academicJournals

Vol. 6(3), pp. 238-246, March 2014
DOI: 10.5897/IJBC2012.134
ISSN 2141-243X © 2014 Academic Journals
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International Journal of Biodiversity and Conservation

Full Length Research Paper

Regeneration potential and stand structure of a proposed plantation site in the transition zone of Ghana

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Receive 11 September, 2012; Accepted 20 February, 2014

A proposed timber plantation site (approximately 1,900 hectares) located in the forest-savanna transition zone of the Ashanti Region, Ghana was surveyed. The objectives of the study were (1) to analyze the present stand structure (2) and to assess the tree regeneration potential on the plantation site. The forest assessment used systematic sampling design which revealed an open and fire disturbed stand structure with an estimated average basal area per hectare (α = 0.05) of 9.89±1.94 m^2. The forest vegetation comprises of a single layer and features an average top height (α = 0.05) of 17.7 ± 0.8 m. The assessment of the tree species composition indicated a relatively homogeneous floristic composition with an average tree species number per sample plot of 10.0±1.0. A total of 65 tree species belonging to 48 genera and 25 families was recorded. Tree regeneration from seeds and resprouts recorded an average number per hectare (α = 0.05) of 3.884 ± 746 with a total of 38 species regenerating. The remnant forest vegetation is assumed to be in a regressive succession stage towards savanna vegetation. A conversion of the remnant forest vegetation to production forest seems to be possible, if the existing socio-economic pressure on the forest resources can be reduced and wildfires can be prevented.

Key words: Savanna, fire, forest regeneration, stand structure, Ghana.

INTRODUCTION

The sustainable management and conservation of remnant forest resources deserves ample attention at the local, regional and international level. Though the tropical forests are estimated to be the host of more than four-fifth of the world's biodiversity (FAO, 2001), the rate of deforestation in the tropics is alarmingly high with West Africa being the hardest hit by this trend (Schroeder et al., 2010). It is estimated that natural forests of the tropics will not be able to sustain increasing domestic and international demands for wood and its products (Tiarks et al., 1998). The establishment of timber plantations is inevitable to meet increasing demand of wood and its products including fire wood, pulpwood and saw logs (Brown et al., 1997). In addition, the establishment of timber plantations can reduce deforestation by decreasing pressures on natural forests, restore degraded soils and enhance biodiversity (Parrotta, 1992, 1995).

Practical and scientific work has been concentrated on sustainable management of mostly temperate and rather

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recently tropical forests. Some scientists have even identified the apparent failure to manage forests sustainably as one of the main concerns with regard to tropical forests destruction (Leslie, 1994). If this is true it can be anticipated that timber which originates from tropical forests will be harvested and marketed to a lower extent in future. Sustainable forest management is an approach that balances economic, social and ecological objectives. Essentially, the difficult task of achieving this goal lies in combining conservation with a potentially destructive use such as timber harvesting. The fact that tropical forests are ecologically the most complex terrestrial ecosystems is a major factor that accounts for the limited success in sustainable forest management. In addition, the socio-economic problems arising from the use of tropical forests for wood production is a contributing factor (Leslie, 1994). Lastly, the dependence of developing countries' economies on wood production greatly hampers the objectives of sustainable forest management.

In terms of protective functions, a requirement for the implementation of sustainable forest management is that existing forest resources, that is, forest area, growing stock, biodiversity of forest ecosystems- are not further degraded by human activities. This can only be accomplished if the pressure on forests of the user groups (forest dwellers, exploration firms, logging concessions) can be reduced. One option is the establishment of timber plantations. Sustainable plantation forestry can ensure the conservation of biodiversity, increase wood production and can produce further benefits. Timber plantations in the tropics consist almost always of one or very few tree species. Such stands are biologically not diverse and have a low ecological value. Experiences with the establishment and management of mixed tree species plantations are widely missing. A new approach towards ecological sound plantation forestry is the integration of existing natural tree vegetation into the plantation concept. This leads to the conservation of remnant forest areas which would have diminished otherwise (Brockerhoff et al., 2008). Such concepts for the implementation of sustainable plantation forestry are needed in the West African Region for the enhancement of economic development, conservation of biodiversity and improvement of rural livelihoods.

