TREE SPECIES ABUNDANCE AND REGENERATION POTENTIAL OF SEMI-DECIDUOUS FOREST FRAGMENTS OF THE ASHANTI REGION OF GHANA

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ABSTRACT

The objective of this study was to determine the regeneration potential of natural forest fragments in the dry semi-deciduous forest zone in the Ashanti region of Ghana. For this reason tree species abundance was studied in two distinct natural forest patches located within a teak plantation. The full sampling revealed a total of 224 individual trees belonging to 26 species and 14 families. A regeneration study using a systematic sampling design recorded a total of 46 tree species from 18 tree families. The majority of the woody species in the remnant natural forest was represented by only a few tree species. About 52% of all mature and regenerating trees were pioneer species. It could be concluded that the higher diversity among the regeneration is due to seed dispersal from outside by birds, mammals and wind. The remnant natural forests show high species abundance and can play an important role for the preservation of a floristic diversity in a converted landscape.

KEY WORDS: Forest fragments, Ghana, plantation, regeneration, species abundance.

RÉSUMÉ

L'abondance des espèces forestières a été étudiée dans un vestige de forêt naturelle de 5 ha localisée dans une plantation de tek en forêt sèche semi-décidue dans la région d'Ashanti au Ghana. Un inventaire complet de deux reliques distinctes de forêt naturelle a montré l'existence de 224 arbres vivants appartenant à 26 espèces issues de 14 familles. Une étude sur la régénération par échantillonnage systématique a montré un total de 46 espèces issues de 18 familles. La majorité des espèces ligneuses dans le vestige de forêt naturelle était représentée par quelques espèces seulement. 52% de tous les arbres matures et régénérés étaient des espèces pionnières. En conclusion, la diversité plus importante parmi les espèces en régénération pourrait être due à la dispersion des graines par les oiseaux, les mammifères et le vent. Le vestige de forêt naturelle montre une forte abondance d'espèces et peut jouer un rôle important pour la préservation de la diversité de la flore dans un paysage profondément transformé.

INTRODUCTION

The tropical forests are estimated to be the host of more than four-fifth of the world's biodiversity (FAO 2001). The rate of disappearance of tropical forests is alarming with West Africa being the hardest hit by this trend (Schroeder et al. 2010).

The forests in West African are recognized as among the most depleted and fragmented in the world and together with Central African forests they are among the most biologically unique (Hall & Swaine 1981; Hawthorne 1988; Myers 1990; Whitmore 1997; Goudie 2000; Myers et al. 2000). Fragmentation is one of the processes that accounts for species loss and loss of diversity (Hunter 1996). The major cause of fragmentation is the expanding human population converting natural ecosystems into human-dominated ecosystems. Fragmentation of habitats caused by human actions is one of the most prevalent impacts acting and modifying natural species assemblages (Ranta et al. 1999; Bolger et al. 2000; Lomolino & Perault 2000). Puhari & Murai (1999) have demonstrated the high correlation between human population density and cumulative forest loss. Agriculture, a dominant land-use technique, is a proximate cause of most fragmentation (Hunter 1996; Johns 1997; FAO 2001). Although fragmented landscapes are now becoming ubiquitous features of the tropical world (Laurance & Bierregaard 1997), fragments of original habitats located in the middle of anthropologically changed landscapes can play an important role as refuge areas for the original biodiversity and as ecological

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corridors. Exchange between the disjunct patches of habitats is essential. These forest fragments could then act as reservoirs from where native species can disperse again when conditions have changed.

Botanical assessments such as floristic composition and structure studies are vital in the context of understanding the extent of plant diversity in forest ecosystems (WCMC 1992; Addo-Fordjour et al. 2009). They are instrumental for the assessment of sustainability of forests since forests play a major role in the conservation of plant species, and ecosystem management (Tilman 1988; Ssegawa & Nkuutu 2006). Ecological data obtained in this regard are not only useful for the application of sound management practices but, among others, also beneficial in identifying important elements of plant diversity, protecting threatened and economic species and monitoring the state of forests (Tilman 1988; Ssegawa & Nkuutu 2006; Addo-Fordjour et al. 2009).

