. The mean basal area per hectare was calculated, using the individual values obtained from the four forest stands. The densities of trees, saplings and seedlings were also calculated on per hectare basis for each stand and used to the calculate mean number of individuals/ha for the entire stands.

Regeneration and Mortality of Tree Species

The linear transformation of the power function model (Hett and Loucks, 1976), relating the diameter of trees or saplings to the number of trees or saplings was used to estimate the recruitment potential and the mortality rate of the trees. Regression analysis was used to assess the rate of mortality (Hett and Loucks, 1976; Veblem et. al., 1980), where the recruitment of trees into the

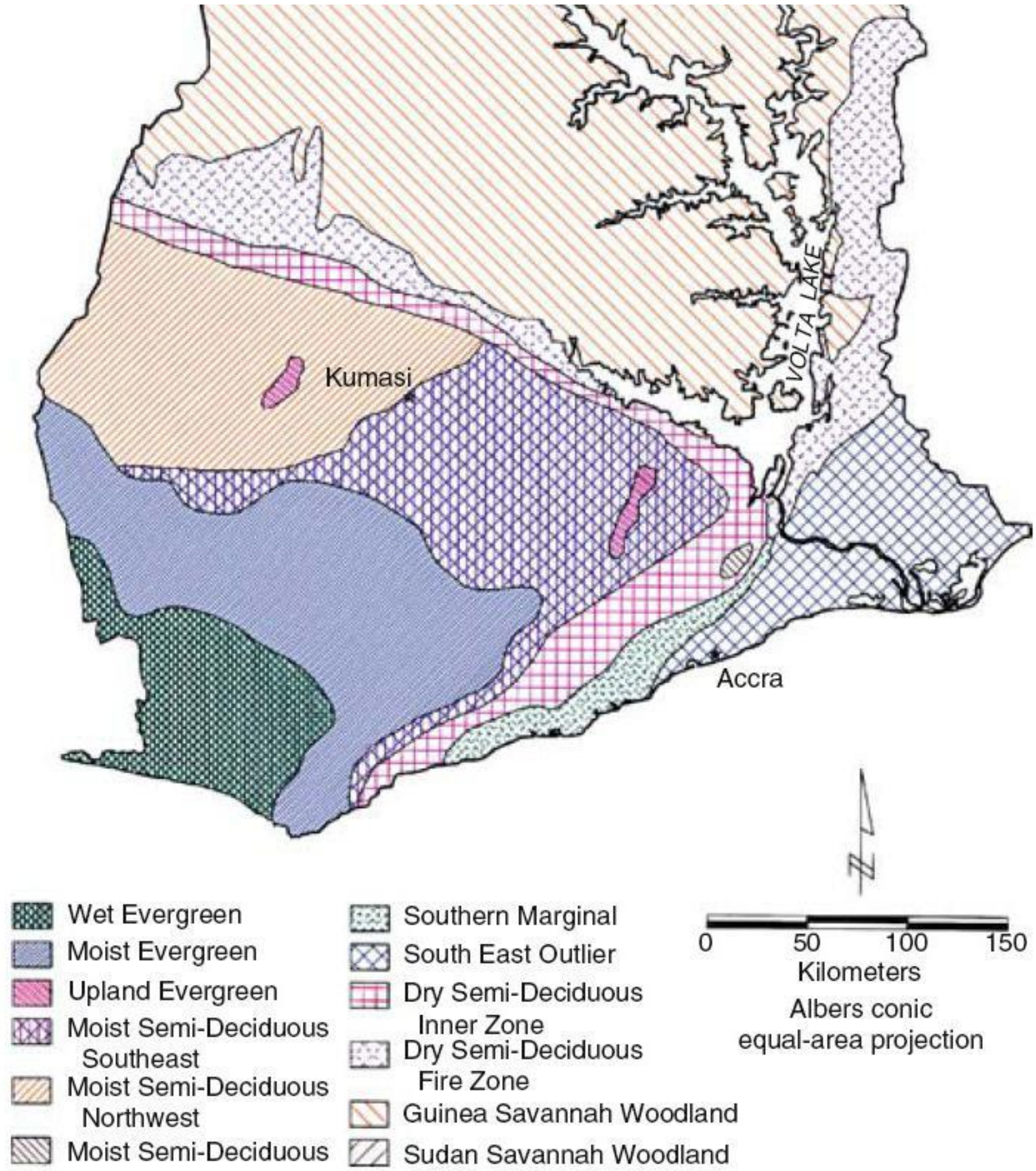

Figure 2. Forest type of the study area (Moist Semi-Deciduous Southeast)

various diameter-size classes was estimated by the coefficient of determination and the number of trees dying in a given size-class was determined from the slope of the regression equation.