Since forests play a key role in the conservation of plant species and ecosystem management (Tilman, 1988; Ssegawa and Nkuutu, 2006) surveys of the floristic composition and stand structure studies are essential for addressing the diversity in forest ecosystems (WCMC, 1992; Addo-Fordjour et al., 2009). Ecological data obtained in this context are not only important for the introduction and application of sound management practices but, among others, are also useful in identifying important elements of tree diversity, protecting threatened and economic species and monitoring the state of forests (Tilman, 1988; Ssegawa and Nkuutu, 2006; Addo-Fordjour et al., 2009). The main objective of this study was to determine

Figure 1. Location of the Ejura plantation site and ecological zones in Ghana (Ackermann, 2007).

the stand structure of the proposed plantation site for the elaboration of a biological diverse forest plantation concept. The specific objectives were (1) Analysis of the present stand structure and (2) determination of the regeneration potential of present tree species on the plantation site.

MATERIALS AND METHODS

Study area

The study was carried out on a privately owned proposed site for a Teak plantation 100 km north of Kumasi, in Ejura - Sekyedumase district of the Ashanti region. The area is located in the forest-savanna transition zone which is characterized by the co-existence of the two distinct ecosystems forest and savanna. The district is marked by two rainfall patterns; the bimodal pattern in the south and the unimodal in the north. The main rainy season is between April and November with annual rainfall varying between 1,200 and 1,500 mm. The plantation site (Figure 1) is approximately 17 km from the Ejura Township and is bordered to the north by two villages Nkrama and Bisiu, Boami to the south, while to the west it is fringed by the Awura forest reserve and to the east by the Afram River (Knoell, 2004). The soil types were classified according to WRB/USDA Soil Taxonomy as Albic Plinthosols/Typic Plinthustalf. The soil-texture consists predominantly of sandy loams. The soils are relatively shallow, encountering a hard ironstone pan at the petroferric contact at an average depth of 42 cm (Werner, 2008).

Sampling design

Long term research is intended for this plantation site, therefore

Table 1. Stem-form classes according to Synnott (1979).

Class	Description
A	Stem is straight in length, no apparent defects or major branches (diameter ≥5 cm) over the top length or the lower 7 m of the stem, suitable for high quality sawn timber and veneer
B	Stem is relatively straight in length, few apparent defects or major branches (diameter ≥5 cm) over the top length or the lower 7 m of the stem, suitable for sawn timber
C	Stem is formed irregularly with limitations of length and/or numerous or major apparent defects, commercially useless, recorded for botanical purposes

the systematic sampling method was used because the systematic distribution of sample plots is more efficient at detecting phenolmena such as variations in species composition and stand structure (Synnot, 1979). A total of 47 circular sample plots were laid on the plantation site. Each plot of 15 m radius (706.5 m^2) was set up on the field with the use of the ultra sonic measure device Vertex IV. Smaller circular sub-sample plots of 5 m radius (78.5 m^2) were established using the same centre point for the assessment of regenerating trees with a height < 1.30 m (seedlings and small saplings).

Tree species inventory and measurements

The sample plot measurements followed standard procedures as described by Synnot (1979). All trees (≥ 5.0cm diameter at breast height (1.3 m), DBH) were counted, tagged and identified to the species level by a botanist from the herbarium in Kumasi. Tree heights were assessed to the nearest decimeter 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 botanical nomenclature in this paper follows Irvine (1961), Arbonnier (2004) and Hawthorne and Jongkind (2006). All tree regeneration with a height <1.30 m which occurred in the inner sub-sample plot were identified, counted and assigned to the three height classes; seedlings < 30 cm, small saplings 30 - 50 cm and big saplings 50 - 130 cm.

The stem-form of all trees with a height ≥ 1.30 m was assessed. A 3 point system relates the straightness of a stem to its utilization potential. For multi-stemmed trees the stem-form of the stem closest to the average DBH was recorded (Table 1).

For the assessment of reoccurring fires, every tree with a height ≥ 1.30 m was assessed for fire signs. A binary system was implemented consisting of two categories; visible fire signs on stem and/or lower branches and no visible fire signs on stem and/or lower branches.

Data analysis

The data on the abundance of tree species, number of trees and number of stems were scaled to number per hectare and represented graphically by the species/area curve. The top height which is the average height of the 100 tallest trees of the survey was calculated by dividing the sum of the maximum height per sample plot with the number of sample plots (Kramer and Akca, 1982). The basal area which is the cross-sectional area of all stems in a stand at 1.3 m height was calculated per hectare. The number of regenerating tree species was also scaled to the number per hectare. All data analysis was carried out with Microsoft Excel software.