The main objective of this study was to determine the potential of the remaining forest fragments as a source of natural regeneration to neighboring teak (*Tectona grandis* L.f) plantation stands in a heavily degraded landscape which has widely changed to grasslands with only a few forest patches left with indigenous tree species. Specific objectives were to (i) determine the tree species abundance and diversity of the forest fragments and (ii) determine the regeneration potential of the tree species.

Study Area

The study was carried out in a privately owned Dupaul Wood Treatment Ltd.-plantation (7°3' N and 1°34' W) 42 km north of Kumasi, the Ashanti regional capital of Ghana. This region is located in the semi-deciduous forest zone (Hall & Swaine 1981). The soils are comparatively rich in nutrients and ideal for the cultivation of cocoa and other cash crops. The identified soils in the plantation area are predominantly sandy and the cation exchange capacity indicates that the nutrient supply from the clay fraction and organic matter is sufficient and suitable for the cultivation of trees (Kuester 2003). The annual rainfall varies between 1200 mm and 1800 mm.

The plantation site covers a total area of 164 hectares, which is grouped into four vegetation areas: the tree plantation area, grassland area, farmlands, and remnants of natural forest. The grassland area was burnt by fires in previous years. The tree plantation area was afforested mainly with teak, to a lesser extent with pine (*Pinus oocarpa* Schiede ex Schltdl., *Pinus caribaea* var. *hondurensis* Morelet, *Pinus taeda* L., and *Cedrela odorata* L. This area is divided in different planting blocks with planting periods from 1995 to 2003 (Ackermann & Kuester 2004).

METHODS

Two remaining forest fragments (5 ha in size) were completely inventoried following standard forest inventory procedures as described by Koehl et al. (2006). No herbarium vouchers were collected. All trees (≥ 10cm diameter at breast height (1.3 m), DBH) were counted, tagged and identified to the species level using fresh material. Staff at the Forestry Department Herbarium in Kumasi assisted with identifications. Tree heights were assessed to the nearest decimetre by using a Suunto hypsometer. The DBH were measured with a diameter measure tape to the first decimal place. In case of stem form anomalies at 1.3 m height the diameter was determined by the mean of measurements above and below the irregularity. The diameter of oil palms (*Elaeis guineensis* Jacq.) was not assessed due to heavy branching all over the trunks. All botanical nomenclature in this paper follows Hawthorne and Jongkind (2006).

The dominance (basal area) and abundance values (total and proportional) of each tree with a DBH of 10 cm or more were calculated from the inventory data as described by Lamprecht (1989). Hoheisel (1976) has shown that there is a straight linear correlation between crown and stem diameters. Since the determination of crown projection is difficult, total dominance (TD) was calculated as basal area from the measured DBH (Hoheisel 1976; Lamprecht 1989; Wattenberg & Breckle 1995). The relative or proportional dominance (PD) was calculated as the percentage of a tree species of the total basal area in the study plot. Total abundance (TA) was calculated as the stem number of a given species per area while the proportional or relative abundance (PA) is the percentage of the total stem number per area.

To estimate the regeneration potential, a grid of 50 m × 50 m was laid out based on an existing 250 m × 250 m grid on a map. Circular sampling plots with a radius of 10.30 m were systematically located at the inter-

