International Journal of Biodiversity and Conservation Vol. 1(2) pp. 021-037 June, 2009
Available online http://www.academicjournals.org/ijbc

Full Length Research Paper

Floristic composition, structure and natural regeneration in a moist semi-deciduous forest following anthropogenic disturbances and plant invasion

P. Addo-Fordjour*, S. Obeng, A. K. Anning and M. G. Addo

Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana.

Accepted 7 May, 2009

The floristic composition, structure and natural regeneration were studied in three 50 x 50 m plot each in undisturbed, disturbed-invaded and disturbed forests (UF, DIF and DF respectively) of the Tinte Bepo forest reserve. A total of 108 plant species belonging to 37 families, 77 genera and 8 life forms were identified in all the forest blocks. Trees represented the most diverse life form. *Celtis mildbraedii* Engl. and *Triplochiton scleroxylon* K. Shum. were the overall dominant species in the forest reserve. Species richness of all life forms was highest in the UF followed by the DIF and DF. Plant species diversity was quantitatively higher in the UF (*H´* = 3.6) compared to the DIF (*H´* = 3.3) and DF (*H´* = 2.9). Plant species densities also differed significantly (p = 0.000) among the forest types. Mean basal area, canopy cover and height were higher in the UF compared to the DF and DIF. There was a significant positive relationship between tree size and height in all the forest types studied. The distribution of trees in the lower and higher diameter classes was highest in the UF. Diversity of saplings was greatest in the DF (*H´* = 2.72). Plant invasion impeded regeneration of native plant species in the DIF. The UF had a higher rate of converting saplings to adult trees. The Tinte Bepo forest reserve looks floristically rich and structurally complex in the face of human activities and plant invasion. Thus, there is the need for proper management intervention to curb these anthropogenic activities and plant invasion so as to protect the integrity of the forest.

Key words: Floristic composition and structure, moist semi-deciduous forest, Tinte Bepo forest reserve, regeneration

INTRODUCTION

Botanical assessments such as floristic composition and structure studies are essential in view of their value in understanding the extent of plant biodiversity in forest ecosystems [World Conservation Monitoring Centre (WCMC), 1992]. Knowledge of floristic composition and structure of forest reserves is also useful in identifying important elements of plant diversity, protecting threatened and economic species, and monitoring the state of reserves, among others (Tilman, 1988; Ssegawa and Nkuutu, 2006). Thus, the study of floristic composition and structure of tropical forest becomes more imperative in the face of the ever increasing threat to the forest ecosystem. Studies have shown that composition and structure of forests are influenced by a number of factors (Klinge et al., 1995; Haugaasen et al., 2003; Wittmann and Junk, 2003). Prominent among these factors are disturbances which are thought to be key aspects, and the cause of local species variation within forests based on their intensity, scale and frequency (Hill and Curran, 2003; Laidlaw et al., 2007). Disturbances can alter the successional pattern and subsequent composition, diversity, and structure of the forest (Doyle, 1981; Busing, 1995). Logging which has imme-

*Corresponding author. E-mail: paddykay77@yahoo.com, paddo-fordjour.sci@knust.edu.gh. Tel.: 233-20-8264118/233-26-7191957. Fax: 233-51-64286.

diate and direct effects on composition and structure (Parthasarathy, 2001) also creates canopy openings which may cause regeneration problems, especially in exposed conditions where soils dry out rapidly and nutrient loss through run-off becomes common. Canopy openings readily support the growth of invasive weeds and other herbaceous plants which usually interfere with regeneration and impede recovery of trees and shrubs (Epp, 1987; Hawthorne, 1993 and 1994; Madoffe et al., 2006). Invasive weeds threaten biodiversity by displacing native species and disrupting community structure (Parker et al., 1999; Richardson et al., 2000; Sala et al., 2000; Stein et al., 2000). Soil water availability is also considered a key factor for the regeneration, survival and growth of seedling communities (Lieberman and Lieberman, 1984; Ceccon et al., 2002). Light conditions influence regeneration pathways strongly (Haugaasen et al., 2003) and ultimately affect the composition and structure of forest. It has been reported that light limitation alone may prevent seedling survival regardless of other resource levels (Tilman, 1982). Flooding as a limiting factor influences seedling and sapling species distribution, and establishment (Klinge et al., 1995; Wittmann and Junk, 2003), probably as a result of physiological stress from highly anoxic conditions, as well as physical flood disturbance (Haugaasen and Peres, 2006).

The Tinte Bepo Forest Reserve, a moist semi-deciduous (MS) vegetation type (Hall and Swaine, 1981) has over the years, played important roles in teaching and research for the KNUST forestry school. It is generally believed to be floristically rich, containing many tropical timber species and medicinal plants as well. Carefully compiled and up-to-date information on these plant resources is however lacking. Though human-induced pressure, mainly through illegal chainsaw logging and access to non-timber forest products (NTFPs) is on the rise, no systematic study has been conducted to assess the impacts of theses activities on the structure and composition of the forest. The current status of the forest reserve with regard to invasion is not known even though certain parts of the forest have been invaded by *Broussonetia papyrifera* Vent. and *Chromolaena odorata* (L.) King and Robinson. For the conservation status of the Tinte Bepo forest reserve to be known, and to allow for the sustainable management of the forest reserve, there should be proper documentation of its plant resources. Knowledge of floristic composition, structure and natural regeneration of the Tinte Bepo forest reserve is critical in this direction. Ecological data obtained in this regard would be useful for the application of sound management practices in the forest. This study was therefore, carried out to determine the composition, structure and natural regeneration in the Tinte Bepo forest reserve in relation to anthropogenic disturbances and plant invasion.

METHODOLOGY

Study area

The study was carried out in the Tinte Bepo forest reserve in the Ahafo Ano South District, Ashanti Region, Ghana (latitude 6° 33´ N - 7° 03´ N and longitude 1° 55´ W - 2° 06´ W). The study was specifically carried out in the West block part of the forest reserve (Figure 1). The moist semi-deciduous forest covers an area of 11,551 ha with *Celtis mildbraedii*, *Triplochiton scleroxylon* and *Nesogordonia papaverifera* being the dominant species (Hall and Swaine, 1981). The topography of the area is undulating with an elevational difference of 30–50 m between summits and valleys, over horizontal distances of 300–500 m (Baker et al., 2002). The reserve is made up of three forest types, namely, the undisturbed forest (UF) which has not undergone any form of human disturbance and thus categorised as a primary forest, the disturbed forest (DF) which has experienced past and recent degradation in the form of illegal logging activities, and the disturbed-invaded forest (DIF) in which both illegal logging and farming activities are taken place (Figure 1). Additionally, some parts of the DIF have been invaded by *B. papyrifera* and *C. odorata*. Both the DF and DIF are categorised as secondary forest.

Data collection

The data was collected from June to December 2008. Nine plots were established in three different forest types within the forest reserve. The forest types were selected to represent the various degrees of anthropogenic disturbances taking place in the forest reserve. These were the UF located in the primary forest, and the DF and DIF located in the secondary forest. These forest types were selected in areas with approximately equal topography and altitude so as to eliminate their effects on plant composition and structure. In each forest type three 50 m x 50 m plots were randomly set up. Each plot was subdivided into four 25 m x 25 m quadrats for easy sampling. All trees and shrubs with dbh (diameter at breast height) ≥ 10 cm were identified and their dbh measured with a diameter tape. The height of all trees was determined with a clinometer. In each quadrat all trees (dbh ≥ 10 cm) were examined for the presence of climbers (lianas with dbh ≥ 2 cm and vines). Trees were also surveyed for epiphytes according to the method described by Addo-Fordjour et al. (in press). Trees (dbh ≥ 10 cm) were classified into four groups based on their height; understorey (< 20 m), lower canopy (20-30 m), upper canopy (30-40 m) and emergent (> 40 m) species. The percentage canopy cover of each plot was determined by a spherical densiometer. At each plot four readings from the four cardinal directions were taken at four different points. The average of all readings for the three plots in each forest type (12 readings) was calculated and used as the percentage canopy cover of that forest type (Anning et al., 2008). The diameter of lianas was determined at 1.3 m from the rooting base (Addo-Fordjour et al., 2009). Each quadrat of 25 m x 25 m was subdivided into twenty-five 5 m x 5 m small quadrats and fifteen of these (accounting for 60% of the plot area) were randomly sampled for herbs and regeneration of the tree species. All herbs as well as tree seedlings and saplings (≤ 2 m high with dbh < 10 cm) were identified and counted. Identification was performed by a plant taxonomist aided by manuals and Floras (Hawthorne, 1990; Arbon- nier, 2004; Poorter et al., 2004; Hawthorne and Jongkind, 2006). Identification of the species was confirmed at the KNUST, Kumasi and the Forestry Commission, Kumasi herbaria. Voucher speci-mens were kept at the KNUST herbarium.

