SHORT-TERM VARIATION IN FOREST DYNAMICS: INCREASE IN TREE DENSITY IN BOABENG-FIEMA MONKEY SANCTUARY, GHANA

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ABSTRACT

The rate at which forest change occurs varies with forest types and time. We measured forest change in a small forest fragment in the forest-savanna transition zone of Ghana. A plot-based survey was conducted to assess tree population dynamics over seven years in the core forest of the Boabeng-Fiema Monkey Sanctuary. A total of 561 trees representing 68 species, 63 genera and 28 families were recorded in 2007 as compared to 432 trees, 70 species, 58 genera and 25 families recorded in 2000. There was a significant increase in total stem density by 29.9 percent from 192 stems/ha in 2000 to 248 stems/ha in 2007. The number of trees with a dbh 10-20 cm increased significantly between censuses. There was no change in tree basal area and species richness. The tree families most represented in 2000 and 2007 were Malvaceae, Combretaceae and Leguminosae. The plot-based method was sensitive at detecting fine-grained changes in forest structure and composition in this ecological zone over a short period of time. It is therefore important to conduct short-term plot-based surveys in forest fragments, which are often under anthropogenic influence in the forest-savanna transition zone, in order to effectively manage or restore the forest ecosystem.

Keywords: ***Deforestation; core forest; forest composition; forest dynamics; plot-based survey***

INTRODUCTION

Tropical forest deforestation and degradation continue to increase (Schroeder *et al.*, 2010) as forests are converted to other land cover types (Achard *et al.,* 2002; Geist and Lambin, 2002; FAO, 2010). Forest degradation alters the structure and composition of the forest (Peres and Barlow, 2004; MEA, 2005), reduces the quantity of woody vegetation cover (Noss, 1999; Fitzsimmons, 2003; FRA, 2010), and transforms the ecosystem for the animal species that use it as their habitat (Chapman *et al.,* 1999; Peres and Barlow, 2004). Assessing forest conditions and monitoring land-cover dynamics is therefore critical to enhance the ability of managers to conserve the flora and fauna of forest habitats in the tropics.

Short-term research on tree population dynamics conducted in South America (Oliveira-Filho *et al.,* 1997), Central America (Hubbell and Foster, 1992) and India (Sundarapandian and Swamy, 2013) reported changes in tree size and diameter in a period less than six years. However, in a 10-yr study in Kibale, Uganda, there were no changes in tree basal area when three forest areas that were selectively logged at different intensities were compared (Chapman and Chapman, 2004; Chapman *et al.,* 2005). There have been no short-term (<10 yr) tree community dynamics studies on diachronic changes in the upper Guinean natural forest-savanna vegetation.

The objectives of this study were to assess short-term changes in tree community composition of trees in the core forest of the Boabeng Fiema Monkey Sanctuary (BFMS), which is potentially under threat of anthropogenic activities. De Almeida *et al*. (2009) have suggested that seven years is a relatively short period to detect change in forest dynamics; however this may depend on forest type. We predicted that there could be changes in tree density, diversity and species richness in the core forest of Boabeng-Fiema Monkey Sanctuary (BFMS) over a seven year period (2000-2007). We compared the information on tree composition and tree sizes recorded in earlier work in that forest in year 2000 (Saj and Sicotte, 2007) with measurements from the same plots seven years later.

METHODS

Study area

The Boabeng-Fiema Monkey Sanctuary (BFMS; Figure 1) is characterized by forest and savanna woodland vegetation (Fargey, 1991). The forest falls within the forest-savanna transition zone of Ghana and is located in the Nkoranza North District in Ghana (7°42′N, 1°41′W). Mean annual precipitation of the area was 1,102.1 mm between 2000 and 2006 (data from Ghana Meteorological Agency). The forest is dry semi-deciduous and falls within the fire-prone zone in Ghana (Hall and Swaine, 1981). The streams in BFMS have forest along them. BFMS is approximately 498 ha, but only the core forest (192 ha) receives protection. The forest shelters two diurnal species of primates (*Colobus vellerosus* and *Cercopithecus campbelli lowei*) (Fargey, 1991; Kankam, 1997) and one nocturnal primate (*Galago senegalensis*) (Bearder, unpublished report).