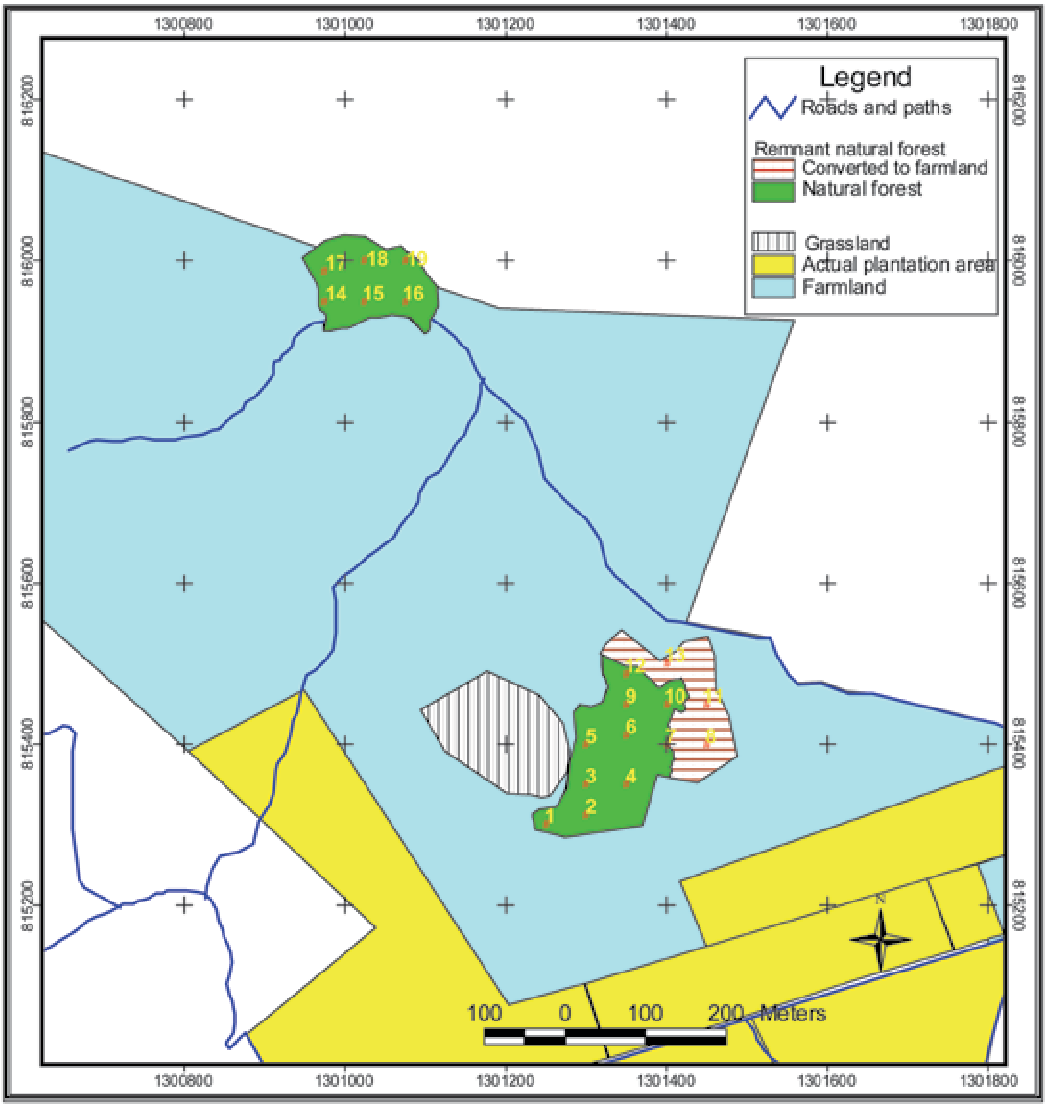

FIG. 1. Map of portions of Papasi plantation showing the sampling points within the forest fragments and the complete grid of the plantation area.

sections of the universal transverse mercator (UTM) grid. The systematic sampling design was used because it is representative and ideal for repeated inventories since long term research is planned for this plantation. The positions of the plots were located in the field with a Global Position System (GPS) instrument (GeoExplorer III) and marked permanently to ensure that plots are located again in the next inventory. A total of 19 sampling points was located in the two forest fragments, 6 on the forest fragment located at the northern border and 13 sampling points on the forest fragment in the middle of the plantation (Fig. 1). As a rule of thumb, any sampling point that was inaccessible was shifted 12 m to the north.

All small trees above a height of 1.30 m and below a diameter of 10.0 cm (regeneration class 1) were recorded. Smaller squared plots of 100 m² were located in the larger plots for the survey of young individuals between 0.50 m and 1.30 m height (regeneration class 2). Small trees of 30 to 50 cm height (regeneration class

3) were recorded in 25 m^2 plots. For the estimation of seedlings below 30 cm, circular subplots of 3.14 m^2 were laid out within the 25 m^2 plots. All individuals in these regeneration plots and subplots were counted by species.

Guilds are ecological groupings of species that can be used to describe functional traits of different types of trees (Hawthorne 1993). Tree species differ in their responses to gaps where more light is available. This differentiation can be used as the basis for categorising forest trees into ecological guilds. Species are classified into (1) pioneer trees, which germinate and grow in canopy gaps or under open conditions and (2) non-pioneer trees which tolerate forest shade (Swaine & Whitmore 1988). Pioneer species are highly competitive in disturbed forests (Agyeman 2000). Non-pioneer tree species are further subdivided into semi-shade-tolerant species and shade-bearers (Lamprecht 1989). Semi-shade-tolerant species are found only as seedlings in the twilight zone and require gaps to develop further. Shade-bearers on the other hand are trees found in all sizes in the twilight zone (Hawthorne 1993).