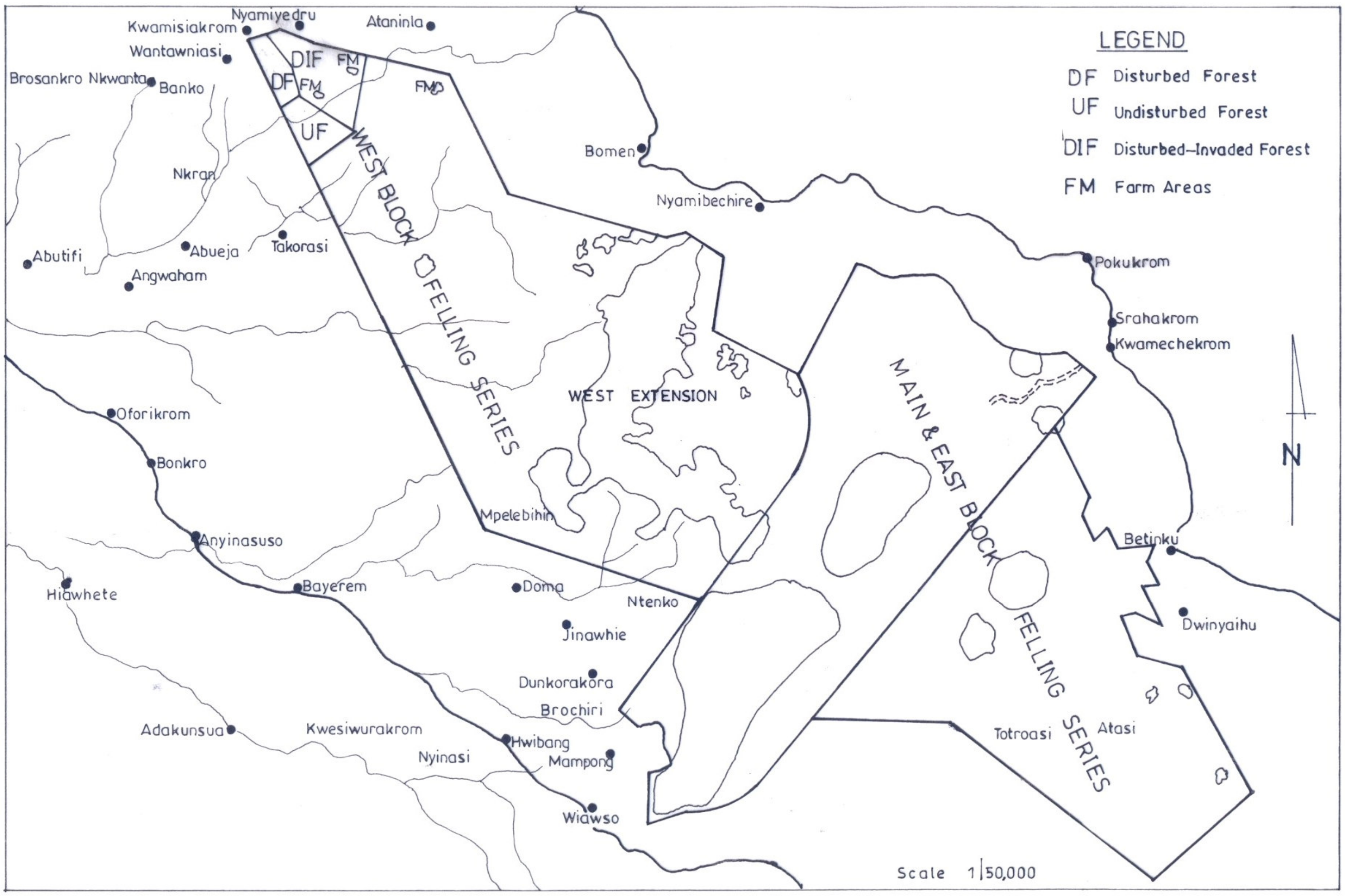

Figure 1. Map of the Tinte Bepo forest reserve showing the various forest types (DF, UF and DIF) in the West block part.

Data analyses

Differences in plant densities between the forest types were tested using one-way ANOVA. The relationship between tree size (dbh) and height in the forest blocks was determined by Pearson correlation analysis. These analyses were performed using Minitab 15 software at a significance level of 5%. The diversity of plant species in the forest types was quantified using the Shannon-Wiener species diversity index (Gimaret-Carpentier et al., 1998; Blanc et al., 2000; Parthasarathy, 2001). The Jaccard's index of similarity (*I*) was calculated for each pair wise plot comparison (Blanc et al., 2000) and this was used to generate a dendrogram showing floristic similarities. The index is given by;

$$I = \frac{c}{u_x + u_y + c} \text{ x } 100\,\%$$

Where;

c = number of species common to both plot X and Y.
U_x = number of species found only in plot X.
U_y = number of species found only in plot Y.

Epiphytes were excluded from all the above mentioned analyses since their densities could not be determined. Importance value index of the species was calculated as the sum of the species relative density, relative frequency and relative dominance (Kiruki and Njung'e, 2007; Addo-Fordjour et al., 2008).

RESULTS

Floristic composition

A total of 108 adult plant species were identified in the three forest blocks in the Tinte Bepo forest reserve. These belonged to 37 families, 77 genera and 8 life forms (Table 1 and Figure 2). Fabaceae, Moraceae and Meliaceae were the overall diverse families (in terms of species

Table 1. List of plant species (excluding seedlings and saplings) identified in the Tinte Bepo forest reserve

Species	Family	Habit
Acacia kamerunensis Gand.	Fabaceae	Liana
Acacia pentagona (Schum. & Thonn.) Hooker f.	Fabaceae	Liana
Acanthaceae sp.	Acanthaceae	Herb
Afromomum sp.	Zingiberaceae	Herb
Afzelia bella Harms	Fabaceae	Tree
Aidia genipiflora (DC.) Dandy	Rubiaceae	Shrub
Alafia barteri Oliv.	Apocynaceae	Liana
Albizia adianthifolia (Schum.) W.F. Wight	Fabaceae	Tree
Albizia glaberrima (Schum. & Thonn.) Benth.	Fabaceae	Tree
Albizia zygia (DC.) J.F. Macbr.	Fabaceae	Tree
Alstonia boonei De Wild.	Apocynaceae	Tree
Amphimas pterocarpoides Harms	Fabaceae	Tree
Anchomanes difformis (Blume) Engl.	Araceae	Herb
Antiaris toxicaria (Rumph ex Pers.) Leschen.	Moraceae	Tree
Antrocaryon micraster A. Chev. & Guillaum.	Anacardiaceae	Tree
Baphia nitida Lodd.	Fabaceae	Tree
Baphia pubescens Hook.f.	Fabaceae	Tree
Blighia sapida Kon.	Sapindaceae	Tree
Blighia welwitschii (Hiern) Radlk.	Sapindaceae	Tree
Bombax buonopozense P.Beauv.	Bombacaceae	Tree
Bridelia atroviridis Müll.Arg.	Euphorbiaceae	Tree
Bridelia grandis Pierre ex Hutch.	Euphorbiaceae	Tree
Broussonetia papyrifera Vent.	Moraceae	Tree
Bussea occidentalis Hutch.	Fabaceae	Tree
Calpocalyx brevibracteatus Harms	Fabaceae	Tree
Calycobolus africanus (G.Don) Heine	Convolvulaceae	Tree
Calycobolus heudelotii (Baker ex Oliv.) Heine	Capsicum sp.	Tree
Calyptrochilum emarginatum Schltr.	Orchidaceae	Epiphyte
Capsicum sp.	Solanaceae	Herb
Ceiba pentandra (L.) Gaertn.	Bombacaceae	Tree
Celtis adolfi-friderici Engl.	Ulmaceae	Tree
Celtis mildbraedii Engl.	Ulmaceae	Tree
Celtis wightii Planch.	Ulmaceae	Tree
Celtis zenkeri Engl.	Ulmaceae	Tree
Centrocema pubescens Benth.	Fabaceae	Herb
Chromolaena odorata (L.) King & Robinson	Asteraceae	Herb
Chrysophyllum perpulchrum Mildbr. ex Hutch. & Dalziel	Sapotaceae	Tree
Chrysophyllum sp.	Sapotaceae	Tree
Cissus sp.	Vitaceae	Liana
Combretum bipindense Engl. & Diels	Combretaceae	Liana
Combretum smeathmannii G.Don	Combretaceae	Liana
Combretum sp.	Combretaceae	Liana
Cordia millenii Baker	Boraginaceae	Tree
Cordia senegalensis Juss.	Boraginaceae	Tree
Corynanthe pachyceras K.Schum.	Rubiaceae	Tree
Rhaphidophora africana N.E.Br.	Araceae	Vine
Dalbergia hostilis Benth.	Fabaceae	Liana

Table 1 Contd.

Diospyros viridicans Hiern	Ebenaceae	Tree
Entandrophragma angolense (Welw.) DC.	Meliaceae	Tree
Ficus asperifolia Miq.	Moraceae	Shrub
Ficus exasperata Vahl	Moraceae	Shrub
Ficus sur Forssk.	Moraceae	Tree
*Ficus tessellata*Warb.	Moraceae	Epiphyte
Ficus thonningii Blume	Moraceae	Epiphyte
Ficus trichopoda Baker	Moraceae	Epiphyte
Ficus umbellata Vahl	Moraceae	Epiphyte
Ficus vogelii Miq.	Moraceae	Epiphyte
Funtumia elastica (Preuss) Stapf	Apocynaceae	Tree
Griffonia simplicifolia (Vahl ex DC.) Baill.	Fabaceae	Liana
Guarea cedrata (A.Chev.) Pellegr.	Meliaceae	Tree
Hannoa klaineana Pierre & Engl.	Simaroubaceae	Tree
Hippocratea sp.	Celastraceae	Liana
Hymenostegia afzelii (Oliv.) Harms	Fabaceae	Tree
Khaya anthotheca (Welw.) C.DC.	Meliaceae	Tree
Khaya grandifolia C.DC.	Meliaceae	Tree
Khaya ivorensis A.Chev.	Meliaceae	Tree
Lannea welwitschii (Hiern) Engl.	Anacardiaceae	Tree
Lecaniodiscus cupanioides Planch. ex Benth.	Sapindaceae	Tree
Leptoderris sp.	Fabaceae	Liana
Lovoa trichilioides Harms	Meliaceae	Tree
Macaranga heudelotii Baill.	Euphorbiaceae	Tree
Mansonia altissima (A.Chev.) A.Chev.	Sterculiaceae	Tree
Marantocloa leucantha (K.Schum.) MilneRedh.	Marantaceae	Herb
Microdesmis puberula Hook.f.	Pandaceae	Tree
Microsorum punctatum (L.) Copel.	Polypodiaceae	Epiphyte
Microsorum scolopendria Copel.	Polypodiaceae	Epiphyte
Milicia excelsa (Welw.) C.C.Berg.	Moraceae	Tree
Millettia chrysophylla Dunn	Fabaceae	Liana
Morinda lucida Benth.	Rubiaceae	Tree
Morus mesozygia Stapf	Moraceae	Tree
Motandra guineensis (Thonn.) A.DC.	Apocynaceae	Liana
Myrianthus arboreus P.Beauv.	Cecropiaceae	Tree
Nephrolepis biserrata (Sw.) Schott	Nephrolepidaceae	Epiphyte
Nephrolepis exaltata (L.) Schott	Nephrolepidaceae	Epiphyte
Nephrolepis undulata J.Sm.	Nephrolepidaceae	Epiphyte
Nesogordonia papaverifera (A.Chev.) R.Capuron	Sterculiaceae	Tree
Olyra latifolia L.	Poaceae	Herb
Panicum maximum Jacq.	Poaceae	Grass
Parquetina nigrescens (Afzelius) Bullock	Asclepiadaceae	Liana
Pennisetum purpureum K.Schum.	Poaceae	Grass
Piptadeniastrum africanum (Hook.f.) Brenan	Fabaceae	Tree
Pisonia aculeata L.	Nyctaginaceae	Liana
Pteris sp.	Pteridaceae	Fern
Pycnanthus angolensis (Welw.) Warb.	Myristicaceae	Tree
Ricinodendron heudelotii (Baill.) Pierre ex Pax	Euphorbiaceae	Tree

Table 1 Contd.