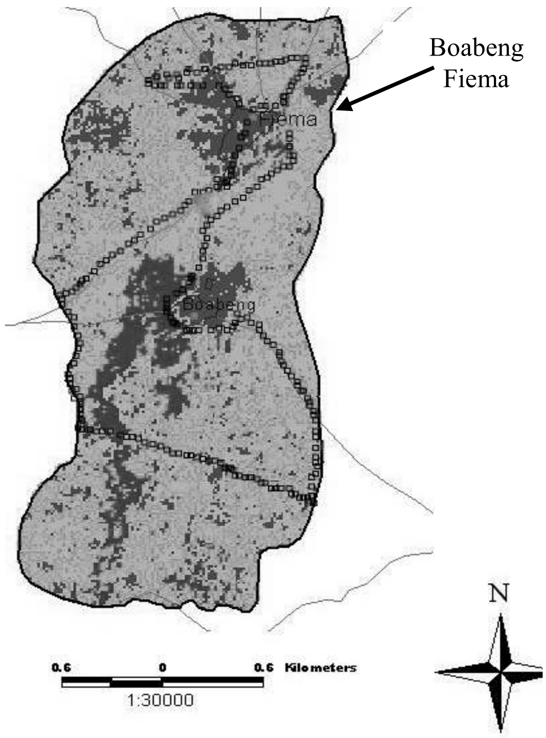

Figure 1: Map of Boabeng-Fiema Monkey Sanctuary. (Open squares boundary represents the core forest area, based on UNDP/GEF sponsored survey map of 1996).

Colobus vellerosus is listed as a vulnerable species in the IUCN Red List (IUCN, 2010). Other animal species seen in the sanctuary include about 375 species of butterflies (Larsen *et al.* 2009), small populations of small mammals, for example royal antelope (*Neotragus pygmaeus*), slender mongoose (*Herpestes sanguine*), African giant rat-(*Cricetomys gambianus*), snakes (*Bitis arietans, Bitis nasicornis* and *Python sebae*) and generalist birds (Beier *et al.,* 2002).

Tree community structure and composition

The original method of measuring quadrats (Mueller-Dombois and Ellenberg, 1974) used by Saj and Sicotte (2007) from their work in 2000 was duplicated to estimate tree species diversity in the core forest of Boabeng. All trees with dbh $\geq$10 cm were measured in 9 quadrats (50 m x 50 m: total 2.25 ha). These quadrats were re-measured in 2007 for the present study.

A compass was used to locate one corner of the plot on the ground with reference to a known large tree located on a grid-based map. This was useful for locating other known individuals that fell within the grid plots. The compass was then used to navigate exactly 90 degrees for 50 m in the direction as shown on the base map to demarcate the 50 m x 50 m tree plots. Although these plots were not permanent sample plots and trees were not tagged, it was possible to locate the corners and identify most of the large trees (stems $\geq$ 40 cm dbh) within the quadrats. The height and the diameter at breast height (dbh) of stems $\geq$ 10 cm were also measured.

Tree diameter was measured at breast height (1.3 m above ground level); however, in cases where buttresses were found diameter was measured above the buttress. Forked trees with the fork below 1.3 m were treated as two stems; however if a stem forked above 1.3 m it was treated as a single stem, and was measured (Condit *et al.* 1998). All dead trees ($\geq$ 10 cm dbh) were identified and recorded; however, the number of dead trees was based on the entire population and not between 2000 and 2007 because the number of dead trees was not recorded in 2000. Tree species were identified in the field, following the nomenclature by Hawthorne and Jongkind (2006), unless otherwise specified.

Species ecological guilds categorization followed Hawthorne (1995, 1996) based on the light requirement of species to germinate and survive under forest conditions as follows: (1) pioneer species, which are well exposed and germinate and survive in open spaces; (2) non-pioneer/light demanders, which germinate in shade conditions at small diameters but need light from canopy gaps to survive as they grow and diameter increases; (3) shade bearers/non-pioneer shade bearers, which can germinate and grow in shade conditions. Species that are usually found in open woodland or savanna only were classified as savanna species (Hawthorne, 1995) whereas species with no guild records were referred to as unclassified (Sheil *et al.,* 2000). In the 2007 survey, new trees $\geq$ 10 cm dbh were recorded in the ecological plots. These new trees were possibly present in the 2000 survey but were less than 10 cm dbh and therefore were not recorded in 2000. There were also ten misidentified species in 2000 that were detected and re-classified in 2007 survey.