RESULTS AND DISCUSSION

General findings

A total of 1,171 trees (with a height ≥ 1.30 m) were assessed in 47 sample plots of 3.3 hectares size. All recorded trees belong to 65 species, 48 genera and 23 families. The species/area curve is a measure for the floristic representativeness of a botanical survey. It indicates how many new species are found when a survey plots becomes enlarged. In our case, the curve performs a strong progression until 0.8 hectares, indicating that 50% of all tree species are represented in this size of the surveyed area (Figure 2). Later, the curve becomes flatter and is almost reaching an asymptote at 3.3 hectares. From this point onwards a further enlargement of the survey area would not increase the tree species spectrum. The trend of the species/area curve follows a natural logarithmic function (R^2 = 0.95). Lamprecht (1989) proposed that the minimum representing area has been reached, when the increase in the number of species per unit area remains below 10% while the sample plot is enlarged in size by 10%. In our case, this point was reached at 1.5 ha sampling area. Thus, the species/area curve proofs that an almost complete tree species survey was carried out.

Stand structure

The assessment of the surveyed forest vegetation revealed an average stem number per hectare (α = 0.05) of 518 ± 88 trees and an average basal area per hectare (α = 0.05) of 9.89 ± 1.94 m^2. Swaine and Whitmore (1988) stated a wide range of tree numbers (395–734 / ha ≥ 10 cm DBH) for natural tropical forests from three continents while for semi-deciduous forests in Venezuela Lamprecht (1989) recorded a range of 284-333 trees/ha. Hall and Swaine (1981) give reference to various forest types of Ghana. According to their findings tree numbers vary from 474 to 514 / ha (Table 2).

On a first view, our results seem to be comparable to the average stand parameters of Hall and Swaine. But their standard error was lower and their minimum diameter threshold was ≥ 10.0 cm whereas our tree numbers

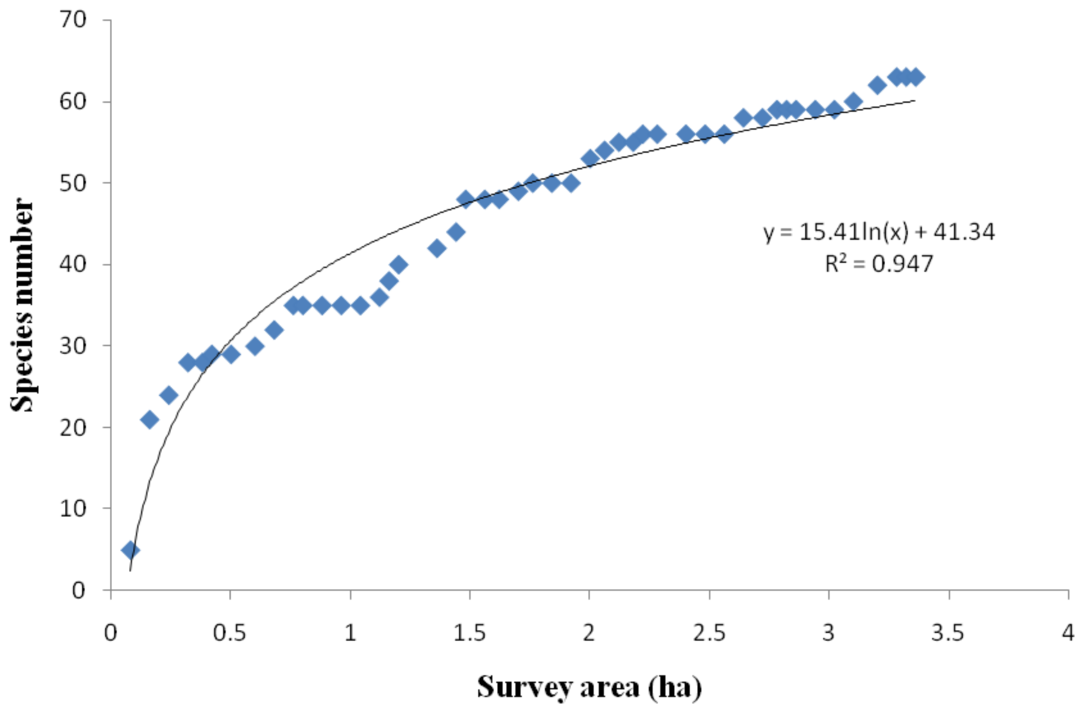

Figure 2. Species/area curve proofs that the surveyed area is representative of the floristic assessment of the tree species composition.