Rinorea oblongifolia (C.H. Wright) Marquand ex Chipp	Violaceae	Tree
Salacia elegans Welw. ex Oliv.	Celastraceae	Liana
Salacia owabiensis Hoyle	Celastraceae	Liana
Salacia sp.	Celastraceae	Liana
Smilax kraussiana Meisn.	Smilacaceae	Liana
Sterculia oblonga Mast.	Sterculiaceae	Tree
Sterculia rhinopetala K.Schum.	Sterculiaceae	Tree
Sterculia tragacantha Lindl.	Sterculiaceae	Tree
Terminalia superba Engl. & Diels	Combretaceae	Tree
Trichilia monadelpha (Thonn.) J.J.de Wild.	Meliaceae	Tree
Trichilia prieureana A.Juss.	Meliaceae	Tree
Trilepisium madagascariense DC.	Moraceae	Tree
Triplochiton scleroxylon K.Shum.	Sterculiaceae	Tree

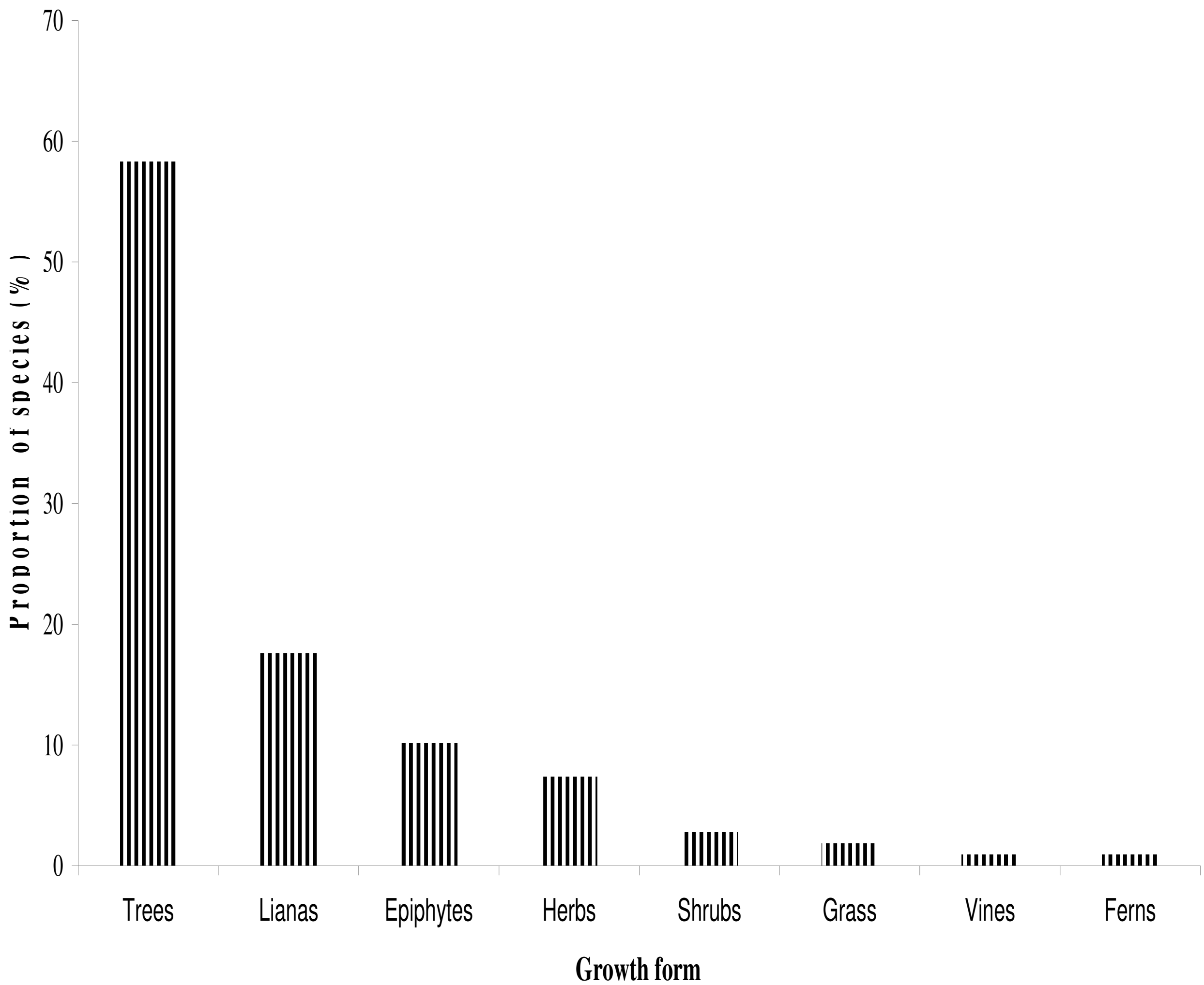

Figure 2. Composition of plant species in the various life forms identified in the Tinte Bepo forest reserve.

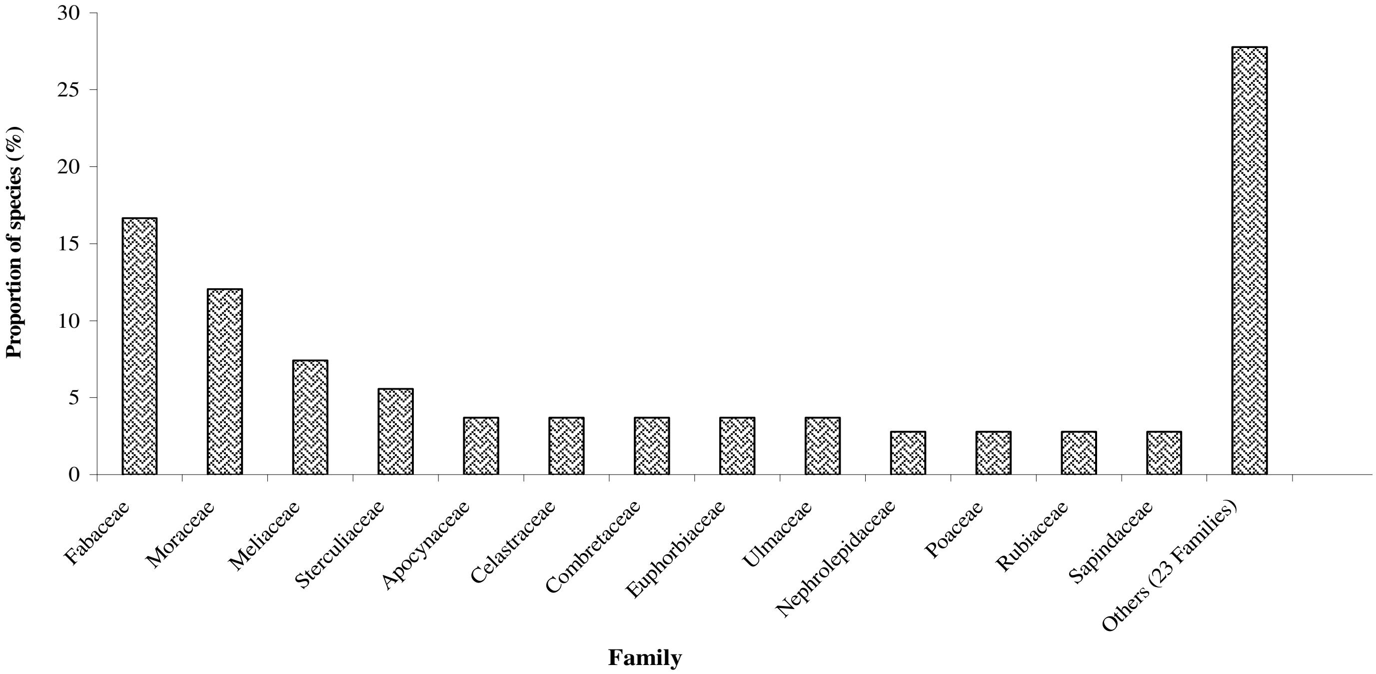

Figure 3. Family dominance of plant species in the Tinte Bepo forest reserve.

richness) of the adult species, contributing 36% of all the species in the study (Figure 3). Trees were the most dominant life form (58.3%) followed by lianas (17.6%), epiphytes (10.2%), herbs (7.4%), shrubs (2.8 %) and the others (3.7%).