RESULTS

Floristic Composition and Occurrence

In our study there were 73 species belonging to 63 genera and 28 families (Table 1). The most common families were the Meliaceae and Sterculiaceae, each represented by 7 species; followed by the Mimosaceae, Moraceae and Annonaceae, represented by 5 species in each case. All the species in our study had a wide range of occurrence, ranging in frequency from 1 to 41 % (Table 1). There were a high number of tree species that occurred only once. The distribution of the 74 species into Raunkaier's frequency classes showed that almost all the species encountered were rare (Table 2). A few species, however, were of the low and intermediate

Table 1. Families, species, ecological importance, guild and star rating of trees (≥ 10 cm dbh) in the Kakum National Park.

Family	Species	Fr (%)	Density (No. of trees)	BA (m^{-2})	IVI	Guild	Star rating
Meliaceae	Entandrophragma angolense (Welw.) C.DC	4	4	2.59	4.95	Non-pioneerlight-demanding	Red
	Entandrophragma cylindricum (Sprague) Sprangue	1	1	0.15	0.57	Non-pioneerlight-demanding	Scarlet
	Khaya ivorensis A. Chev.	3	3	0.59	1.92	Non-pioneerlight-demanding	Scarlet
	Trichilia heudelotii Planch	7	14	0.67	4.75	Non-pioneerlight-demanding	Green
	Trichilia lanata A. Chev.	1	1	0.04	0.43	Non-pioneerlight-demanding	Green
	Trichilia prieuriana A. Juss.	9	9	0.87	4.56	Non-pioneerlight-demanding	Green
	Turraeanthus africana (Welw. Ex C.DC)	6	7	0.78	3.48	Shade-bearing	Pink
Sterculiaceae	Cola gigantea A. Chev.	7	7	0.56	3.40	Non-pioneerlight-demanding	Green
	Cola nitida (Vent) Schott. & Engl.	1	1	0.02	0.40	Shade-bearing	Pink
	Nesogordonia papaverifera (A. Chev.) R Capuron	16	18	2.38	9.56	Shade-bearing	Pink
	Sterculia oblongata Mast.	1	1	0.06	0.45	Non-pioneerlight-demanding	Green
	Sterculia rhinopetala K. Schum	14	15	1.93	8.03	Non-pioneerlight-demanding	Pink
	Tarrietia utilis Sprague	6	6	0.16	2.64	Non-pioneerlight-demanding	Red
	Triplochiton scleroxylon K. Schum	2	2	0.22	1.04	Pioneer	Scarlet
Annonaceae	*Cleistopholis patens* (Benth.) Engl. & Diels	3	3	0.15	1.33	Pioneer	Green
	Enantia polycarpa Engl. & Diels	9	10	0.34	4.03	Shade-bearing	Green
	Monodora myristica Dunal	8	8	1.75	5.35	Shade-bearing	Green
	Xylopia parviflora (A Rich.) Benth.	6	6	0.37	2.75	Shade-bearing	Green
	Xylopia quintasii Engl. & Diels	3	3	0.15	1.33	Shade-bearing	Green
Mimosaceae	*Albizia adiantifolia* (Schumach) W.F. Wright	7	8	0.36	3.30	Non-pioneerlight-demanding	Green
	Albizia ferruginea Benth	1	1	1.27	2.06	Non-pioneerlight-demanding	Scarlet
	Cylicodiscus gabunensis Harms	2	2	2.88	4.58	Shade-bearing	Blue
	Parkia bicolor A. Chev.	2	2	0.92	1.98	Non-pioneerlight-demanding	Green
	Piptadeniastrum africanum (Hook. F.) Brenan	6	6	2.97	6.06	Non-pioneerlight-demanding	Pink
Moraceae	Antiaris toxicaria Lesch	6	6	1.18	3.82	Non-pioneerlight-demanding	Pink
	Bosqueia angolensis Ficalho	4	4	0.80	2.55	Non-pioneerlight-demanding	Green
	Milicia excels (Welw.) Benth.	2	2	0.41	1.30	Pioneer	Scarlet
	Morus mesozygia Stapf.	2	2	0.08	0.86	Pioneer	Green