Table 2. Average stand parameters of Ghanaian forest types (Hall and Swaine, 1981).

Forest Type	Stem number (trees/ha)	Basal area (m^2/ha)
Moist semi-deciduous	514 ±29	24.3 ± 1.1
Dry semi-deciduous (inner zone subtype)	504 ± 32	24.2 ±1.1
Dry semi-deciduous (fire zone subtype)	474 ± 32	22.3± 1.2

refer to a diameter threshold of ≥ 5.0 cm. If we would have applied a ≥ 10.0 cm diameter threshold, the average tree number would have been reduced to only 168 ± 38 per hectare (α= 0.05) which accounts just for 35% of the category "Fire Zone Subtype" from Hall and Swaine. The tree numbers ranged from a minimum of 28 to a maximum of 481 trees/ha.

The average top height of the forest vegetation (α= 0.05) of this research site was determined as 17.7±0.8 m. The maximum height of 27.6 m was recorded for a specimen of *Daniellia oliveri*. Hall and Swaine (1981) mention an average top height of 49 m for moist semi-deciduous forest and 36 m for dry semi-deciduous forest. From this point of view, the top height of the assessed forest is very low as compared to the given literature values, which indicates that the forest vegetation might be severely degraded or belong to a different forest type.

The mean height of the forest vegetation (α= 0.05) is low with 6.8 ±1.4 m and differs widely from the average top height. The mean heights of the various sample plots range from 4.6 to 10.2 m. The large difference between the average top height and the mean height is due to the relatively high number of tree saplings (trees of DBH <10.0 cm), which contribute to the development of the single layer canopy structure of the forest vegetation. The low average values of the aforementioned stand parameters in combination with large differences between the maximum stand height (height of the tallest tree per sample plot) and the mean height per sample plot indicate disturbances of the stand structure of the forest vegetation. "Shifting cultivation" and fire are estimated to be among the major causes. During the field survey, large trees were observed to be often left standing, that is, due to their missing utilization potential or for cultural reasons (Lovett and Haq, 2000) or simply for lack of technical equipment to fell the trees while other parts of the vegetation were cleared. When the cultivated areas are abandoned, secondary forest vegetation develops, which consists of an early succession stage of numerous small trees (saplings) and a small number of "old"/large trees. In a later succession phase the secondary forest vegetation grows higher which results in a closer gap between