RESULTS

General findings

A total of 224 individual trees with DBH ≥ 10 cm belonging to 26 species and 14 families were found on the 5 hectares of remnant forest. The oil palm *Elaeis guineensis* Jacq. showed the greatest number with a total of 77 (34%) palm trees. *Bombax buonopozense* P. Beauv. was represented with a total of 39 trees. The majority of species in the remnant natural forest was represented by only few trees. Eight (8) species were found with only one individual.

The total basal area—excluding oil palms—in the two forest fragments was 45.69 m^2 (i.e. 9.00 m^2 / ha). *Bombax buonopozens* P. Beauv. recorded the greatest basal area with 15.33 m^2 while *Nesogordonia papaverifera* A. Chev. only measures 0.01 m.

It can be observed from Table 1 that the most abundant tree species are also the most dominant ones. This is illustrated by the following species: *Bombax buonopozense* P. Beauv., *Ceiba pentandra* L., *Mangifera indica* L. and *Spathodea campanulata* P. Beauv. In the case of *Broussonetia papyrifera* L'Hér. ex Vent., however, this pattern was not followed. This species recorded a high percentage of abundance (7.14), but a very low percentage of dominance (1.39), which indicates these trees remain in the narrow diameter class. *B. papyrifera* L'Hér. ex Vent., the paper mulberry tree, is an exotic tree species from east and southeast Asia. The fast growing species was introduced to Ghana with the purpose to produce fuel wood. Beyond cultivation the tree species regenerated rapidly and spread naturally. Today the species is regarded as invasive to Ghana (IUCN 2009). The dominance value of oil palm could not be calculated because diameter measurements were not taken for this species.

Floristic Structure

The forest fragments attained a maximum height of 36 m with only 1.34% of all trees constituting the highest layer of trees. The tree height distribution shows a hyperboloid function (Fig. 2). The lower height classes recorded more numbers of trees.

The DBH distribution featured a similar function as that of the tree heights with many small and only few thick trees. DBH values ranged from 10 cm to 217 cm. Figure 3 shows the number of trees in the various DBH classes.

Regeneration

The regeneration study revealed a total of 46 tree species in all 19 sampling sites representing 18 tree families with Moraceae accounting for 39%, thus being the most abundant family. The regeneration class 2 and 3 showed the highest number (N = 333) of regenerating plants per hectare. Regeneration class 1 featured the lowest number of regenerating trees with only 18% of the total regenerating plants. The average number of trees per hectare in the various regeneration height classes is illustrated in Figure 4. However six tree species *Vernonia amygdalina* Delile, *Macaranga heterophylla* Müll.Arg., *Millettia zechiana* Harms, *Massularia acuminata* (G. Don) Bullock ex Hoyle, *Glyphaea brevis* (Spreng.) Monach. and *Baphia nitida* Lodd.recorded as regenerating