Table 1. continue

	Musanga cercropioides R.Br.	1	1	0.11	0.51	Pioneer	Green
Apocynaceae	Alstonia boonei De Wild	6	6	1.63	4.42	Pioneer	Green
	Funtumia elastica (Preuss.) Stapf	7	7	0.41	3.19	Not available	Pink
	Pleiocarpa muttica Benth.	5	6	0.20	2.32	Shade-bearing	Green
	Voacanga africana Stapf.	1	1	0.01	0.39	Pioneer	Green
Caesalpinaceae	*Daniellia ogea* (Harms) Rolfe ex Holland	3	3	1.30	2.86	Pioneer	Pink
	Distemonanthus benthamianus Bail	2	2	0.90	2.02	Non-pioneerlight-demanding	Pink
	Guibourtia ehie J. Leonard	1	1	0.50	1.04	Not available	Not available
	Cynometra ananta Hutch. & J.M. Dalz	15	18	0.50	6.85	Shade-bearing	Pink
Euphorbiaceae	*Alchornea cordifolia* (Schum & Thonn) Muell Arg.	16	19	0.21	6.92	Pioneer	Green
	Antidesma venosum Tul	3	3	0.20	1.41	Not available	Not available
	Ricinodendron heudelotii (Baill) Pierre ex Pax	5	5	0.95	3.16	Pioneer	Green
	Uapaca guineansis Muell. Arg.	1	5	0.96	2.77	Non-pioneerlight-demanding	Green
Lecythidaceae	Carapa procera DC	27	36	1.07	14.03	Shade-bearing	Green
	Combretodendron macrocarpum (P. Beauv) Keay	12	15	4.08	10.47	Pioneer	Green
	Napoleona leonensis Hutch & Dalz	3	3	0.02	1.16	Shade-bearing	Green
Rubiaceae	Corynanthe paniculata Welw.	1	1	0.07	0.46	Non-pioneerlight-demanding	Green
	Morinda lucida Benth.	2	4	0.11	0.90	Not available	Not available
	Nauclea diderrichii (De Wild) Merrill	1	1	0.29	0.75	Pioneer	Scarlet
Sapotaceae	Chrysophyllum albidum G. Don	3	3	0.14	1.31	Shade-bearing	Pink
	Chrysophyllum pentagonocarpum Engl. & Krause	1	1	0.19	0.62	Shade-bearing	Blue
	Tieghemella heckelii Pierre ex A. Chev.	1	2	0.57	1.12	Non-pioneerlight-demanding	Scarlet
Ulmaceae	Celtis adolphi-friderici Engl.	37	44	6.02	23.17	Pioneer	Green
	Celtis mildbraedii Engl.	19	22	1.73	10.00	Shade-bearing	Green
	Celtis zenkeri C.H. Wright	1	1	0.19	0.62	Non-pioneerlight-demanding	Green
Bombacaceae	Bombax buonopozense P. Beauv.	13	15	1.76	7.59	Pioneer	Green
	Ceiba peniandra (linn). Gaertn.	2	2	1.48	2.73	Pioneer	Green
Guttiferae	Allanblackia parviflora A. Chev.	14	16	1.30	7.36	Shade-bearing	Green
	Mammea africana Sabine	2	3	0.61	1.74	Shade-bearing	Pink
Papilionaceae	Amphimas pterocarpoides Harms	2	2	0.10	0.95	Non-pioneerlight-demanding	Green
	Baphia nitida Lodd.	1	1	0.02	0.39	Shade-bearing	Green
Sapindaceae	Blighia sapida Konig.	17	21	3.28	11.47	Non-pioneerlight-demanding	Green
	Blighia welwitschill (Hien) Radlk.	21	25	3.77	13.62	Non-pioneerlight-demanding	Green
Anacardiaceae	Antrocaryon micraster A. Chev & Guil	2	2	1.00	2.07	Non-pioneerlight-demanding	Red
Boraginaceae	Cordia millenii Baker	2	2	0.04	1.29	Pioneer	Green
Burseraceae	Canarium schweinfurthii Engl.	9	11	1.74	6.41	Pioneer	Pink
Combretaceae	Terminalia superba Engl. & Diels	6	6	3.81	7.31	Pioneer	Pink
Ebenaceae	Diospyros sanza-minika A. Chev.	23	28	0.19	10.72	Shade-bearing	Blue
Irvingiaceae	Klainedoxa gabonensis Pierre ex Engl.	1	2	0.58	1.14	Non-pioneerlight-demanding	Green
Myristicaceae	Pycnanthus angolensis (Welw.) Exel	4	4	0.60	2.32	Non-pioneerlight-demanding	Pink
Ochnaceae	*Lophira alata* Banks ex Gaetn. f.	3	3	2.34	4.24	Pioneer	Red