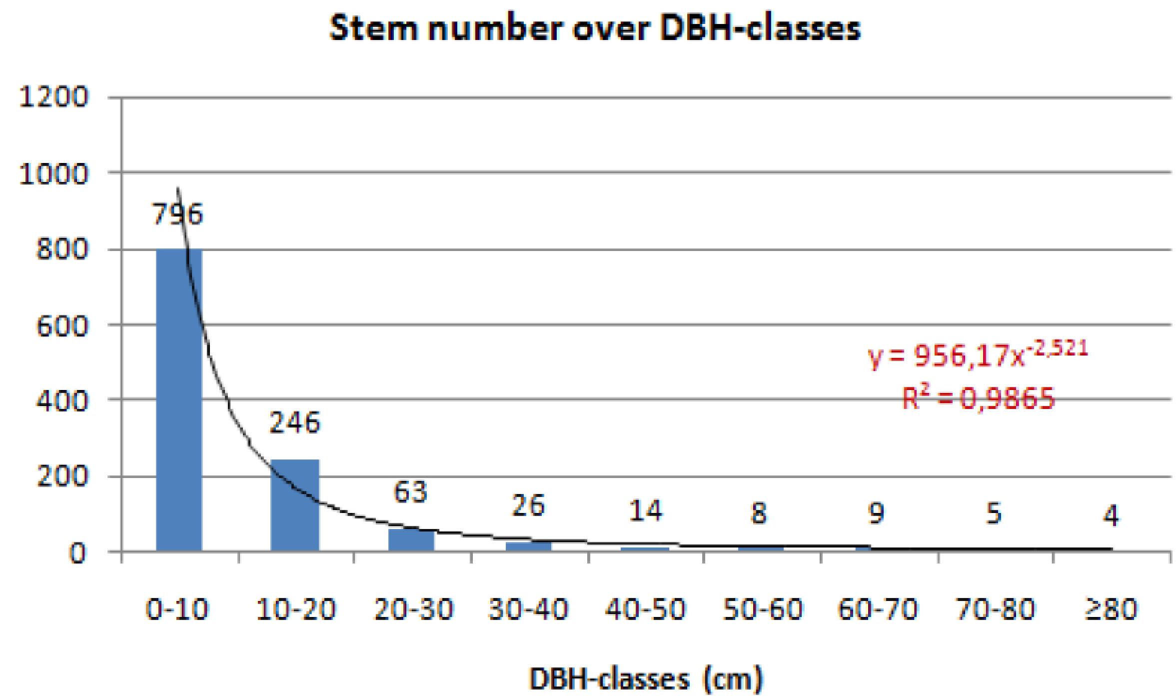

Figure 3. Distribution of stem number over DBH-classes illustrating the absence of thick diameter classes.

maximum height and mean height.

The diameter distribution shows a hyperboloid function (Figure 3) with the lower diameter classes containing more trees. The distribution of stem number over DBH-classes features an exponentially decreasing curve (R^2= 0.99) towards the larger DBH-classes. The trend is characteristic for natural forests regenerating from seeds (Lamprecht, 1989). Only 381 trees of the survey area (32.5% of surveyed trees) recorded a DBH ≥ 10.0 cm, while 796 trees (77.5% of surveyed trees) featured a DBH < 10.0 cm with an average DBH of 5.1 ±0.5 cm. Moist and dry semi-deciduous forests regenerating from seeds demonstrate exponentially decreasing distribution trends, but feature higher stem numbers in all DBH-classes (Lamprecht, 1989). Especially trees of the medium DBH-classes (30–60 cm) and higher DBH-classes (≥ 60 cm) are represented with extremely low stem numbers. Thus, the trend of the exponentially decreasing curve resembles a natural stand structure only in the lower diameter classes.

A further proof for severe disturbances of the forest vegetation is revealed when the distribution of the relative basal area - percentage of the total basal area – over DBH-classes is analyzed (Figure 4). The bimodal distribution shows a dominant peak for the DBH-classes, 10–30 cm and a minor peak for the DBH-class, 60–70 cm. Illegal wood harvest for charcoal production which has been reported from the site is assumed to have a drastic impact on the disappearance of trees of the medium DBH-classes (30–60 cm) since they are targeted for such operations and thereby severely reduce the average basal area per hectare. As a result the forest vegetation develops to an “over thinned” stand structure, that is, in terms of stem number and basal area per hectare. According to Pancel (1993) this phenomenon is also typical for “fire degenerated” forest vegetation. The open stand structure of the forest vegetation (Figure 5) in combination with the single layer canopy structure suggests that the majority of trees are pioneer species or tree species that are adapted to habitats of the savanna vegetation.

Wildfires belong to the natural site condition in the transition zone of West Africa. But today their frequency is by far higher than under natural conditions. Gautier and Spichiger (2004) even assume that “almost all fires are currently of anthropogenic origin” in West Africa. On our research site, 83% of all trees were visibly affected by fire. Beyond wildfires shortened fallow cycles under shifting cultivation and increased population pressure have further reduced the vitality of the forest vegetation and have a determining influence on the structure and the current tree species composition (Bongers et al., 2004). The majority of the trees show a crooked and/or low branching habitus, typical for fire disturbed forest vegetation (Lamprecht, 1989). Only 1% of the surveyed trees are classified as potential crop trees and can potentially be utilized for sawn timber production (feature a relatively straight stem form with minor defects) (Table 2), while 99% of the surveyed trees are classified as non-potential crop trees for sawn timber. Thus, the surveyed forest vegetation features characteristic traits of fire climax vegetation.