Data analysis

Paired *t*-tests were used to test for significant differences of total stem abundance, tree basal area and species richness between the two years surveyed. The differences in tree dbh size-classes between censuses were determined using the repeated measures analysis. Evenness of plant species (Alatalo, 1981) was calculated using the Shannon Evenness index as $E = (N_2-1)/(N_1-1)$, where N_1 is expressed as $exp\,(H')$, and $N_2 = 1/\sum pi^2$. SPSS software version 17 (2008) was used to conduct all analyses. The significance was set at $P \leq 0.05$ for all tests.

RESULTS

Forest structure

A total of 561 stems representing 68 species, 63 genera and 28 families were recorded in 2007 as compared to 432 stems, 70 species, 58 genera and 25 families recorded in 2000 within the same nine 0.25 - ha plots (Table 1a-1d). There was an increase in total stem density by 29.9 percent from 48.0 stems/plot (i.e. 192 stems ha^{-1}) in 2000 to 62.0 stems/plot (i.e. 248 stems ha^{-1}) in 2007. The increase in total stem density was significant between censuses (paired-*t* test = -4.03, df = 8, P = 0.004). There was no statistical difference in mean tree basal area from 2000 (28.4 m^2 ha^{-1}, SD = 10.2) to 2007 (35.6 m^2 ha^{-1}, SD = 15.4; t = -1.21, df = 8, P = 0.261) despite the 25.3 percent increase shown by our data.

Size-classes

There was a significant increase (77.9%) in the number of trees with a dbh 10-20 cm between censuses (paired-*t* test = -3.10, df = 8, P = 0.015). The number of trees with a dbh between 20-39 cm did not differ between censuses with 2.6% increase (t = -0.217, df = 8, P = 0.834), nor did the number of mature trees with a dbh ≥ 40 cm increase (6.4%) significantly (t = -0.450, df = 8, P = 0.665).

Species diversity and composition

The mean number of species recorded in 0.25 ha was 18 for 2000 (max. = 26, min. = 11, SD = 4.9, n = 9) and 20 for 2007 (max. = 28, min. = 12, SD = 5.4, n = 9).

Tree species richness increased by 2.9 percent from 68 in year 2000 to 70 in 2007; however, this difference was not statistically significant (t = 1.06, df = 8, P = 0.322).

There was no change in tree species diversity within the plots from 2000 to 2007 (2000: H′ = 3.49 and 2007: H′ = 3.48). The same trend was shown in species evenness as indicated by the Shannon evenness index which dropped by 0.01 from E = 0.83 in 2000 to E = 0.82 in 2007 (Table 2).

Ecological guild compositions of tree species were almost identical for both surveys in 2000 and 2007. Pioneer species were more abundant followed by non-pioneer light demanders and shade bearers respectively in the 2000 and 2007 surveys. Only shade bearers increased in the number of species by 25 percent from 12 species in 2000 to 15 species in 2007 (Table 2).

Table 1a: Changes in stem abundance of forest species in core forest of Boabeng-Fiema Monkey Sanctuary (2000-2007). Ecological guilds: Pioneer (P), Non-pioneer light-demander (NPLD), Non-pioneer shade-bearer (NPSH) (Hawthorne, 1993, 1995, 1996; Swaine *et al.,* 1992) and Unclassified (–).

Species	Family	Ecological Guild	No. of stems		Change
			2000	2007	
Aidia genipiflora	Rubiaceae	NPSH	0	2	2
Amphimas pterocarpoides	Leguminosae	NPLD	11	19	8
Aubrevillea kerstingii	Leguminosae	NPLD	6	11	5
Blighia sapida	Sapindaceae	NPLD	7	5	-2
Bridelia grandis	Euphorbiaceae	P	4	3	-1
Carapa procera	Meliaceae	NPSH	4	4	0
Celtis mildbraedii	Ulmaceae	NPSH	0	2	2
Celtis philippensis	Ulmaceae	NPSH	0	2	2