Table 1. continue

Olacaceae	Strombosia glaucescens var lucida J. Leonard	41	63	1.88	23.14	Shade-bearing	Green
Rutaceae	Fagara macrophylla Engl.	2	2	0.16	0.97	Pioneer	Green
Simaroubaceae	Hannoa klaineana Pierre & Engl.	3	3	0.13	1.31	Pioneer	Green
Verbenaceae	Vitex fosteri C.H. Wright	1	1	0.07	0.47	Not available	Not available

Table 2. Distribution of trees according to Raunkaier's classification scheme.

Code	**Class**	**Number of species (%)**	**Remark**
A	0–20	69 (93.24)	Rare
B	20–40	4 (5.41)	Low
C	40–60	1 (1.35)	Intermediate frequency
D	60–80	0 (0)	Moderately high frequency
E	80–100	0 (0)	High frequency (Common)

frequency classes; namely; *Blighia welwitschia*, *Carapa procera*, *Celtis adolphi-friderici*, and *Diospyros sanza-minika* and *Strombosia glaucescens* respectively. This distribution does not follow the expected A>B>C ≥≤ D<E frequency distribution proposed by Raunkaier (1934) in that frequency classes D and E were not represented.

Ecological Importance of the Tree Species

Overall, the IVI of the species were generally low with a mean of 4.05 ± 0.53. Two species that had the high IVI values were *Celtis adolphi-friderici* and *Strombosia glaucescens*; both of which had identical IVIs of 23.17. The relative frequency, relative density and relative dominance contributed to the IVI of *Celtis adolphi– friderici* in almost equal proportions. *S. glaucescens* owed its IVI largely to the relative density and relative frequency. *Baphia nitida* and *Voacanga africana* had the lowest IVI values of 0.39 and were encountered only once (Table 1).

Ecological Guild and Star Rating of Tree Species

The guilds and star rating of 69 species of trees were determined whiles 4 were not available (Table 1). A large proportion of the trees (~ 40%) was non-pioneer light-demanding followed by shade-bearing species (~ 29 %) and pioneer species (~ 29 %). There was a preponderance of green star species (~ 59 %) followed by pink star (~ 22 %) and scarlet (~ 10 %) whiles the proportion (~ 4 %) was identical for red and blue star species.

Tree Species Diversity

There was high diversity of tree species as revealed by the indices of Shannon-Weaver and Simpson (Table 3). The Shannon-Weaver diversity index gave a mean of 3.43 ± 0.049 while Simpson's index gave a mean diversity value of 0.95 ± 0.004. The mean evenness value of the species was also very high, 0.80 ± 0.012. Variations in the diversity of tree, as revealed by the coefficient of variation, were minimal (Table 3).

Distribution of Climbers

On the average 95±2.27 trees per hectare representing 37.33 % bore climbers; 3.69 % were overgrown with climbers while 9.06% had climbers restricted to the main stem, 6.41% had climbers in the crown only and 18.17% had climbers both the stem and in the crown (Figure. 3).

Stand Structure

There was decline in the number of trees with increasing size (Figure. 4). The mean basal area (33.76 ± 1.81 m^2/ha) of trees was quite high, however, variations in basal area of the trees within the stands were also generally high as can be seen from the values of the coefficient of variation (Table 4). A few families contributed most to the total basal area. These included the Sterculiaceae (7.1 %) Meliaceae (7.6 %), Lecythidaceae (7.8 %), Sapindaceae (9.4 %), Ulmaceae (10.6 %) and Mimosaceae (11.1 %). The decline in number of trees with increasing tree size occurred in all

Table 3. Structural characteristics of plants and diversity measures of trees in the Kakum National Park.