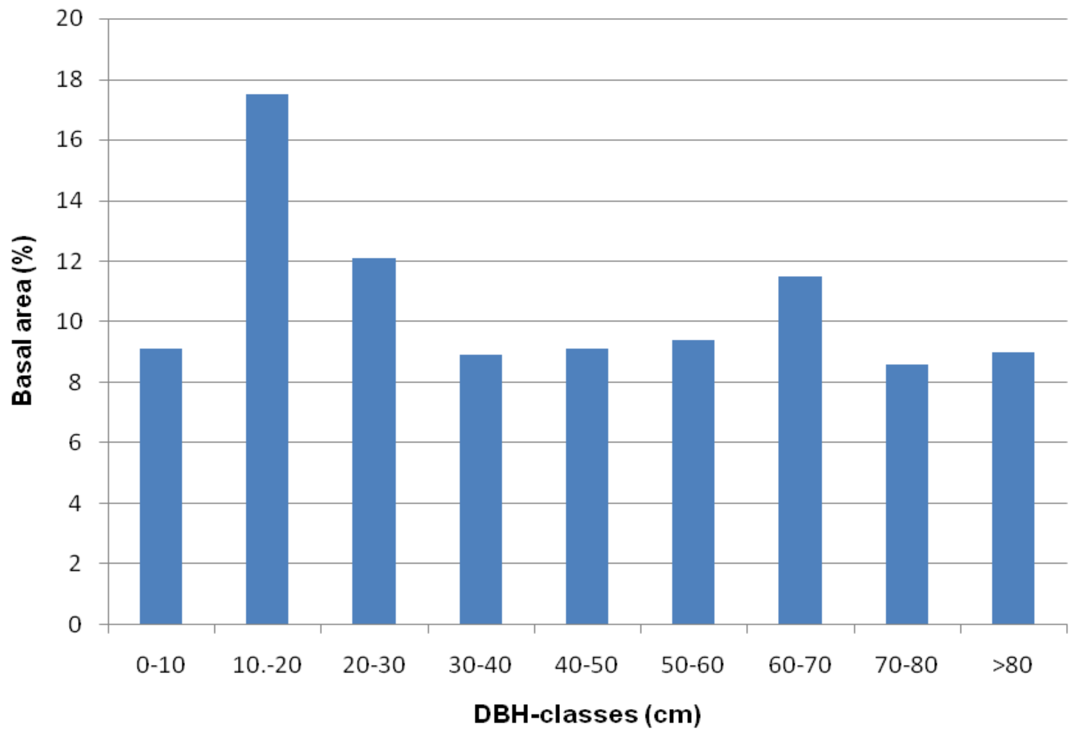

Figure 4. The irregular distribution of relative basal area over DBH-classes indicating that the forest is severely disturbed.

Figure 5. The indigenous vegetation on the proposed plantation site displaying the open stand structure

Table 3. List of regenerated tree species encountered, their plant families and abundance.

Specie	Family	Number of trees/hectare
Afzelia africana Sm.	Leguminosae	3
Albizia adianthifolia W.Wight	Leguminosae	18
Albizia zygia J.F.Macbr.	Leguminosae	26
Anogeissus leiocarpus Guill.&Perr.	Combretaceae	56
Baphia pubescens Hook.f.	Leguminosae	15
Borassus aethiopium Mart.	Arecaceae	3
Bridelia ferruginea Benth.	Euphorbiaceae	126
Cola chlamydantha K.Schum.	Sterculiaceae	100
Crossopteryx febrifuga Afzel. (ex Guill.&Perr.)	Rubiaceae	21
Cussonia barteri Seem.	Araliaceae	3
Daniellia oliveri (Rolfe.) Hutch.&Dalziel	Leguminosae	462
Elaeis guineensis Jacq.	Arecaceae	3
*Ficus kamerunensis*Warb. (ex.Mildbr.&Burret)	Moraceae	3
Ficus sur Forssk.	Moraceae	179
Ficus vogeliana Miq.	Moraceae	3
Grewia mollis Juss.	Tiliaceae	47
Holarrhena floribunda T.Durand.&Schinz	Apocynaceae	62
Lannea acida A.Rich.	Anacardiaceae	26
Lonchocarpus sericeus (Poir.)DC	Leguminosae	6
Lophira lanceolata Tiegh.	Ochnaceae	21
Lychnodiscus spp.	Sapindaceae	138
Manilkara obovata (Sabine&G.Don)J.H. Hemsl	Sapotaceae	9
Margaritaria discoidea (Baill.)G.L.Webster	Euphorbiaceae	276
Maytenus buchananii (Loes) Wilczek	Celastraceae	24
Nauclea latifolia Sm.	Rubiaceae	512
Parkia biglobosa (Jacq.)R.Br. (exG.Don)	Leguminosae	6
Pileostigma thonningii (Schumach.) Milne-Redh	Leguminosae	109
Pseudospondias spp.	Anacardiaceae	21
Pterocarpus erinaceus Fern. Vill.	Anacardiaceae	18
Spathodea campanulata P. Beauv.	Polygalaceae	3
Sterculia tragacantha Lindl.	Sterculiaceae	65
Stereospermum acuminatissimum K.Schum.	Sterculiaceae	123
Terminalia glaucescens Planch.exBenth.	Bignoniaceae	100
Trichilia roka (Forssk)Chiov.	Meliaceae	509
Trichilia monadelpha (Thonn.)J.J. de Wilde	Meliaceae	12
Vitellaria paradoxa C.F.Gaertn	Meliaceae	670 (IUCN listed “vulnerable”)
Vitex doniana Sweet.	Sapotaceae	9
Vitex micrantha Guerke	Lamiaceae	71
Total		**3854**