Species	Family	Ecological guild	No. of stems 2000	2007	Change
Celtis zenkeri	Ulmaceae	NPLD	2	3	1
Cola gigantea	Malvaceae	NPLD	71	87	16
Cola millenii	Malvaceae	NPLD	7	5	-2
Combretum racemosum	Combretaceae	P	0	3	3
Cordia millenii	Boraginaceae	P	2	3	1
Daniellia ogea	Leguminosae	P	1	0	-1
Dictyandra arborescens	Rubiaceae	NPSH	2	26	24
Diospyros monbuttensis	Ebenacae	NPSH	2	2	0
Diospyros viridicans	Ebenaceae	NPSH	1	0	-1
Distemonanthus benthamianus	Leguminosae	P	3	6	3
Dracaena arborea	Dracaenaceae	P	1	1	0
Ficus ottoniifolia	Moraceae	–	1	5	4
Ficus mucuso	Moraceae	P	1	0	-1
Funtumia elastica	Apocynaceae	NPLD	1	4	3
Garcinia smeathmannii	Guttiferae	NPSH	0	1	1
Holarrhena floribunda	Apocynaceae	P	23	16	-7
Holoptelea grandis	Ulmaceae	P	2	2	0
Lecaniodiscus cupanoides	Sapindaceae	NPSH	8	10	2
Macaranga hurifolia	Euphorbiaceae	P	12	10	-2
Monodora tenuifolia	Annonaceae	NPSH	0	1	1
Monodora myrsitica	Meliaceae	NPSH	23	12	-11
Myrianthus arboreus	Cecropiaceae	NPSH	23	33	10
Napoleonaea vogelii	Lecythidaceae	NPSH	1	0	-1
Ouratea reticulata	Ochnaceae	NPSH	2	1	-1
Oxyanthus unilocularis	Rubiaceae	NPSH	2	1	-1
Parkia bicolor	Leguminosae	NPLD	2	1	-1
Piptadeniastrum africanum	Leguminosae	NPLD	6	5	-1
Pterygota macrocarpa	Malvaceae	NPLD	5	8	3
Spathodea campanulata	Bignoniaceae	P	0	1	1
Sterculia tragacantha	Malvaceae	NPLD	0	1	1
Terminalia glaucescens	Combretaceae	P	2	1	-1
Trichilia monadelpha	Meliaceae	–	2	4	2
Trichilia prieureana	Meliaceae	NPSH	7	6	-1
Trilepisium madagascariense	Moraceae	NPLD	14	22	8
Triplochiton scleroxylon	Malvaceae	P	3	1	-2
Vernonia conferta	Compositae	P	1	2	1
Vitex ferruginea	Verbenaceae	NPLD	0	2	2
Vitex rivularis	Verbenaceae	NPLD	2	1	-1
Zanthoxylum leprieurii	Rutaceae	P	4	6	2
Total			271	341	70

Table 1b: Changes in stem abundance of forest species (which sometimes persist in thickets and savanna) in core forest of Boabeng-Fiema Monkey Sanctuary (2000-2007). Ecological guilds: Pioneer (P), Non-pioneer light-demander (NPLD), Non-pioneer shade-bearer (NPSH) (Hawthorne, 1993, 1995, 1996; Swaine *et al.,* 1992) and Unclassified (–).

Species	Family	Ecological Guild	No. of stems		Change
			2000	2007	
Albizia ferruginea	Leguminosae	NPLD	1	0	-1
Antiaris toxicaria	Moraceae	NPLD	8	6	-2
Ceiba pentandra	Malvaceae	P	6	1	-5
Dichapetalum madagascariense	Dichapetalaceae	NPLD	3	14	11
Ficus sur	Moraceae	P	2	0	-2
Khaya grandifoliola	Meliaceae	NPLD	5	5	0
Milicia excelsa	Moraceae	P	4	3	-1
Morus mesozygia	Moraceae	P	2	1	-1
Pycnanthus angolensis	Myristicaceae	NPLD	12	11	-1
Uvaria chamae	Annonaceae	–	0	3	3
Total			45	46	1

Table 1c: Changes in stem abundance of savanna species (which sometimes persist in other forest types) in core forest of Boabeng-Fiema Monkey Sanctuary (2000-2007). Ecological guilds: Pioneer (P), Non-pioneer light-demander (NPLD), Non-pioneer shade-bearer (NPSH) (Hawthorne, 1993, 1995, 1996; Swaine *et al.,* 1992) and Unclassified (–).