Characteristic	Mean ± s.e.	Coefficient of variation (%)
Tree basal area (m^2/ha)	33.76 ± 1.81	68.4
Tree density (individuals/ha)	257 ± 6.09	22.04
Small trees (10 – 30 cm dbh)	92.22 ± 3.16	11.82
Intermediate trees (30 – 50 cm dbh)	62.22 ± 1.43	4.57
Large trees (>50 cm dbh)	41.47 ± 0.08	3.19
Sapling density (individuals/ha)	15,043 ±519.94	26.78
Seedling density (individuals/ha)	50,250 ± 6,277.39	50.70
Shannon-Weaver index (H^1)	3.43 ± 0.049	3.50
Simpson diversity (D)	0.95 ± 0.004	1.05
Evenness (E)	0.80 ± 0.012	3.75

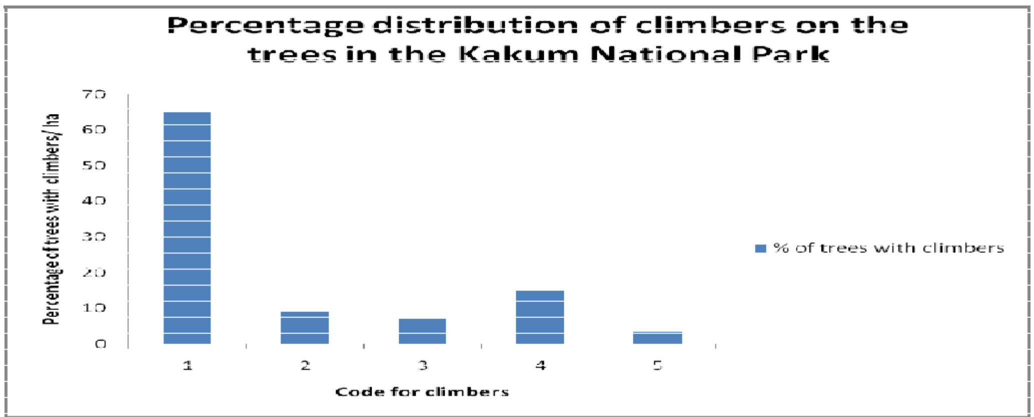

Figure 3. Percentage distribution of climbers in the KNP

the stands investigated (Figure 4).

Thus, many (~ 154 individuals/ha) small trees (10 – 30 cm dbh), a considerable population (~ 61 individuals/ha) of intermediate trees (30 – 50 cm dbh) and a few (~ 41 individuals/ha) large trees (> 50 cm dbh) were encountered.

Abundance of Plant Species

The densities of trees and saplings were low, whereas the density of seedlings was high. The mean tree and sapling densities were 257 ± 6.09 and 15,043 ± 519.39 individuals/ha respectively. The variations in the densities of the trees and saplings were not substantial with mean coefficient of variation of 22.04 % for the trees and 26.38 % for the saplings (Table 3). However, the variations in the density of the seedlings were fairly considerable. The mean coefficient of variation in abundance of the seedling was 50.70 %. The mean seedling density was 50,250 ± 6,277.39 individuals/ha (Table 3).

Tree Species Regeneration and Mortality

The application of the power model to the diameter-size distribution of trees shows that the rate of recruitment of trees into the various diameter-size classes was very high (R^2 = 0.94). The estimated tree mortality in a given size-class was 2.22 per annum (Figure. 5).