Generally, species richness (of all life forms) was highest in the UF (68 adult and 3 juvenile species) followed by the DIF (51 adult and 1 juvenile species) and DF (34 adult and 5 juvenile species). The adult species were distributed in 25, 27 and 18 families in the UF, DIF and DF respectively. Fabaceae, Moraceae and Meliaceae were the most diverse families in the UF whereas Fabaceae and Euphorbiaceae constituted the most diverse families in the DIF. The most important families in the DF were Fabaceae, Moraceae and Meliaceae (Figure 4). More species of herb were recorded in the DIF (6) than in the DF (4) and UF (2) whereas epiphyte species richness was greater in the UF (9) in relation to the other forest types (6 and 2 epiphyte species in the DF and DIF respectively). *C. odorata* was the most dominant species of herb in terms of number of individuals accounting for 69% of individual herbs in the DIF and 45% of all the herbs in the three forest types. In the dendrogram similarity levels were high ranging between 83.5 and 89.4 % (Figure 5). Some plots from different forest types were floristically identical. Plots in the DF and DIF were more similar to one another than to that of the UF. The UF2 was floristically more similar to the DF1, DIF3, DIF1 and DF2 than to the UF1 and UF3.

A total of 13 tree species occurred in the canopy layer (lower and upper canopies) whereas 9 species were present in the emergent layer (Table 2). In the UF only one species (*Celtis zenkeri*) was present in all the three topmost layers whereas *C. mildbraedii* and *sterculia rhinopetala* occurred in the upper canopy and emergent layer. All the lower canopy species identified in the DIF were absent in the upper canopy. However, six out of the seven species (*C. mildbraedii*, *N. papaverifera*, *Piptadeniastrum*, *salacia oblonga*, *S. rhinopetala*, *T. scleroxylon*) that were identified in the upper canopy were also present in the emergent layer. In the DF *C. mildbraedii* and *Lannea welwitschii* occurred in all the three topmost layers of the forest while *T. scleroxylon* did not occur in the lower canopy. More than half of the individual trees (64.2 %) identified in all the forest types occurred in the understorey layer (Figure 6). The DIF had the most understorey trees (75.3%) followed by the DF (68.4%) and UF (48.8%). The UF contributed more than half (53.8%) of the canopy trees in the forest reserve. Both the UF and DIF contributed equal numbers of trees (13% each) to the emergent layer of the forest.

Structure

There were a total of 863 individuals of woody species (ex-

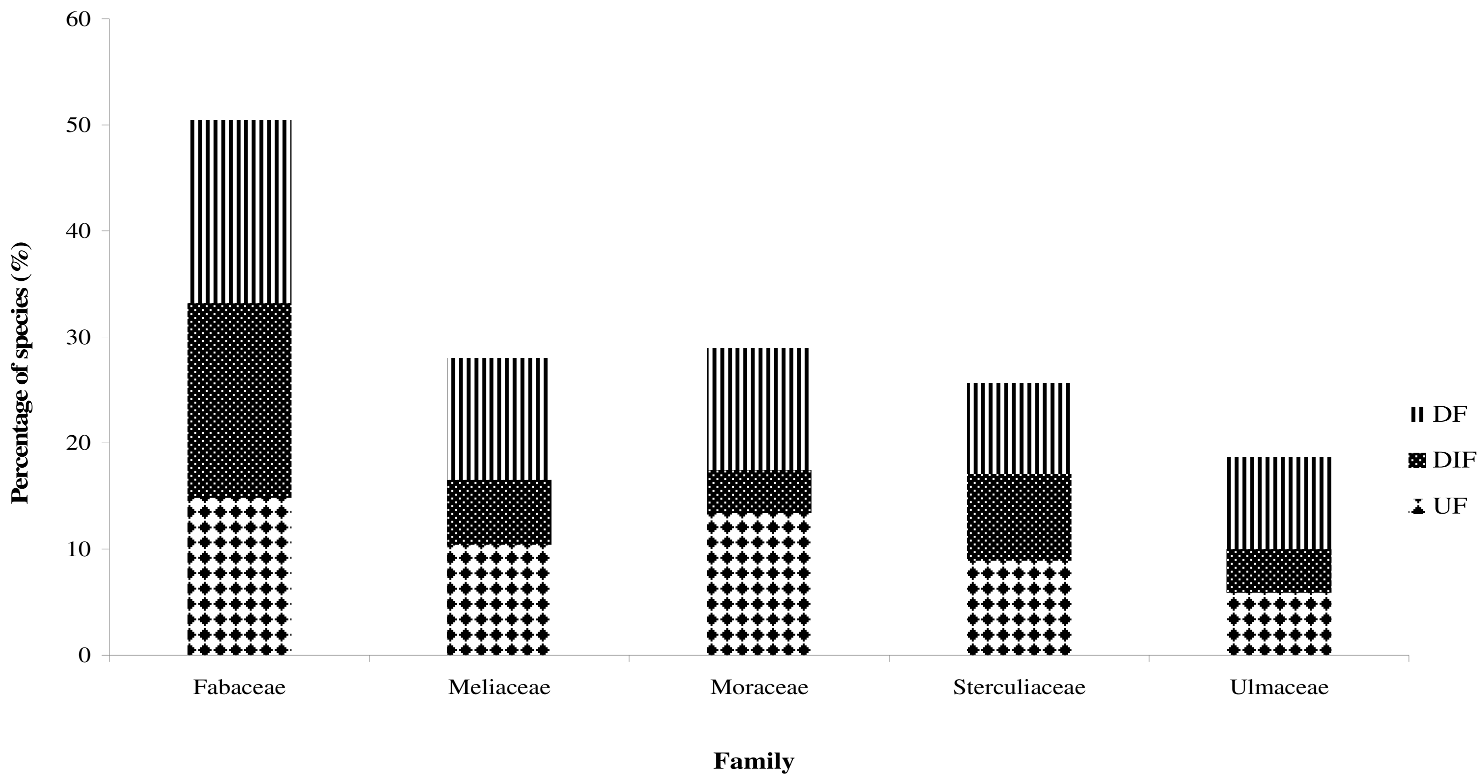

Figure 4. Dominance of the top five families based on species richness in the respective forest types.

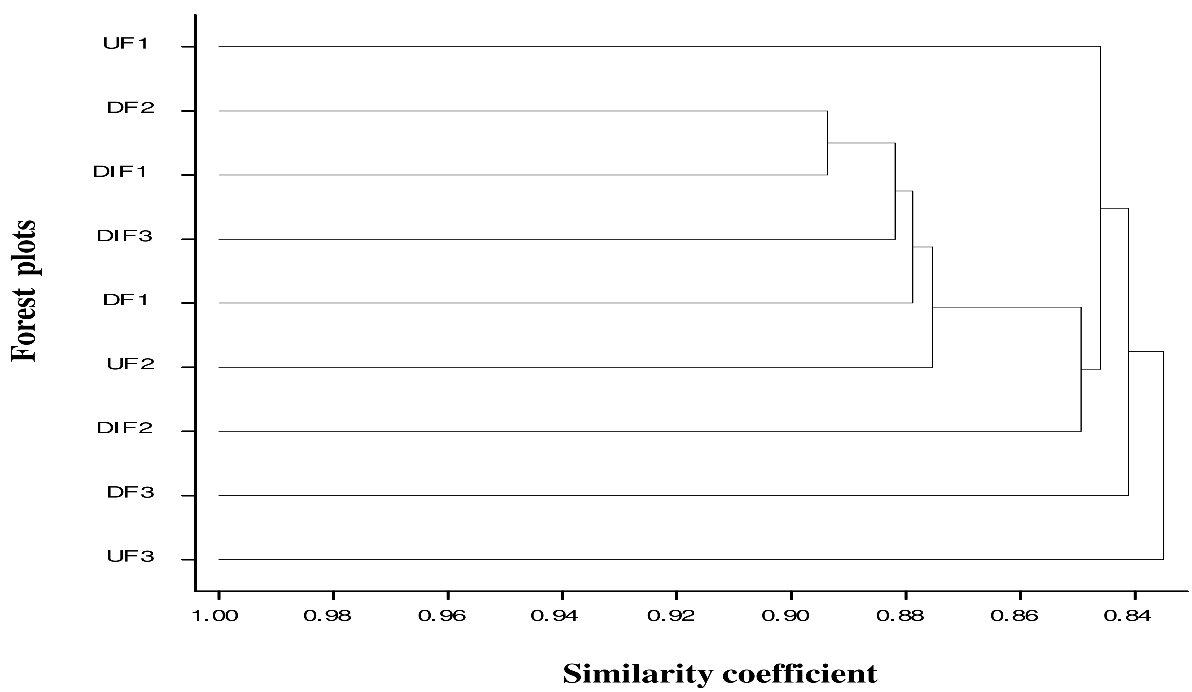

Figure 5. Dendrogram constructed from similarity Jaccard Index matrix based on species composition in the various plots within the forest types

Table 2. Tree species present in the canopy and emergent layers in the Tinte Bepo forest reserve

Species	Emergent			Lower canopy			Upper canopy		
	UF	DIF	DF	UF	DIF	DF	UF	DIF	DF
Albizia zygia	-	-	-	+	-	-	-	-	-
Bridelia grandis	-	-	-	-	+	-	-	-	-
Celtis mildbraedii	+	+	+	-	-	+	+	+	+
Celtis zenkeri	+	-	-	+	-	-	+	-	-
Chrysophyllum sp.	-	-	-	-	-	-	-	+	-
Khaya ivorensis	-	-	-	+	-	-	-	-	-
Lannea welwitschii	-	-	+	-	-	+	-	-	+
Nesogordonia papaverifera	-	+	-	+	-	-	-	+	-
Piptadeniastrum africanum	-	+	-	-	-	-	-	+	
Ricinodendron heudelotii	-	-	-	-	+	-	-	-	-
Sterculia oblonga	-	+	-	-	-	-	-	+	-
Sterculia rhinopetala	+	+	-	-	-	-	-	+	-
Triplochiton scleroxylon	-	+	+	+	-	-	-	+	+