Species	Family	Ecological Guild	No. of stems		Change
			2000	2007	
Albizia coriaria	Leguminosae	P	1	0	-1
Anogeissus leiocarpus	Combretaceae	P	43	39	-4
Antidesma membranaceum	Euphorbiaceae	P	3	1	-2
Dialium guineense	Leguminosae	P	1	1	0
Ficus polita	Moraceae	–	3	0	-3
Lannea nigritana	Anacardiaceae	P	2	0	-2
Lonchocarpus sericeus	Leguminosae	P	13	6	-7
Morinda lucida	Rubiaceae	P	1	1	0
Phyllanthus reticulatus	Euphorbiaceae	NPLD	1	0	-1
Pouteria alnifolia	Sapotaceae	NPLD	13	13	0
Pavetta corymbosa	Rubiaceae	NPLD	2	1	-1
Vernonia colorata	Compositae	NPLD	1	0	-1
Total			84	62	-22

Table 1d: Changes in stem abundance of disturbed area species (which include often cultivated species and tree species commonly found in disturbed areas) in core forest of Boabeng-Fiema Monkey Sanctuary (2000-2007). Ecological guilds: Pioneer (P), Non-pioneer light-demander (NPLD), Non-pioneer shade-bearer (NPSH) (Hawthorne, 1993, 1995, 1996; Swaine *et al.,* 1992) and Unclassified (–).

Species	Family	Ecological Guild	No. of stems		Change
			2000	2007	
Elaeis guineensis	Palmae	P	3	41	38
Ficus exasperata	Moraceae	P	0	3	3
Ficus lutea	Moraceae	–	1	1	0
Grewia mollis	Malvaceae	P	14	35	21
Griffonia simplicifolia	Caesalpiniaceae	NPLD	0	1	1
Hura crepitans	Euphorbiaceae	NPSH	5	11	6
Jatropha gossypiifolia	Euphorbiaceae	P	2	2	0
Mangifera indica	Anacardiaceae	NPLD	2	4	2
Millettia zechiana	Leguminosae	P	0	10	10
Solanum erianthum	Solanaceae	P	0	3	3
Theobroma cacao	Sterculiaceae	NPLD	1	1	0
Thevetia peruviana	Apocynaceae	P	4	0	-4
Total			32	112	80

Table 2: Comparison of tree species diversity and guild in the core forest at Boabeng-Fiema Monkey Sanctuary (2000-2007).

	Survey year	
Parameter	2000	2007
Diversity parameter:		
Tree species diversity within plots (*H'*)	3.49	3.48
Shannon evenness index (E)	0.83	0.82
Species richness (S)	68	70
Number of species by guild		
Pioneers	28	28
Non-pioneer Light Demanders	23	23
Non-pioneer Shade Bearer	12	15
Unclassified species	4	4
Unknown species‡	3	-

Tree families, namely Malvaceae (24.5%), Combretaceae (10.4%), Leguminosae (9.7%), Meliaceae (9.5%), Moraceae (8.8%), Apocynaceae (6.5%), Euphorbiaceae (6.2%) and Cecropiaceae (5.3%) were the most abundant representing 81.0% out of 26 tree families recorded on the plot in 2000 (Table 3). Six out of the eight most represented families in 2000 were again well represented in 2007 (Table 3); these were Malvaceae (24.6%), Leguminosae (10.5%), Moraceae (7.7%), Combretaceae (7.7%), Cecropiaceae (5.9%) and Meliaceae (5.5%). Rubiaceae and Palmae were among the less represented families in 2000 but they increased by 5.52 percent and 7.31 percent respectively from 2000 to 2007.

Table 3: Families and number of species recorded in 2000 and 2007 at Boabeng-Fiema Monkey Sanctuary.