DISCUSSION AND CONCLUSIONS

Floristic Composition

The species richness of a forest ecosystem depends on the number of species per unit area; the more species there are per unit area, the higher the species richness. The total of 73 species/ 2.25 ha in the KNP is low compared to the typical 60 to 70 species/ha that have been observed in other studies in West African tropical high forests (Lawson, 1985). Indeed, Vordzogbe et al. (2005) recorded 80 species/ha in a similar forest type in Ghana. However, other researchers have reported lower species richness; 37 species/ha (Anning et al, 2008) and 28 species/ha (Addo-Fordjour et al., 2009) in Ghana. Although the alpha diversity may seem low (32.4 species/ha) in our study, it is comparable to what Anning et al. (2008) recorded in a disturbed semi-deciduous

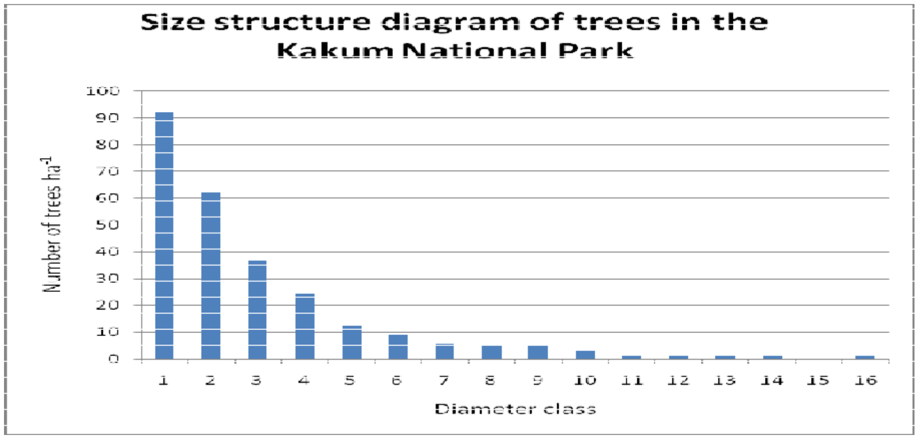

Figure 4. Size structure of trees in the KNP

1=10-20 cm 2=20-30 cm 3=30-40 cm 4=40-50 cm 5=50-60 cm
6=60-70 cm 7=70-80 cm 8=80-90 cm 9=90-100 cm 10=100-110 cm
11=110-120 cm 12=120-130 cm 13=130-140 cm 14=140-150cm 15=150-160 cm
16=160-170 cm

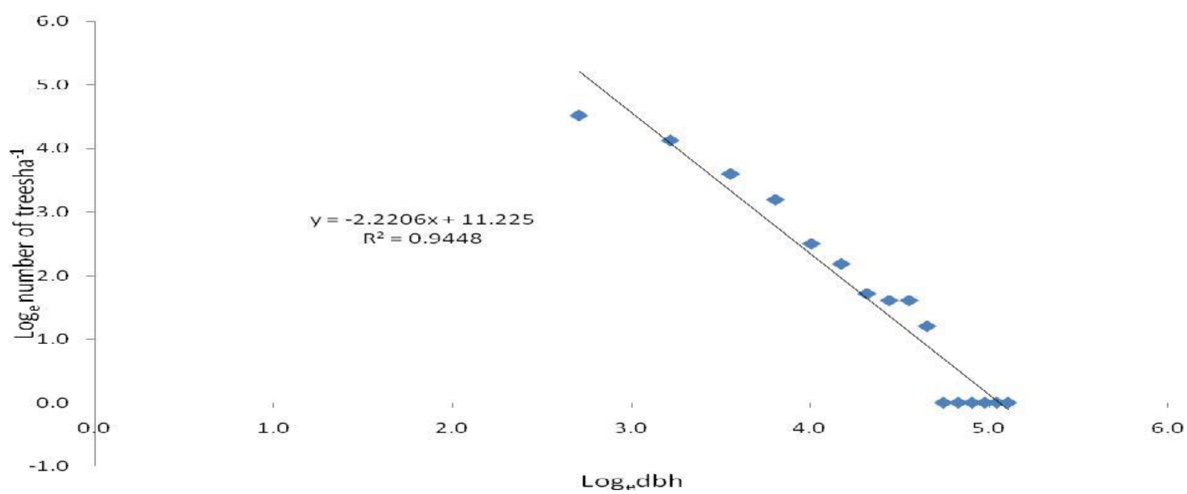

Figure 5. Number of trees dying per size class

forest in Ghana. Thus, the low alpha diversity in this study can be ascribed to the past logging operations.