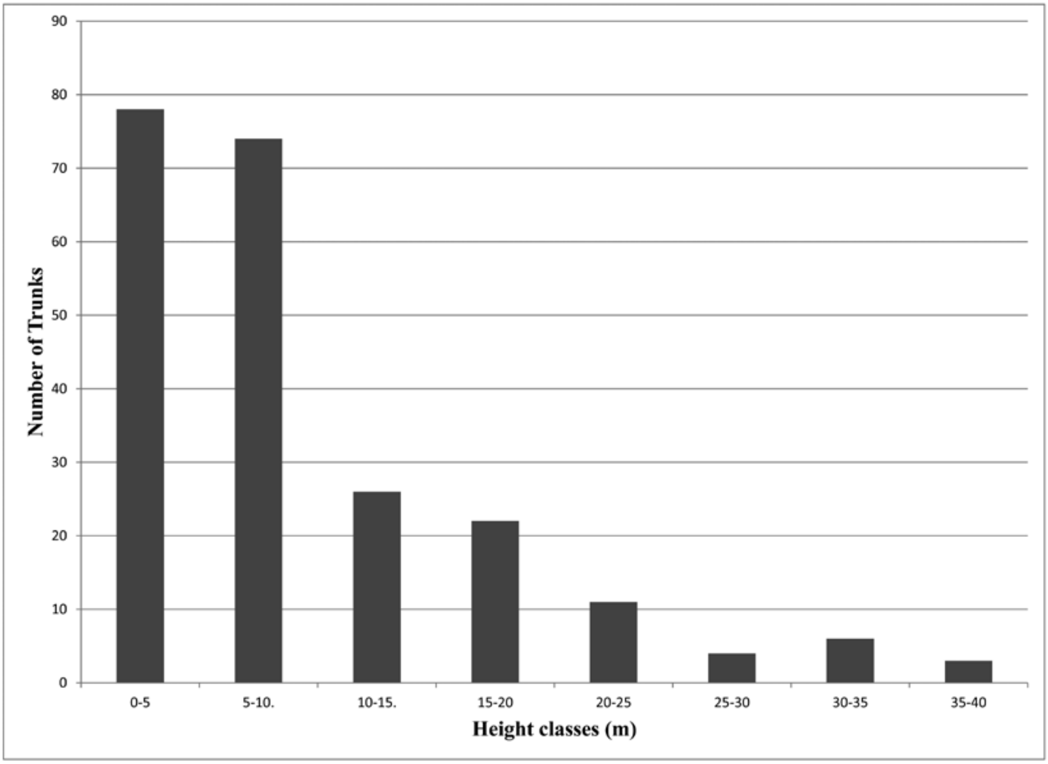

FIG. 2. The distribution of individual tree species (≥ 10 cm DBH) within the various height classes (m).

plants may be fully grown trees since literature (Hawthorne & Jongkind 2006) describe them as small trees growing up to a maximum height of between 8–10 m.

During this research it could be observed that various tree species regenerated under thick grass cover except under the composite species *Chromoleana odorata*, an invasive weed species.

Species guilds

Trees were classified into the described species guilds (Table 2) according to Hall and Swaine (1981) and Hawthorne (1993; 1994).

About 52% of all mature and regenerating trees recorded in the forest fragments are pioneer species while 48% are non-pioneer species. When the non-pioneer species are further divided into semi-shade-tolerant species and shade-bearers 28% of the non-pioneer species are semi-shade-tolerant while 20% are shade-bearers.

DISCUSSION

The vital role that floristic composition and structure play for the conservation of plant species, sustainability of forests and the management of forest ecosystems as a whole is well acknowledged (Tilman 1988; Ssegawa & Nkuutu 2006; Addo-Fordjour et al. 2009). Few studies (Hall & Swaine 1981; Vordzogbe et al. 2005; Anning et al. 2008; Addo-Fordjour et al. 2009) have been conducted in Ghana, the results of our research is compared to the above. The tree species inventory within the forest fragments showed a low species abundance. The average number of 45 trees / ha is very low compared to 552 trees / ha in a moist semi-deciduous forest at Kade, Ghana (Swaine et al. 1987). Swaine and Whitmore (1988) state a wide range of tree numbers (395–734 / ha ≥ 10 cm DBH) for tropical forests from three continents. For semi-deciduous forests in Venezuela, Lamprecht (1989) recorded a range of 284–333 stems / ha. The reason for the low tree appearance in the surveyed forest patches

TABLE 1. Total and proportional abundance (TA, PA) and the total and proportional dominance (TD, PD) of all trees with a DBH of 10 cm or more in the remnant natural forest patches. The trees are arranged alphabetically by species (n.d. = not determined).