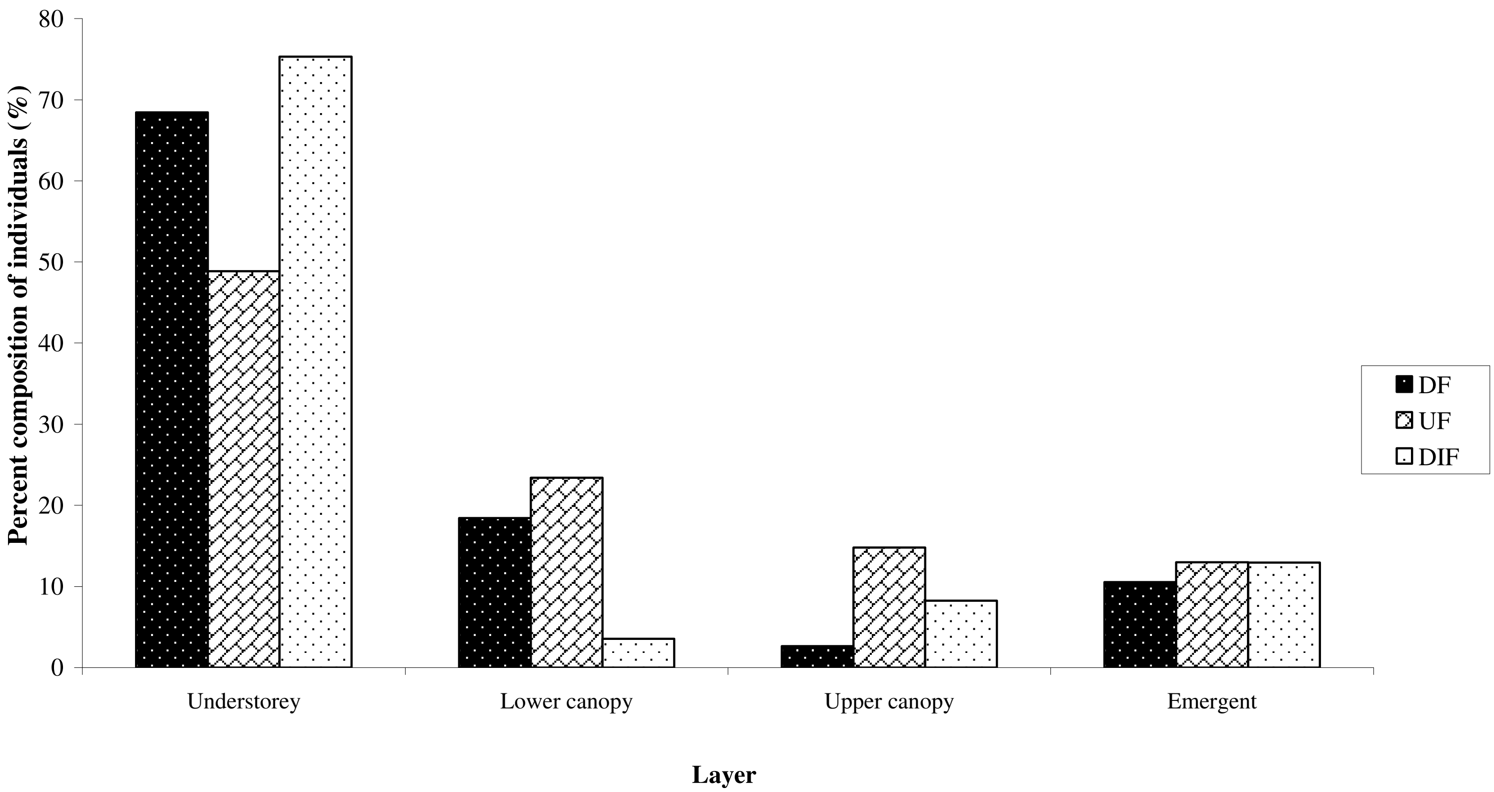

Figure 6. Composition of individual trees (dbh≥ 10 cm) in the various layers of the forest.

cluding epiphytes) identified in the three forest types. Trees were more abundant (649 individuals) compared with lianas (284 individuals) and shrubs (20 individuals) (Table 3 and 4). Tree density was greatest in the UF (461/ha) than in the DF (117/ha) and DIF (285/ha). Liana density also followed the same trend (69, 141 and 168 /ha in the DF, DIF and UF respectively). Shannon-Wiener index was greater in the UF ($H' = 3.60$) compared to DIF ($H' = 3.30$)

Table 3. Abundance and dominance of woody species in the various forest types of the Tinte Bepo forest reserve.

Species	UF				DIF				DF			
	RD	RF	RBA	IV	RD	RF	RBA	IV	RD	RF	RBA	IV
Acacia kamerunensis	-	-	-	-	0.69	2.5	0.04	3.23	-	-	-	-
Acacia pentagona	-	-	-	-	2.10	2.5	0.08	4.68	-	-		-
Afzelia bella	0.47	1.10	0.35	1.92	-	-	-	-	-	-		-
Aidia genipiflora	-	-	-	-	-	-	-	-	1.59	2.44	0.67	4.70
Alafia barteri	3.32	4.40	0.04	7.76	2.80	3.75	0.05	6.60	1.59	7.32	0.03	8.94
Albizia adianthifolia	-	-	-	-	0.69	1.25	5.29	6.66	-	-	-	-
Albizia glaberrima	0.47	1.10	0.97	2.54	-	-			-		-	-
Albizia zygia	0.47	1.10	3.29	4.86	0.69	3.75	0.98	5.42	-	-	-	-
Alstonia boonei	0.47	1.10	1.88	3.45	-	-	-	-	-	-	-	-
Amphimas pterocarpoides	-	-	-	-	-	-	-	-	1.59	2.44	0.27	4.30
Antiaris toxicaria	0.47	1.10	0.79	2.36	-	-	-	-	-	-	-	-
Antrocaryon micraster	0.47	1.10	0.53	2.10	-	-	-	-	-	-	-	
Baphia nitida	0.47	2.20	0.77	3.44	-	-	-	-	-	-	-	-
Baphia pubescens	1.90	3.30	3.00	8.20	2.10	3.75	0.90	6.75	1.59	2.44	0.29	4.32
Blighia sapida	0.47	1.10	0.41	1.98	-	-	-	-	-	-	-	-
Blighia welwitschii	0.95	1.10	1.12	3.17	-	-	-	-	-	-	-	-
Bombax buonopozense	-	-	-	-	1.40	2.50	1.10	5.00	-	-		
Bridelia atroviridis	-	-	-	-	1.40	1.25	0.71	3.36	-	-	-	-
Bridelia grandis	-	-	-	-	1.40	1.25	1.50	4.15	-	-	-	-
Broussonetia papyrifera	-	-	-	-	16.70	2.50	0.89	20.09	-	-	-	-
Bussea occidentalis	1.90	1.10	1.26	4.26	-	-	-		-	-	-	-
Calpocalyx brevibracteatus	0.95	1.10	8.56	10.61	-	-	-	-	-	-	-	-
Calycobolus africanus	4.74	2.20	0.13	7.07	4.20	1.25	0.03	5.48	-	-	-	-
Calycobolus heudelotii	-	-	-	-	4.90	1.25	0.18	6.33	-	-		
Ceiba pentandra	1.90	2.20	1.36	5.46	2.10	2.50	1.50	6.10	-	-	-	
Celtis adolfi-friderici	1.90	1.10	0.7	3.70	-	-	-	-	1.59	2.44	5.57	9.60
Celtis mildbraedii	8.53	4.40	8.16	21.09	7.60	6.25	5.51	19.36	14.29	9.76	6.48	30.53
Celtis wightii	0.47	1.10	1.57	3.14	-	-	-	-	-	-	-	-
Celtis zenkeri	5.21	4.40	3.07	12.68	0.69	1.25	0.50	2.44	1.59	2.44	1.64	5.67
Chrysophyllum perpulchrum	1.90	1.10	0.62	3.62	0.69	1.25	0.76	2.70	6.35	2.44	5.50	14.29
Chrysophyllum sp	-	-	-	-	0.69	1.25	5.10	7.04	-	-	-	-
Lecaniodiscus cupanoioides	0.47	1.10	1.17	2.74	-	-	-	-	-	-	-	-
Leptoderris sp.	-	-	-	-	-	-		-	9.52	2.44	0.02	11.98
Lovoa trichilioides	-	-	-	-	0.69	1.25	1.15	3.09	-	-	-	-

Table 3 Contd.

Macaranga heudelotii	-	-	-	-	0.69	1.25	3.53	5.47	-	-	-	-
Mansonia altissima	1.90	2.20	8.65	12.75	1.40	1.25	0.58	3.23	-	-	-	-
Microdesmis puberula	1.90	1.10	0.50	3.50	0.69	1.25	0.49	2.43	-	-	-	-
Milicia excelsa	0.47	1.10	8.86	10.43	-	-	-	-	-	-	-	-
Millettia chrysophylla	2.84	4.40	0.05	7.29	2.80	2.50	0.18	5.48	4.76	4.88	0.02	9.66
Morinda lucida	0.47	1.10	0.43	2.00	-	-	-	-	-	-	-	-
Morus mesozygia	-	-	-	-	-	-		-	1.59	2.44	0.14	4.17
Motandra guineensis	5.69	1.10	0.03	6.82	-	-	-	-	1.59	9.76	0.01	11.36
Myrianthusarborus	0.47	1.10	1.57	3.14	-	-	-	-	3.17	4.88	2.40	10.45
Nesogordonia papaverifera	8.10	4.40	0.93	13.43	4.20	5.00	6.66	15.86	4.76	2.44	1.12	8.32
Parquetina nigrescens	-	-	-	-	5.55	3.75	0.05	9.35	-	-	-	-
Piptadeniastrum africanum	-	-	-	-	1.40	2.50	27.1	31.00	-		-	-
Pisonia aculeata	-	-	-	-	0.69	1.25	0.02	1.96	-	-		-
Pycnanthus angolensis	0.47	1.10	0.50	2.07	-	-	-	-	-	-	-	-
Ricinodendron heudelotii	2.40	1.10	1.40	4.90	4.20	7.50	4.13	15.83	-	-	-	-
Rinorea oblongifolia	0.47	1.10	0.50	2.07	-	-	-	-	-	-	-	-
Salacia elegans	0.47	1.10	0.09	1.66	-	-	-	-	-	-	-	-
Salaciaowabiensis	3.79	1.10	0.03	4.92	-	-	-	-	-	-	-	-
Salacia sp.	-	-	-	-	-	-	-	-	3.17	2.44	0.02	5.63
Smilax kraussiana	-	-	-	-	0.69	1.25	0.03	1.97	-	-	-	-
Sterculia oblonga	0.47	1.10	1.57	3.14	1.40	1.25	10.4	13.05	-	-		-
Sterculia rhinopetala	0.95	1.10	2.30	4.35	2.10	3.75	1.04	6.89	-	-	-	-
Sterculia tragacantha	0.47	1.10	2.90	4.47	-	-	-	-	1.59	2.44	0.24	4.27
Terminaliasuperba	-	-	-	-	3.47	3.75	2.02	9.24	-	-	-	-
Trichilia monadelpha	1.90	2.20	0.97	5.07	1.40	2.50	3.23	7.13	-	-	-	-
Trichilia prieureana	0.47	1.10	0.45	2.02	2.10	3.75	1.61	7.46	3.17	4.88	0.28	8.33
Trilepisium madagascariense	0.95	1.10	2.84	4.89	-	-	-	-	-	-	-	
Triplochiton scleroxylon	2.84	1.10	7.52	11.46	-	-	-	-	3.17	2.44	67.9	73.51

RD = Relative density, RF = Relative frequency, RBA = Relative basal area, IV = Importance value.

and DF (*H´* =2.90) (Table 4). Density of plant species differed significantly between the forest types (F=8.96: df = 2; p = 0.000).