It has become common practice in quantitative descriptive studies to use IVI, which combines frequency, density and dominance into a single measure to analyze a plant community. Though vegetation can be described in terms of a number of parameters including frequency, density and cover, the use of any one of these quantitative parameters could lead to over-simplification or under-estimation of the status of the species (Kigomo et. al., 1990, Oyun et. al., 2009). Low ecological status of most of the species in our study, as evidenced by the IVIs, may be attributed to lack of dominance by any one species, which suggests positive interactions among the tree species. In other words, resource spaces are shared to minimize negative species interactions and plants can obtain resources with relative ease (Tsingalia, 1990). The low IVIs may also imply that most of the species in this forest are rare (Pascal and Pellissier, 1996; Oyun et. al., 2009), as confirmed by Raunkiaer's frequency distribution of the tree species (Table 1). It should be noted that the summing of the three parameters into one has the effect of increasing the difference between the same species among areas of similar species composition (Oyun et. al., 2009).

The rarity of species may be attributed to the occurrence of abundant sporadic species with low frequency in the stands (Oyun et. al., 2009). The high percentage (93 %) of rare species observed in this study confirms the generally acclaimed notion that most of the species in an ecological community are rare, rather than common (Magurran and Henderson, 2003). The evenness value and Simpson's diversity index of 0.80 and 0.95 respectively imply that up to 80 % of the trees were equitably distributed among the species (Magurran, 1991) while up to 95 % of the trees may be of different species (Pascal and Pellissier, 1996). The mean Shannon-Weaver diversity of 3.43 that was found in our study is slightly lower than the 3.6 recorded in a similar forest type in Ghana (Addo-Fordjour et. al., 2009) that has not been disturbed. This shows that despite its past history of logging, species diversity has not been significantly altered.

The classification of the tree species into guilds revealed a preponderance of non-pioneer light-demanding species over pioneer species. This observation is consistent with Hawthorne (1993). The non-pioneer light-demanding species need gaps to grow just like the pioneer species. However, unlike the latter which regenerate only in gaps, non-pioneer light-demanders require "minor sun-flecks" (Hawthorne 1993). The totality of these two guilds underpins the existence of numerous gaps in the KNP. Surprisingly, the proportion of shade-bearers in relation to pioneers was similar. Typically, shade-bearers are frequently found in the understory; however, their considerable presence may have arisen as a result of the fact that the guild might contain some cryptic pioneers which tolerate light later in life, but whose exact predilections are not known (Hawthorne 1993).

Investigations into the star rating of the trees revealed a high proportion of green star species. This is owing to the fact that these species are common in Ghana and are of no particular conservation concern (Hawthorne and Gyakari, 2006). The pink star species constituted a little over 20 % of the star-rated tree species and are much higher than the scarlet star species which in turn were far higher than the red and blue star species. This can be attributed to the fact that pink star species are non-abundant species (Hawthorne 1993) of high commercial value (Hawthorne 1993; Hawthorne and Gyakari, 2006). Serious pressure from heavy exploitation (Hawthorne and Gyakari, 2006) in the past may be responsible for the low proportion of the scarlet star species. According to Hawthorne and Gyakari (2006), pink star species are threatened in Ghana. Also, pressure from past exploitation might account for the least proportion of red star species encountered in the KNP. Pink star are known to be heavily exploited in Ghana (Hawthorne and Gyakari, 2006). However, the lowest proportion of blue star species could be due to the fact that they are of rarity value in Ghana (Hawthorne and Gyakari, 2006).

The distribution of climbers on the trees of the KNP was considerably high, amounting to 37.33%. This may have arisen as a result of the past logging operations that may have broken the canopy, thereby allowing more light to reach the forest floor to trigger vigorous growth of climbers (Babweteera et al., 2001). Climbers impact on the vitality of trees negatively (Parren, 2003; Toledo-Aceves and Swaine, 2008), causing loss of foliage thereby reducing the surface area available for metabolic processes and reproductive potential as well as impeding or obstructing forest succession (Toledo-Aceves and Swaine, 2008). Notwithstanding their negative impacts, climbers form bridges between the forest canopies, thereby facilitating the movement of arboreal animals across the forest. They also protect weaker trees from strong winds (Schnitzer and Bongers, 2002).