Species	Family	TA (N)	PA (%)	TD (m^2)	PD (%)
Albizia ferruginea	Mimosaceae	1	0.45	0.93	2.02
Albizia zygia	Mimosaceae	4	1.79	0.16	0.35
Alstonia boonei	Apocynaceae	4	1.79	1.12	2.46
Antiaris toxicaria	Moraceae	2	0.89	1.59	3.47
Bombax buonopozense	Bombacaceae	39	17.41	15.33	33.54
Borassus aethiopium	Palmae	3	1.34	0.25	0.54
Broussonetia papyrifera	Moraceae	16	7.14	0.63	1.39
Ceiba pentandra	Bombacaceae	10	4.46	8.91	19.51
Cola gigantea	Sterculiaceae	4	1.79	7.38	16.15
Cordia senegalensis	Boraginaceae	3	1.34	0.20	0.43
Elaeis guineensis	Palmae	77	34.38	n.d.	n.d.
Ficus exasperata	Moraceae	1	0.45	0.03	0.06
Ficus sp.	Moraceae	6	2.68	1.75	3.82
Glyphaea brevis	Tiliaceae	6	2.68	0.64	1.41
Khaya ivorensis	Meliaceae	1	0.45	0.70	1.53
Lannea welwitschii	Anacardiaceae	1	0.45	0.06	0.13
Mangifera indica	Anacardiaceae	17	7.59	1.30	2.85
Margaritaria discoidea	Euphorbiaceae	2	0.89	0.41	0.90
Nesogordonia papaverifera	Sterculiaceae	1	0.45	0.01	0.02
Newbouldia laevis	Bignoniaceae	2	0.89	0.10	0.22
Ricinodendron heudelotii	Euphorbiaceae	2	0.89	1.14	2.49
Spathodea campanulata	Bignoniaceae	17	7.59	2.35	5.13
Tetrapleura tetraptera	Mimosaceae	2	0.89	0.02	0.04
Trema orientalis	Ulmaceae	1	0.45	0.03	0.07
Trichilia tessmannii	Meliaceae	1	0.45	0.62	1.36
Triplochiton scleroxylon	Sterculiaceae	1	0.45	0.05	0.11
26 species	14 families	224	100.00	45.69	100.00

is due to former logging operations and shifting cultivation practices. 90% of all trees ≥ 10 cm DBH showed abiotic damages on roots, buttresses or crowns caused by fire or felling activities. The two forest fragments are not protected and surrounded by other land-use forms. The fact that the studied forest fragments are degraded could have accounted for the low density of trees compared to what have been recorded elsewhere.

Although the calculation of tree species' diversity by dividing the total number of species by the recorded area is systematically incorrect, it was done here to compare survey results with those of other authors from Ghana. The tree species' diversity of 5 species per ha determined in this study is very low compared to 37 species / ha assessed by Anning et al. (2008) in a disturbed semi-deciduous forest. In a similar forest type Addo-Fordjour et al. (2009) recorded 48 tree species / ha in the Tinte Bepo Forest Reserve and Vordzogbe et al. (2005) calculated a tree species diversity of 80 species / ha in the same forest type.

The Simpson's reciprocal diversity index determines the number of species in relation to the abundance of each species. A low value represents little, a high value great diversity. In the remnant forest Simpson's reciprocal diversity index was 6.02, calculated for all trees ≥10 cm DBH. Thus, the diversity of trees in the surveyed remnant natural forest was low compared to the maximum diversity of 26. Although species diversity indices have been criticized, they are still widely used in plant and animal ecology to evaluate, survey, and conserve ecosystems (Mouillot & Leprêtre 1998).

Similar to the tree species diversity the average total dominance (basal area) of 9.14 m^2 / ha is also minor compared to values recorded in disturbed forests at Kade with 30.85 m^2 / ha (Swaine et al. 1987) and the range of 28 to 52 m^2 / ha stated by Swaine and Whitmore (1988) for tropical countries and Lamprecht (1989) who reports 29 m^2 / ha from Venezuela. The low value in dominance is partly due to the presence of oil palms which have not been measured as explained above and is partly caused by logging and shifting cultivation activities.

Almost all floristic structure and general stand parameters indicate that the surveyed remnant natural