Regeneration potential

A total number of 38 regenerating tree species were encountered (Table 3). The average number of regenerating trees per hectare (α=0.05) was 3,854 ± 746. It ranges from a minimum of 127 individuals per hectare to a maximum of 9,555. In this survey, the number of regenerating tree species is high as compared to the literature values given by Swaine (1992) who recorded 2,133 seedlings and 18 resprouts per hectare in the “Inner zone” of the Ghanaian semi-deciduous forest subtype while the “Fire zone” subtype featured 156 seedlings and 2,032 resprouts per hectare. In comparison, Addo-Fordjour et al. (2009) reported only 29 regenerating tree species from 12 families for the Tinte Bepo Forest Reserve in Ghana, while Tom-Dery and Schroeder (2011) recorded 46 tree species which also contained double the number of big trees (≥ 40 cm DBH) from a site located about 70 km west of the proposed plantation.

This suggests that the remnant forest surveyed in this study still has a vigorous regeneration potential and that seed dispersal vectors are active. The high tree regeneration might be due to a variety of reasons. The open stand structure of the remnant tree vegetation allows a strong solar radiation of the forest floor and soil layer, which can lead to high germination rates. While the majority of the surveyed tree species must be regarded as pioneer species and non-pioneer light demanders, they are well adapted to full overhead light conditions. The high tree regeneration number might also be a result of good resprouting capability of many of the tree species. The above ground parts of small saplings (height 50–130 cm) and tree saplings (trees of DBH < 10cm) are probably frequently damaged or killed by the occurrence of bush fires. If the root parts survive, the trees can resprout under favorable conditions. Due to a high fire frequency tree regeneration is probably not given enough time to grow to a tall tree. Therefore a permanent resprouting phase is prevailing which over time, results in an accumulation of saplings and trees of small diameter. Despite the relatively high regeneration rate, it can be assumed that under the present fire regime, the forest is in a regressive phase and develops towards a savanna of secondary origin as described by Gautier and Spichiger (2004).

Conclusions and recommendations

The assessment of the stand structure and tree regeneration of the remnant forest vegetation has revealed severe disturbances of anthropogenic origin. Hence, integrated forest management strategies are needed, which should consider the demands of adjacent communities. The medium to high diversity of the remnant forest vegetation gives credence to the conservation of part of the remnant natural forest. The occurrence of commercial timber species and the open stand structure of the remnant forest vegetation open a long-term perspective for their integration into production forest. Although, it will be a challenge for silviculturists to develop a forest plantation scheme consisting of an uneven aged mixture of exotic and indigenous tree species, it can be a rewarding contribution to the conservation of forests and biodiversity in a sparsely wooded landscape. Furthermore, the constant endangerment of forests through wildfires must be managed. For that purpose, fire preventing measures for example, fire breaks, buffer zones, prescribed burning techniques and awareness creation should be taken into consideration as an essential precondition for a successful forest management in the Ashanti region.

Conflict of Interests

The author(s) have not declared any conflict of interests.

ACKNOWLEDGEMENTS

We wish to sincerely thank DuPaul Wood Treatment Ltd. for the logistic support throughout this research. We are also thankful to Mr. Thomas Agyekum of the Forestry Commission in Kumasi, Ghana for aiding in species identification. Furthermore, we are very grateful to the Foundation for Forest Conservation in Africa (Stiftung Walderhaltung in Afrika), Hamburg, Germany for funding the field research.

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