In all, *C. mildbraedii* was by far the most abundant species accounting for an average 10% of stems in all the habitats whereas *T. scleroxylon* was the most domi-

Table 4. Summary characteristics of the floristic composition and structure of the Tinte Bepo forest reserve.

Characteristic	UF	DIF	DF
Number of tree individuals (Density/ha)	347 (461)	214 (285)	88 (117)
Number of individual shrubs (Density/ha)	5 (7)	10 (13)	5 (7)
Density of lianas/ha	126 (168)	106 (141)	52 (69)
Shannon-Wiener index	3.6	3.3	2.9
Shannon-Wiener index for saplings	2.35	1.34	2.72
Mean canopy height (m)	36.7±3.8	29.9±4.2	30.3±4.1
Mean canopy cover (%)	83.1±5.6	55.3±5.3	61.7±2.9
Mean basal area (m^2/ha)	65.7±3.6	32.7±0.7	54.2±4.9

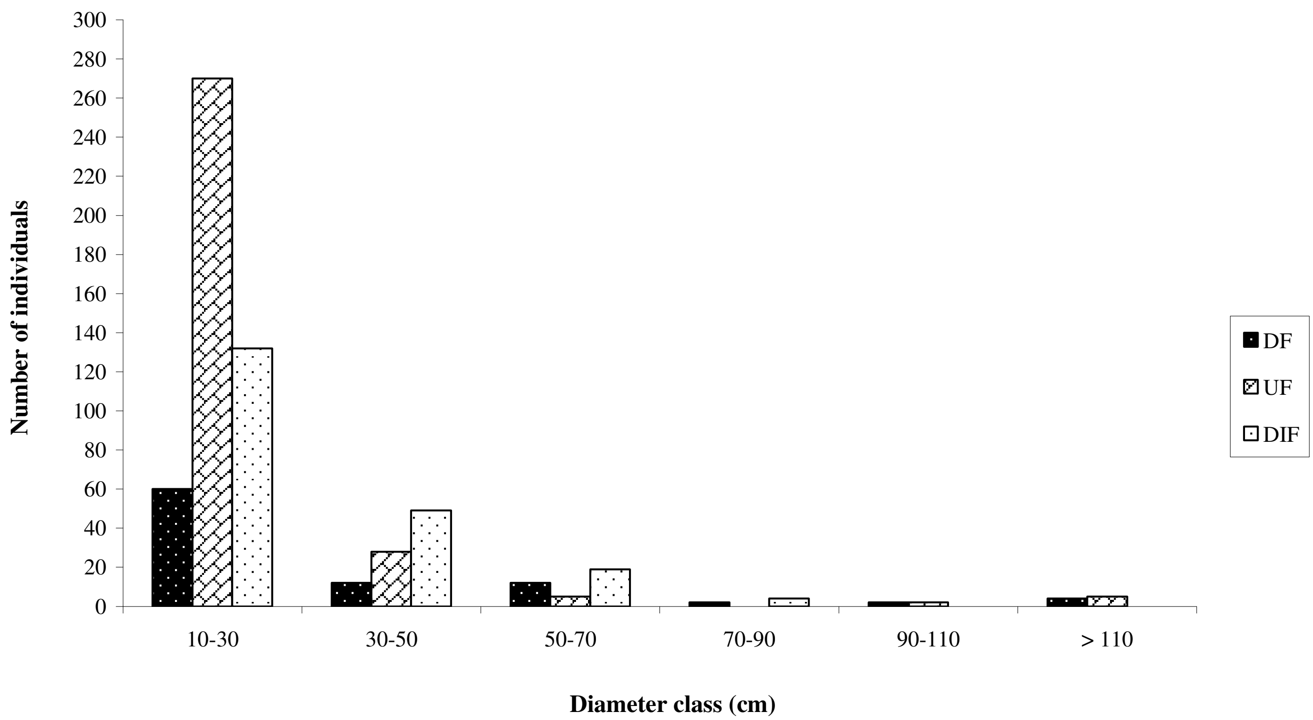

Figure 7. Diameter class distribution of trees (≥ 10 cm) in the forest types.

nant species in terms of basal area representing 25% on the average (Table 3). The overall dominant species in terms of the species importance value (average) were *T. scleroxylon* (28.2) and *C. mildbraedii* (23.7). The commonest species were *C. mildbraedii* and *A*lafia *barteri* with the average occurrence of 6.8 and 5.2 % respecttively.

On forest type basis *C. mildbraedii, C.* zenkeri, *L. welwitschii*, *Mansiona altissima*, *N. papaverifera* and *T. scleroxylon* were the dominant species in the UF (Table 3). In the case of the DIF *B. papyrifera*, *C. mildbraedii*, *N. papaverifera*, *P. africanum* and *S. oblonga* were the dominant species. In the DF *C. mildbraedii*, *Griffonia*. *Simplicifolia* and *T. scleroxylon* were the species that dominated the woody flora**.**

In terms of size, majority of the trees were of the lower diameter class (10-30 cm) (Figure 7). The number of individual trees in the categories decreased with increasing size of the trees. Larger diameter trees (90-110 and > 110 cm) were not found in the DIF. Mean basal area recorded in the UF (65.7±3.6 m^2/ha) was higher compared with that of DF (54.2±4.9 m^2/ha) and DIF (32.7± 0.7 m^2/ha) (Table 4). In the same way, mean canopy cover and height were higher in the UF (83.1 ±

Table 5. Regeneration of tree species in the Tinte Bepo forest reserve.

Species	Family	UF		DIF		DF	
		#Sd	#Sp	#Sd	#Sp	#Sd	#Sp
Albizia zygia	Fabaceae	-	-	-	-	4	-
Antiaris toxicaria	Moraceae	-	8	-	-	-	
Baphia nitida	Fabaceae	-	16	-	43	-	7
Baphia pubescens	Fabaceae	-	4	-	5	-	3
Broussonetia papyrifera	Moraceae	-	-	-	104	-	-
Bussea occidentalis	Fabaceae	-	-	49	-	-	-
Calpocalyx brevibracteatus	Convolvulaceae	-	4	-	-	-	-
Celtis adolfi-friderici	Ulmaceae	-	-	-	-	-	4
Celtis mildbraedii	Ulmaceae	-	9	45	-	10	4
Celtis wightii	Ulmaceae	-	-	-	-	-	5
Celtis zenkeri	Ulmaceae	-	-	-	-	-	4
Chrysophyllum perpulchrum	Sapotaceae	-	-	-	4	-	3
Daniellia ogea	Fabaceae	-	-	-	-	-	3
Diospyros viridicans	Ebenaceae	-	-	-	-	-	5
Elaeis guineensis	Aracaceae	-	4	-	-	-	-
Grossera vignei	Eurphorbiaceae	-	-	81	5	-	6
Guibourtia ehie	Fabaceae	-	-	-	-	-	4
Lecaniodiscus cupanioides	Sapindaceae	-	4	4	-	-	-
Mansonia altissima	Sterculiaceae	-	17	28	-	-	-
Microdesmis puberula	Pandaceae	-	4	-	-	-	4
Milletia thonningii	Fabaceae	13	-	-	-	-	-
Nesogordonia papaverifera	Sterculiaceae	-	33	44	41	17	-
Piptadeniastrum africanum	Fabaceae	-	4	-	-	-	-
Pouteria altissima	Sterculiaceae	4	-	-		-	4
Rinorea oblongifolia	Violaceae	-	3	-	-	-	7
Sterculia rhinopetala	Sterculiaceae	-	9	-	5	-	5
Sterculia tragacantha	Sterculiaceae	-	8	-	-	-	-
Strombosia pustulata	Olacaceae	-	-	-	-	-	9
Triplochiton scleroxylon	Sterculiaceae	-	8	-	-	-	-

#Sd = number of seedlings, #Sp = number of saplings.

5.6% and 36.7 ± 3.8 m respectively) than in the DF (61.7 ± 2.9% and 30.3 ± 4.1 m respectively) and DIF (55.3 ± 5.3% and 29.9 ± 4.2 m respectively). There was a significant positive relationship between tree size and height in all the forest types studied (r^2 = 0.812; p = 0.000, r^2 = 0.741; p = 0.000 and r^2 =0.362; p = 0.002 in the DF, DIF and UF respectively).

Natural regeneration

There were 29 species belonging to the regeneration flora (tree seedlings and saplings) in the three forest types, out of which 7 species were not present in the adult tree population (Table 5). These juvenile species belonged to 24 genera and 12 families. Fabaceae and Sterculiaceae dominated in both the UF and DIF while Fabaceae and Ulmaceae were the dominant families in the DF. Sapling diversity (H´) was highest in the DF (2.72) followed the UF (2.35) and the DIF (1.34) (Table 4). In all the forest types seedlings and saplings were dominated by the understorey species.