Family	2000		2007	
	Number of species	% composition of stems	Number of species	% composition of stems
Anacardiaceae	2	0.93	1	0.71
Annonaceae	0	0.00	2	0.71
Apocynaceae	3	6.48	2	3.56
Bignoniaceae	0	0.00	1	0.18
Boraginaceae	1	0.46	1	0.53
Caesalpiniaceae	0	0.00	1	0.18
Cecropiaceae	1	5.32	1	5.88
Combretaceae	2	10.42	3	7.65
Compositae	2	0.46	1	0.36
Dichapetalaceae	1	0.69	1	2.49
Dracaenaceae	1	0.23	1	0.18
Ebenaceae	2	0.69	1	0.36
Euphorbiaceae	6	6.25	5	4.81
Guttiferae	0	0.00	1	0.18
Lecythidaceae	1	0.23	0	0.00
Leguminosae	10	9.72	8	10.52
Malvaceae	6	24.54	7	24.60
Meliaceae	5	9.49	5	5.52
Moraceae	9	8.80	8	7.67
Myristicaceae	1	2.78	1	1.96
Ochnaceae	1	0.46	1	0.18
Palmae	1	0.69	1	7.31
Rubiaceae	4	1.62	5	5.52
Rutaceae	1	0.93	1	1.07
Solanaceae	0	0.00	1	0.53
Sapindaceae	2	3.47	2	2.67
Sapotaceae	1	3.01	1	2.32
Sterculiaceae	1	0.23	1	0.18
Ulmaceae	2	0.93	4	1.60
Verbenaceae	1	0.46	2	0.53
Unknown*	1	0.69	0	0.00

* Three unknown species were recorded in 2000 survey. It was excluded from total number of families in plots.

Seventeen new species were recorded in 2007 that were presumably not recorded in 2000 because specimens were smaller than 10 cm dbh. *Millettia zechiana* of the family Fabaceae was the most abundant new species that was recorded in 2007 (Table 4). Nine out of the fourteen new species were forest species with four species commonly found in disturbed vegetation and one that was a forest tree but usually found in thickets and savanna areas. Three species that could not be identified in 2000 might have been recorded as part of the new species identified in 2007. Ten out of twelve tree species that were recorded in 2000 but disappeared in 2007 were recorded as dead (Table 5).

DISCUSSION

There was an increase in total tree density between 2000 and 2007 in the core forest of BFMS. This increase was the result of an increasing number of smaller trees (between 10-20 cm dbh) in the core forest over this seven-year period. Most of these smaller trees that were measured in 2007 were not measured in 2000 because they were either less than 10 cm dbh or were not present yet. For example, a species such as *Khaya grandifoliola* is a fast-growing tropical forest tree that can attain a mean stem diameter of about 11.5 cm after 8 years (Opuni-Frimpong, 2008).

Also, *Elaeis guineensis* (a palm tree) takes less than seven years to grow from seedlings to a larger palm tree with diameter >10 cm dbh (Jaafar and Kasiran, 2008). An increase in tree density in this protected core forest area of BFMS is probably a result of management practices; also, this is an indication that the forest is in the early stages of succession after some areas of the forest were farmed prior to the establishment of the forest as a Wildlife Sanctuary in 1975 (Kankam *et al.,* 2010) and its subsequent protection.

Table 4: New trees and diameter recorded in ecological plots at Bobeng-Fiema Monkey Sanctuary in 2007.

			Tree dbh range (cm)	
Species*	Family	Number	Minimum	Maximum
Uvaria chamae	Annonaceae	3	10.1	15.7
Celtis mildbraedii	Ulmaceae	3	10.5	12.5
Combretum racemosum	Combretaceae	3	10.0	13.2
Celtis philippensis	Ulmaceae	2	11.0	12.6
Vitex ferruginea	Verbenaceae	2	12.0	15.6
Millettia zechiana	Fabaceae	11	10.0	16.7
Griffonia simplicifolia	Caesalpiniaceae	1	13.0	-
Aidia genipiflora	Rubiaceae	2	10.2	14.0
Spathodea campanulata	Bignoniaceae	1	11.0	-
Garcinia smeathmannii	Guttiferae	1	15.5	-
Monodora tenuifolia	Annonaceae	1	12.5	-
Solanum erianthum	Solanaceae	3	10.7	12.3
Sterculia tragacantha	Sterculiaceae	1	10.0	-
Ficus exasperata	Moraceae	3	10.5	14.0
Total		37		

* Trees species that were not previously recorded in 2000 survey because the trees were less than 10 cm dbh.

Table 5: The number of dead tree species recorded in core forest of Boabeng-Fiema Monkey Sanctuary in 2007.