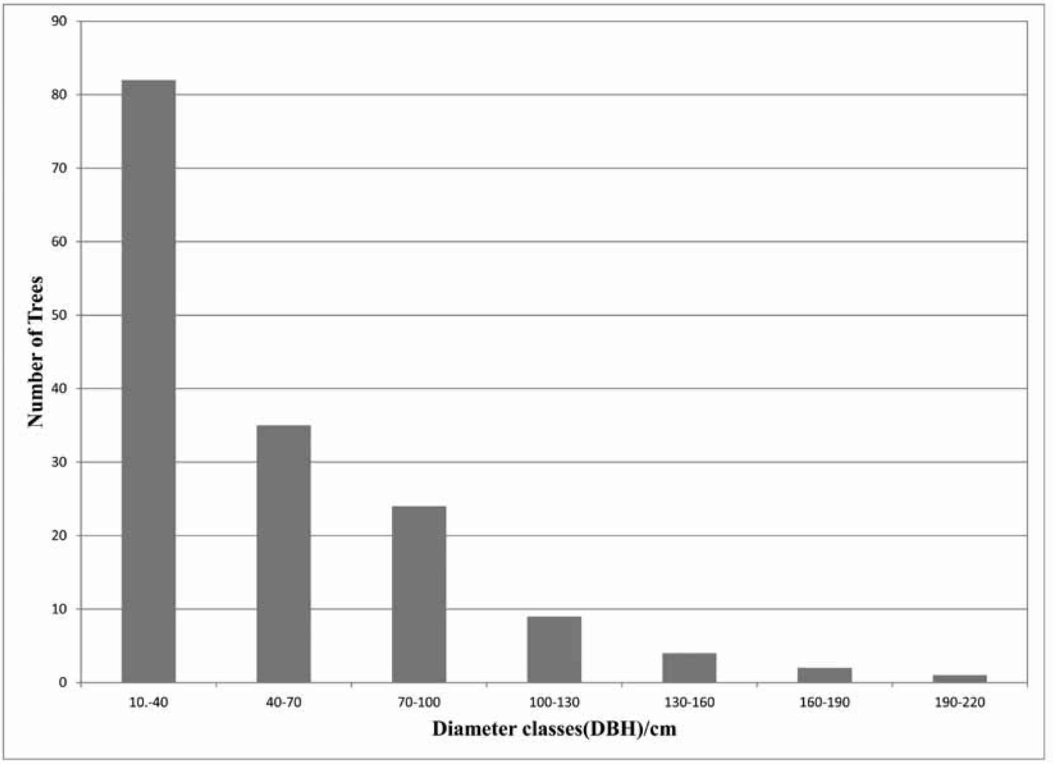

FIG. 3. Number of trees in the various DBH classes.

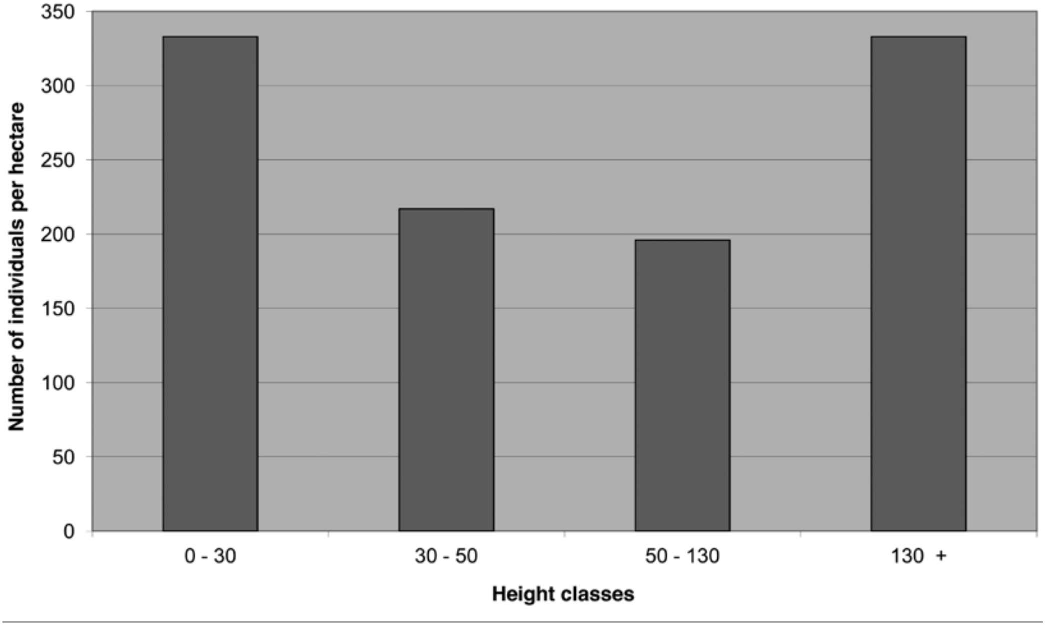

FIG. 4. Number of individual regenerating plants in different height classes.

TABLE 2. Classification of trees species into guilds.