Stand Structure

Stand structure parameters allow predictions of forest biomass and can provide spatial information on potential determinants of plant species distributions (Couteron et al., 2005). In our work stand structure relates to the basal area of trees, density of trees, their distribution into various diameter-size classes and densities of saplings and seedlings. The high mean coefficient of variation (68.40 %) in the basal area among the stands implies that for every 100 individual trees in the KNP as many as 68 belonged to different diameter-size classes (Pascal and Pellissier 1996). The mean tree basal area of 33.76 m^2/ha is high and comparable to the 33.26 m^2/ha obtained at Kade by Greenland and Kowal (1960). High basal area is a characteristic of mature forest stands and serves as a reflection of high performance of the trees. It may also presuppose the development of an extensive root system for efficient nutrient absorption for tree-growth to take place. The high basal area has an implication for subordinate plants as the big trees suppress the growth of small plants by intercepting much of the solar radiation that might otherwise reach the forest floor.

The Mimosaceae had the highest basal area in the present study, followed by the Ulmaceae. These families contain important timber species such as *Piptadeniastrum africanum* and *Celtis* spp. However, the Moraceae, which contains tree species with natural inclination to grow very large, did not contribute very much to the total basal area. The low contribution by the Moraceae to the total basal area in the KNP may be due to an over-exploitation of certain species belonging to the family (*e.g.*, *Antiaris toxicaria* and *Milicia excelsa*) for their economic value (Hawthorne and Gyakari, 2006).

The Boraginaceae, Irvingiaceae, Myristicaceae, Papilionaceae, Rubiaceae, Rutaceae, Simaroubaceae and Verbenaceae did not contribute much to the total basal area. In all the stands investigated, Verbenaceae was represented by one individual while Boraginaceae, Irvingiaceae and Rutaceae were represented by two individuals each. The Papilionaceae and Simaroubaceae were represented by three individuals each with Myristicaceae and Rubiaceae being represented by four individuals in each case. This implies that the very low contributions of these families to the total basal area may be due to their low numbers. Thus, these families may not be very important in terms of dominance. For instance, the Rutaceae has been noted not to be important in tropical forests (Mwavu and Witkowski, 2009). However, species of this family become more important in their populations and distribution under drier conditions (Lieberman, 1982). Other families that appeared not to be important included the

Anacardiaceaea, Combretaceae, Euphorbiaceae, Ochnaceae, Sapindaceae, and Ulmaceae.

The long history of exploitation of the trees for timber might have led to the low representation of individual trees with more than 110cm dbh and the relatively few trees with diameters between 70 and 110cm dbh. Nevertheless, the high number of individuals within the lower and middle size class ranges seems to suggest that the structure of the stands is such as to allow for the recruitment of tree species from the lower layers to the emergent layer (Pascal and Pellissier 1996). The mean tree density of 257 individuals/ha in the KNP may be on the low side when compared to other similar forest types. For instance, Bernhard-Reversat et al. (1978) recorded 168–294 individuals/ha in the Ivory Coast whilst Malaisse (1978) recorded 226 individuals/ha in Zaire.

The recruitment rate of trees at the KNP was comparable with that of the Ngong forest in Kenya (Kigomo et. al., 1990). In both cases the coefficient of determination (R2) was high. The high R2 has been interpreted as reflective of high regeneration of the forest with regard to the various size-classes of the trees (Kigomo et al., 1990), and it also refutes the allegation that tropical forest trees have poor regeneration abilities after damage (Stocker 1983 as reported in Tsingalia, 1990). The estimated annual mortality rate of approximately two individuals within each size-class did not vary much from the one or two individuals estimated for the Ngong forest in Kenya (Kigomo et al., 1990).

There appears to be no literature available to compare the sapling and seedling densities with at the local level. However, the fewer numbers of saplings in relation to seedlings in this study implies that most of the saplings are transiting into young trees. It could also mean that most of the seedlings probably die due to intense competition (Weidelt, 1988) for available resources before they reach the sapling stage. Nevertheless, the totality of saplings and seedlings is colossal and reflects high regeneration potential of the forest (Mishra et al., 2005).

CONCLUSION

The study has shown that the species richness in KNP is low. The long history of timber exploitations prior to its conversion into a national park has resulted in the alteration of structure of the forest whereby the very huge trees were represented by very few individuals with even a non-representation for a particular (150–160 cm dbh) diameter-size class. The ecological importance of the trees was low, which reflected rarity of most of the species. However, the abundance of small trees coupled with the colossal sum of saplings and seedlings reflects a high regeneration potential of the forest.

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