In the DIF, *C. mildbraedii* one of the most dominant species regenerated well with regards to seedlings but poorly in terms of saplings. Another dominant species, *B. papyrifera* constituted 50.5% of the sapling density in the DIF but this species had no seedlings. None of the adult tree species in the UF had seedlings.

DISCUSSION

Studies on floristic composition and structure in forests are instrumental in the sustainability of forests since they play a major role in the conservation of plant species, and the management of forest ecosystems as a whole (Tilman, 1988; Ssegawa and Nkuutu, 2006). That not withstanding, only a few studies (Hall and Swaine, 1981; Vordzogbe et al., 2005; Anning et al., 2008) in this regard have been conducted in Ghanaian forests. For this reason, the results of this study cannot be compared with a wide range of other similar studies in Ghana. On the whole, floristic composition of the Tinte Bepo forest reserve (48 species/ha) was lower than many other tropical forests. For instance, Vordzogbe et al. (2005) reported of much higher species richness (80 species/ha) in a moist semi-deciduous forest in Ghana. Even at a higher diameter cut-off point of ≥ 30 cm, Parthasarathy (2001) recorded 125 species in a tropical wet evergreen forest in Sengaltheri of the Western Ghats in India. On the other hand, Anning et al. (2008) recorded a much lower species richness (37 species/ha) in another disturbed semi-deciduous forest located in Ghana. On the basis of only trees (dbh ≥ 10 cm) the number of species recorded in this study (28 species/ha) was relatively lower in comparison with similar studies in other tropical forests. For example, Campbell et al. (1986) and Riswan (1987) recorded 189 species/ha and 160 species/ha in Brazilian Amazon and Lempake Indonesia respectively. The cutting of mature trees for timber, farming, collection of fuelwood and other non-timber forest products, and their attendant invasion of some parts of the forest might have had effects on the species composition of the reserve (Terborgh, 1992; Odoom, 2005; Opoku, 2006).

Trees constituted the predominant life form in all the forest types reminiscent of other studies (Vordzogbe et al., 2005; Anning et al., 2008). Although shrubs and herbs were generally less prominent in all the forest types, the diversity of herbs was greater in the DIF and DF compared to the UF. This might be an indicator of greater anthropogenic disturbances in the DF and DIF (Mishra et al., 2008). The comparatively high proportion of *Ficus* spp. in the epiphytic flora is good for the health of the Tinte Bepo forest reserve since a lot of *Ficus* spp. are keystone species in many tropical forests (Lambert and Marshall, 1991).

The dominance of *C. mildbraedii* and *T. scleroxylon* in the flora of the Tinte Bepo forest reserve is considered as a major characteristic of semi-deciduous forests (Taylor, 1960; Hall and Swaine, 1981; Vordzogbe et al., 2005). Furthermore, the dominance of Fabaceae, Moraceae and Meliaceae in some semi-deciduous forests has been reported (Vordzogbe et al., 2005; Anning et al., 2008). Thus, the semi-deciduousness of the Tinte Bepo forest reserve as well as the dominance of these species (*C. mildbraedii* and *T. scleroxylon*) (Hall and Swaine, 1981) has been maintained for more than two decades. The presence of some species such as *A. barteri*, *B. pubescens*, *C. mildbraedii* and *G. simplicifolia* in all the three forest blocks may indicate their wider range of ecological adaptation (Senbeta et al., 2005; Addo-Fordjour et al., 2008). Some authors have even reported of *G. simplicifolia* as the commonest climbing plant in Ghana's forests showing its plasticity to different habitats (Swaine et al., 2005; Addo-Fordjour et al., 2009).

Floristic composition did not vary much between the various forest types although the composition of some UF plots was generally more dissimilar to that of the DF and DIF plots. Plant diversity (H') was quantitatively higher in the UF than in the other forest types which continue to be disturbed by human activities. This is buttressed by the density of plant species which was also significantly greater ($p = 0.000$) in the UF compared to the DF and DIF. Logging activities in both the DF and DIF on one hand, and farming activities in the DIF on the other hand, have affected plant diversity through the removal of plant species, creation of gaps, and consequently a reduction in the canopy cover of these forests. Both canopy gaps and farming activities in the DIF have favoured the growth of invasive species among the native species, with *C. odorata* and *B. papyrifera* which have been identified as notorious invasive weeds in Ghana (CSIR, 2002) being common phenomena. Though invasive species have been found to exert severe negative consequences on biodiversity, displacing native species and disrupting community structure (Ambika, 1996; Parker et al., 1999; Richardson et al., 2000; Sala et al., 2000; Stein et al., 2000; Madoffe et al., 2006) plant species diversity was significantly higher in the DIF in relation to the DF. This could be attributed to the early stage of invasion in the DIF, indicating that invasion is yet to have it full impact on the flora of the area. Therefore, there is still an opportunity for management intervention to control *B. papyrifera* and *C. odorata* so as to protect the biodiversity of the forest.

Compared with other tropical forests, the Tinte Bepo forest reserve vertically presented a higher structural complexity. For instance, González (1988) classified emergent layer at an average height of 25 m in a dry forest at Llannos, Venezuela as against > 40 m observed in this study. In fact, the emergent and upper canopy layers classified by González (1988) corresponded with the lower canopy (20-30 m) and understorey (< 20 m) layers respectively at the Tinte Bepo forest reserve. In Cat Tien National Park, Vietnam, trees > 25 m were consi-dered as emergent species (Blanc et al., 2000) which was far below the minimum height (> 40 m) set for emer-gent species in this study. Though trees in all the forest types studied were generally tall, those in the UF were on the average taller (36.7 ± 3.8 m) than trees in the DF (30.3 ± 4.1 m) and DIF (29.9 ± 4.2 m). The difference could be partly explained by degradation in the form of logging of tall and big trees which has undoubtedly affected the vertical structure of the DF and DIF. Even though tree size (dbh) correlated with tree height in all the forest types, the relationship was stronger in the DF ($r = 0.812$; $p = 0.000$) and DIF ($r = 0.741$; $p = 0.000$) com-pared with the UF ($r = 0.368$; $p = 0.002$). Thus, dbh of trees in the DF and DIF could be a better predictor of tree height than tree dbh in the UF. Age of trees has been found to influence the relationship between tree height and dbh with younger forests showing a stronger rela-tionship than matured forests (Ryan and Yoder, 1997). Thus, the cutting down of matured trees in the DF was at least partly responsible for the better correlation between these parameters compared to the other forest types.

Generally, tree density in relation to vertical structure of the forest, decreased with increasing height of canopy layers. The number of trees in the understorey layer was far higher than the number of trees in the upper strata (lower canopy, upper canopy and emergent layers) in both the DF and NIF. On the contrary in the UF, tree density in the upper strata exceeded that of the understorey, an indication that the UF is more matured in relation to the other forest types. The diameter class distribution pattern for all the forest types was negative exponential or reverse 'J-shaped' curve, suggesting mature forests (Rollet, 1978; Blanc et al., 2000). However, the relatively high frequency of trees in the medium diameter class of DF and DIF points to disturbed matured forests, given further credence to the finding that the UF is more matured than the others. The cutting down of large trees in the DF and DIF could explain the relatively lower mean basal area of woody species in these forest types.

The greatest diversity of saplings (H´) in the DF could be attributed to higher sunlight intensity in the forest floor (following gap creation) that supported growth and development of seedlings and saplings. Nevertheless, sapling diversity was still lower in the DIF compared to the UF. Invasion of the DIF by *B. papyrifera* and *C. odorata* partly contributed to the poor regeneration of this forest. Sapling and seedling diversity decreased with increasing cover of *B. papyrifera* and *C. odorata* until there were no seedlings or saplings of the native species in areas where the invasive species had formed monotypic stands. This is supported by the findings of Sharma and Raghubanshi (2006). *B. papyrifera* alone constituted 47 % of all the regenerating stems in the DIF, showing their dominance among the regenerating species. The continual dominance of these species may likely affect the regeneration of more native species. The devastating effects of *B. papyrifera* on the regeneration capacity of some native species have also been reported in Ghana (CSIR, 2002). Seedling diversity was poor in the UF but the relatively higher numbers of saplings and trees in the smaller diameter class may indicate the ability of the UF to recruit more seedlings into the adult phase. This finding is supported by the work of Mishra et al. (2008) in which a higher rate of conversion of saplings to trees was recorded in undisturbed forests.

Conclusion

Human disturbances have influenced the floristic composition of the DF and DIF to some extent. Invasion on the other hand did not have much effect on floristic composition of the DIF due to the early stage of invasion. Thus, proper management intervention is required to mitigate the impact of *B. papyrifera* and *C. odorata* before it gets out of control. Logging affected the structural complexity of the forest reserve through the removal of large and tall trees as well as gap creation. The UF was a more matured forest since tree density in the upper-storey was greater than that of the under-storey. The UF had better capacity of recruiting saplings into the adult stage. Invasion of the DIF by *B. papyrifera* and *C. odorata* affected regeneration of native species. The Tinte Bepo forest reserve looks floristically rich and structurally complex in the face of logging, farming activities and invasion in some parts of the forest. Thus, there is the need to curb the anthropogenic activities and plant invasion so as to protect the integrity of the forest.

ACKNOWLEDGEMENTS

The authors are grateful to the Forest Services Division of the Forestry Commission, Nkawie District, for given approval for the work to be conducted in the Tinte Bepo forest reserve. We are also appreciative to Mr. Ntim Gyakari for helping with the identification of the plant species. We thank the Department of Theoretical and Applied Biology, and the Forestry Commission of Ghana, Kumasi for their logistical support.

REFERENCES

Addo-Fordjour P, Anning AK, Addo MG, Osei MF (in press). Composition and distribution of vascular epiphytes in a tropical semi-deciduous forest, Ghana. Afr. J. Ecol.