Pioneer species	Non-pioneer species Semi-shade-tolerant	Shade-tolerant
Alstonia boonei	*Albizia adianthifolia*	*Baphia nitida*
Bombax buonopozense	*Albizia ferruginea*	*Blighia unijugata*
Borassus aethiopium	*Albizia zygia*	*Blighia sapida*
Broussonetia papyrifera	*Antiaris toxicaria*	*Cola caricifolia*
Ceiba pentandra	*Cola gigantea*	*Deinbollia grandifolia*
Cordia senegalensis	*Entandrophragma utile*	*Funtumia elastica*
Elaeis guineensis	*Glyphaea brevis*	*Hymenostegia afzelii*
Erythroxylum mannii	*Khaya ivorensis*	*Lannea welwitschii*
Ficus exasperata	*Myrianthus arboreus*	*Mallotus oppositifolius*
Ficus sp.	*Myrianthus libericus*	*Massularia acuminata*
Ficus sur		*Millettia zechiana*
Holarrhena floribunda		*Microdermis keayana*
Lecaniodiscus cupaniades		*Nesogordonia papaverifera*
Macaranga heterophylla		*Tetrapleura tetraptera*
Mangifera indica		*Trichilia monadelpha*
Mareya micrantha		
Margaritaria discoidea		
Morinda lucida		
Morus mesozygia		
Milicia excelsa		
Newbouldia laevis		
Rauvolfia vomitoria		
Ricinodendron heudelotii		
Sterculia tragacantha		
Spathodea campanulata		
Terminalia ivorensis		
Trema orientalis		
Triplochiton scleroxylon		
Vernonia amygdalina		

forest in Ghana's Ashanti region is highly degraded. It has a low number of trees, fewer tree species and small basal area per hectare as compared to other forest types of its kind, i.e. the semi-deciduous forest. The height and diameter classes follow a similar pattern with more trees in the lower height and diameter classes. The maximum height (36 m) and diameter (218 cm) are however typical for deciduous forests in Ghana (Addo-Fordjour et al. 2009). The great number of pioneer trees in the lower layers of the tree canopy is an indication of a secondary forest.

The analysis of the regeneration data indicate that almost twice the number of species (46) and families (18) are present than among the mature trees (26). In comparison Addo-Fordjour et al. (2009) report only 29 tree species from 12 families from the Tinte Bepo Forest Reserve. This suggests that the remnant forest surveyed in this study still has a vigorous regeneration potential and that seed dispersal vectors are active.

Consequently we analysed the possible ways how the new tree species got into the forest fragments. Most probably these seeds do not originate from the soil seed bank as no mature individuals of these species exist in the forest fragments. Though there are no other natural forests present in the area and far beyond, wind, birds and mammals are possible vectors of seed dispersal. Wind plays an important role in the dissemination of pioneer species' seeds, which are light, often winged and can be carried to considerable distances. The recorded small tree species *Vernonia amygdalina* is an example for seed dispersal by wind.

Birds and mammals, especially flying foxes, are however the most likely dispersal vectors because they move and can carry seeds over long distances. Regular observations of different bird and bat species within the remnant forest underline our assumption which also corresponds with the findings of Swaine and Whitmore (1988) and Whitmore (1990) while Sayer el al. (1992) identified the role of animals for seed dispersal and forest rehabilitation processes. In this context remnant natural forests hold an important function as they can serve as retreat and corridor for plants and animals in fragmented landscapes. Thus, forest patches contribute to the preservation of biodiversity.

The absence of tree regeneration under the invasive species *Chromolaena odorata* calls for weed control in the remnant forest patches. Agyeman (2000) states that *Broussonetia papyrifera* could be used to effectively control the spread of herbaceous invasive species like *C. odorata*, but this appears not to be a valid solution since *B. papyrifera* itself is an invasive species and an efficient coloniser. The devastating effects of *B. papyrifera* on the regeneration of some native species have been documented in Ghana (CSIR 2002). Research to find an efficient way of controlling *B. papyrifera* in natural forests is therefore required.

Our forest inventory and data analysis revealed that the surveyed remnant natural forest is seriously degenerated in terms of structure and composition but it still holds a regeneration potential and contributes to the preservation of biodiversity. To maintain these functions appropriate measures in form of protection and effective silvicultural practices should be applied. If this succeeds, the natural forest patches might become richer in species number, growing stock and even more diverse in the near future. Thus, these last remnant forest pockets serve as retreat for native floristic diversity in a highly converted environment.

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