Scientific Name	No. of Stems	Dead stems			
		Snap, Dead	Standing, Dead	Cut, Dead	Fallen, Dead
Cola gigantea	15	4	2	9	
Lecaniodiscus cupaniodes	1		1		
Anogeissus leiocarpus	16	2	2	12	
Dichapetalum guineense	1		1		
Terminalia glaucescens	1			1	
Bridelia grandis	1			1	
Grewia mollis	2		1	1	
Holarrhena floribunda	1		1		
Carapa procera	1		1		
Aubrevillea kerstingi	2		1	1	
Ficus mucuso	1		1		
Celtis mildbraedii	1			1	
Vernonia colorata	1			1	
Diospyros viridicans	1			1	
Myrianthus arboreus	3	1	1	1	
Dictyandra arborescens	1		1		
Antiaris toxicaria	1				1
Ouratea reticulata	1			1	
Milicia excelsa	1				1
Albizia coriaria	1		1		
Albizia ferruginea	1			1	
Daniella ogea	1			1	
Thevetia peruviana	3			3	
Ficus polita	3		3		
Monodora myristica	9		1	8	
Lannea nigritana	2		1	1	
Napoleonaea vogelii	1				1
Unidentified species*	21			21	
All species	94	7	19	65	3
(%)		(7.4)	(20.2)	(69.2)	(3.2)

Tree species in bold indicate species that disappeared in 2007 survey.
*Stems were cut to the soil level and destroyed beyond recognition for identification.

The increase in forest tree density could mean that the core forest, which is undergoing succession, has features (*e.g.,* micro-site effects or climate) that allow forest trees to increase while savanna trees decrease in abundance. Absence of fire in the core forest area may also have contributed to the increase in forest tree density (Swaine *et al*., 1992); the cutting down of trees, especially savanna trees may also be a contributing factor. The increase was within the range observed in other natural tropical forests, for instance in Sabah, South-east Asia (Nicholson, 1965) and in Panama, Central America (Lang and Knight, 1983; Putz and Milton, 1982), but there is no similar data for upper Guinean natural forest-savanna vegetation (*but see* Swaine, *et al.,* 1992).

The increase in tree basal area is another indication that the core forest is undergoing succession (Chazdon *et al.,* 2007). The forest in this zone can therefore increase in number of tree species and tree density when protected against external pressure such as fires and anthropogenic activities, which suggest that forest expansion could probably occur (Lwanga *et al.,* 2000). Forest expansion will also increase if tree mortality reduces (Table 5).

Twelve tree species were lost from 2000 to 2007; at the same time, fourteen more were recruited. This accounted for no change in tree species diversity and species richness between the two census years. The statistical results do not show how dynamic the forest environment was during this period, something that is only revealed when one compares the actual species recorded. As the forest tree crowns begin to close and overshadow the understory trees, shade bearers grow faster as compared to pioneer trees (Whitmore, 1989) perhaps favouring the survival of non-pioneer shade bearers over time (Hawthorne, 1996; Ndam and Healey, 2001). This may have led to the recruitment of more shade bearers than were lost as compared to pioneers and non-pioneer light demanders.

Leguminosae and Malvaceae were the most species-rich families, followed by Moraceae in 2007. The increasing presence of the families Malvaceae (Aristide *et al.,* 2009), Leguminosae and Moraceae has also been reported in semi-deciduous forests in Benin and Ghana respectively (Vordzogbe *et al*., 2005; Addo-Fordjour *et al*., 2009). The abundance of Malvaceae at BFMS is probably due to their ability to withstand drought better than the other families (Steentoft, 1988).

Both species richness and diversity are small in comparison to other sites in transition zone (Addo-Fordjour *et al*., 2009; Gonmadje *et al*., 2011). The increase in plant species richness by 2.9 percent between census periods may be due to an absence of fire and major anthropogenic disturbances in the period considered. The increase could be as a result of growth in dbh of some tree species that were below 10 cm dbh during the year 2000 to $\geq$ 10 cm during the current survey.

Detection and understanding short-term variation in the diversity of forest fragments is fundamental to forest management to foresee long-term changes and future forest stand structure. The information generated by this research demonstrates the importance of conducting short-term plot-based surveys in forest fragments under threat of anthropogenic disturbance in order to effectively manage or restore the forest ecosystem. Future re-assessment of these plots is essential to get a sense of long-term changes.

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