Addo-Fordjour P, Anning AK, Atakora EA, Agyei PS (2008). Diversity and distribution of climbing plants in a semi-deciduous rain forest, KNUST Botanic Garden, Ghana. Int. J. Bot. 4: 186-195.

Addo-Fordjour P, Anning AK, Larbi JA, Akyeampong S (2009). Liana species richness, abundance and relationship with trees in the Bobiri forest reserve, Ghana: impact of management systems. For. Ecol. Manage. 257:1822-1828.

Ambika SR (1996). Ecological adaptations of Chromolaena odorata (L.) King & Robinson. In: Proceedings of the Fourth International Workshop on Biological Control and Management of *Chromolaena odorata*, Bangalore, India, pp. 1–10.

Anning AK, Akyeampong S, Addo-Fordjour P, Anti KK, Kwarteng A, Tettey YF (2008). Floristic composition and vegetation structure of

the KNUST Botanic Garden, Kumasi, Ghana. JUST 28: 103-116.
Arbonnier M (2004). Trees, shrubs and lianas of West African dry zones. CIRAD, MARGRAF Publishers.
Baker TR, Affum-Baffoe K, Burslem DFRP, Swaine MD (2002). Phenological differences in tree water use and the timing of tropical forest inventories: conclusions from patterns of dry season diameter change. For. Ecol. Manage. 171: 261–274.
Blanc L, Maury-Lechon G, Pascal J-P (2000). Structure, floristic composition and natural regeneration in the forests of Cat Tien National Park, Vietnam: an analysis of the successional trends. J. Biogeogr. 27: 141–157.
Busing RT (1995). Disturbance and the population dynamics of Liriodendron tulipifera: simulations with a spatial model of forest
Campbell DG, Douglas CD, Prance GT, Maciel UN (1986). Quantitative ecological inventory of terra firme and varzea tropical forest on the Rio Xingu, Brazilian Amazon. Brittonia 38: 369-393.
Ceccon E, Omstead I, Vázquez-Yanes C, Campo-Alves J (2002). Vegetation and soil properties in two tropical dry forests of differing regeneration status in Yucatán. Agrociencia 36: 621-631.
CSIR (2002). Country Report on Invasive Alien Species in Ghana: Removing Barriers to Invasive Plant Management in Africa. Council for Sci. and Ind. Res., Accra, Ghana, pp 49–57.
Doyle TW (1981). The role of disturbance in the gap dy-namics of a montane rain forest: an application of a tropical forest succession model. In West DC, Shugart HH, Botkin DB (eds) Forest succession: concepts and application. Springer-Verlag, Berlin, Germany, pp. 56-73.
Epp GA (1987). The seed bank of Eupatorium odoratum along a successional gradient in a tropical rain forest in Ghana. J. Trop. Ecol. 3: 139-149.
Gimaret-Carpentier C, Pelissier R, Pascal J-P, Houillier F (1998). Sampling tree species diversity in a dense moist evergreen forest with regard to its structural heterogeneity. J. Veg. Sci. 9: 161–172.
González V (1988). Los Bosques de los Llanos Orientales. Segundo informe de avance presentado al CONICIT. Instituto de Zoología Tropical, Universidad Central de Venezuela, Caracas, Venezuela.
Hall JB, Swaine MD (1981). Distribution and ecology of vascular plants in a tropical rain forest. Dr W. Junk Publishers, The Hague. succession. J. Ecol. 83:45-53.
Haugaasen T, Barlow J, Peres CA (2003). Surface wildfires in central Amazonia: Short-term impact on forest structure and carbon loss. For. Ecol. Manage. 179: 321-331.
Haugaasen T, Peres CA (2006). Floristic, edaphic and structural characteristics of flooded and unflooded forests in the lower Rio Purús region of central Amazonia, Brazil. Acta Amazon. 36: 25–36.
Hawthorne WD (1990). Field guide to the forest trees of Ghana. Chatham: Natural Resources Institute, for the Overseas Development Aministration, London. Ghana Forestry Series 1.
Hawthorne WD (1993). Forest regeneration after logging: findings of a study in the Bia South Game Production Reserve, Ghana. ODA Forestry Series. Natural Resources Institute, Chatham.
Hawthorne WD (1994). Fire damage and forest regeneration in Ghana. ODA Forestry Series. Natural Resources Institute, Chatham.
Hawthorne WD, Jongkind C (2006). Woody plants of western African forests: a guide to the forest trees, shrubs and lianes from Senegal to Ghana. Royal Botanic Gardens, Kew, UK.
Hill JL, Curran PJ (2003). Area, shape and isolation of tropical forest fragments: effects on tree species diversity and implications for conservation forest area. J. Biogeogr. 30: 1391–1403.
Kiruki H, Njung'e J (2007). Population density, structure and early growth characteristics of *Tarchonanthus camphorates* in a woodland at Naivasha, Kenya. Afr. J. Ecol. 45: 31-40.
Klinge H, Adis J, Worbes M (1995). The vegetation of a seasonal várzea in the lower Solimões river, Brazilian Amazon. Acta Amazonica 25: 201-220.
Laidlaw M, Kitching R, Goodall K, Small A, Stork N (2007). Temporal and spatial variation in an Australian tropical rainforest. Austral Ecol. 32: 10–20.
Lambert FR, Marshall AG (1991). Keystone characteristics of bird-dispersed *Ficus* in a Malaysian Lowland Rain Forest. J. Ecol. 79:793-809.
Lieberman D, Lieberman M (1984). The causes and consequences of synchronous flushing in a dry tropical forest. Biotropica 16: 193-201.
Madoffe S, Hertel GD, Rodgers P, O'Connell B, Killenga R (2006). Monitoring the health of selected eastern arc forests in Tanzania. Afr. J. Ecol. 44: 171-177.
Mishra RK, Upadhyay VP, Mohanty RC (2008). Vegetation ecology of the Similipal Biosphere Reserve, Orissa, India. Appl. Ecol. Env. Res. 6: 89-99.
Odoom FK (2005). Chainsawing in the Natural Forests of Ghana: An assessment of the socio-economic impacts of this practice, Forest Harvesting Case-Study 21 Food and Agriculture Organization of the United Nations, Rome.
Opoku K (2006). Forest governance in Ghana: An NGO perspective. A report produced by Forest Watch Ghana for FERN. Zuidam Uithof, Utrecht, Netherlands.
Parker IM, Simberloff D, Lonsdale WM, Goodell K, Wonham M (1999). Impact: toward a framework for understanding the ecological effects of invaders. Biol. Invasions 1: 3-19.
Parthasarathy N (2001). Changes in forest composition and structure in three sites of tropical evergreen forest around Sengaltheri, Western Ghats. Curr. Sci., 80: 389-393.
Poorter L, Bongers F, Kouamé FN, Hawthorne WD (Eds) (2004). Biodiversity of West African forests: an ecological atlas of woody plant species. CABI publishers.
Richardson DM, Pyešk P, Rejmánek M, Barbour MG, Panetta FD, West CJ (2000). Naturalization and invasion of alien plants: concepts and definitions. Divers. Distrib. 6: 93–107.
Riswan S (1987). Structure and floristic composition of a mixed dipterocarp forest at Lempake, East Kalimantan. In: Kostermans, A.G.J.H. (Ed.), Proceedings of the Third Round Table Conference on Dipterocarps (16-20 April 1985, Mulawarman University, Samarinda, East Kalimantan, Indonesia), pp 435-457.
Rollet B (1978). Description, functioning and evolution of tropical forest ecosystems: organization. Tropical forest ecosystems (Ed by UNESCO, UNEP and F.A.O.), UNESCO, Paris, pp. 112–142.
Ryan MG, Yoder BJ (1997). Hydraulic Limits to Tree Height and Tree Growth. Bio. Sci., 47: 235-242.
Sala OE, Chapin FS, Armesto JJ, Berlow E, Bloomfield J (2000). Global biodiversity scenarios for the year 2100. Sci. 287: 1770-1774.
Senbeta F, Schmitt C, Denich M, Demissew S, Vlek PLG, Preisinger H, Woldemariam T, Teketay D (2005). The diversity and distribution of lianas in the Afromontane rain forests of Ethiopia. Divers. Distrib. 11: 443-452.
Sharma GP, Raghubanshi AS (2006). Tree population structure, regeneration and expected future composition at different levels of *Lantana camara* L. invasion in the Vindhyan tropical dry deciduous forest of India. Lyonia 11: 27-39.
Ssegawa P, Nkuutu DN (2006). Diversity of vascular plants on Ssese Islands in Lake Victoria, Central Uganda. Afr. J. Ecol. 44: 22–29.
Stein B, Kutner LS, Adams JS (2000). Precious Heritage: The Status of Biodiversity in the United States. Oxford: Oxford University Press, pp 399.
Swaine MD, Hawthorne WD, Bongers F, Toledo Aceves M (2005). Climbing plants in Ghanaian forests. In: Bongers F, Parren MPE, Traore´ D (Eds) Forest climbing plants of West Africa: diversity, ecology and management. CAB International, Wallingford, Oxfordshire, UK, pp. 93–108.
Taylor CJ (1960). Synecology and silverculture in Ghana. Thomas Nelson and Sons, London, UK.
Terborgh J (1992). Maintenance of diversity in tropical forests. Biotropica 24: 253–292.
Tilman D (1982). Resource Competition and Community Structure. Princeton University Press, NJ.
Tilman D (1988). Plant strategies and the dynamics and structure of plant communities. Princeton University Press. Princeton, New

Jersey.
Vorddzobe VV, Attuquayefio DK, Gbogbo F (2005). The flora and mammals of the moist semi-deciduous forest zone in the Sefwi-Wiawso District of the Western Region, Ghana. W. Afr. J. Appl. Ecol. 8: 49-64.
Wittmann F, Junk WJ (2003). Sapling communities in Amazonian white-water forests. J. Biogeogr. 30: 1533-1544.
WCMC (1992). World Conservation Monitoring Centre. Global Biodiversity: Status of Earth's Living Resources. Chapman and Hall, London, UK.