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Mapping and tree species diversity of the forest savanna mosaic in Ashanti region, Ghana

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The objectives of the study are; (1) to stratify the existing degraded forest into defined land cover types using satellite imagery; (2) to assess the level of canopy cover and (3) ecological stratification of forest and savanna according to vegetation cover based on a terrestrially assessed parameter canopy cover was conducted as a supervised classification of satellite images. Two vegetation strata were identified and classified as forest and savanna. The forest vegetation featured an open canopy structure with an estimated average canopy cover of 21.6 ± 3.2%. The canopy cover ranges from a minimum of 10% to a maximum of 51.8%. A tree species assessment recorded a total of 65 tree species belonging to 49 genera and 23 families. A comparison of the tree composition of the forest and savanna vegetation strata revealed no significant differences. A literature review of the inventoried tree species revealed that, the majority of tree species are characteristic forest species (47.7%), while typical savanna woodland species and species found in both vegetation types recording 36.9 and 15.4% respectively.

Key words: Mapping, transition zone, canopy cover, species diversity, Ghana.

INTRODUCTION

Globally the tropical forests are estimated to host more than four-fifth of the world's biodiversity (FAO, 2001) but despite the high populations and rapid deforestation in recent years (FAO, 2005), the tropical forest still retains about half of the world's species, even though they occupy only seven percent of the land area (Wilson, 1992). African forest resources suffer from continuous degradation caused by overutilization (e.g., for fuel wood collection, hunting, logging) and the regular occurrence of fires. The rate of disappearance of tropical forests is alarming with West Africa being the hardest hit by this trend (Schroeder et al., 2010). In a typical year, Africa accounts for more than half of the global forest area damaged by wildfires (FAO, 2007). Fire therefore plays an important role in shaping the vegetation. In recent decades, West Africa has developed wood-based industries (that is, sawmilling and panel-products) stimulated by policies and legislation discouraging the export of unprocessed logs. West Africa has been a major source of tropical hardwood however; the sub region's ability to be a major producer of tropical hardwood is on the decline. From being exporters of tropical logs in the 1980s and 1990s, many countries are finding that their forest resources have depleted to such an extent that they are unable to even meet the domestic demand for wood and wood products (FOSA, 2003). The conversion of degraded tropical forests into forest tree plantations is widely practised throughout the tropics and is taking place in Ghana on moderate extent. The estimated area of forest plantations, a subset of planted forests defined as those consisting primarily of introduced species is about 5.2 million hectares worldwide and accounts for app. 18 million hectares in the tropics (FAO, 2010). The purpose of tree plantations are generally grouped into economic,

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social and environmental benefits (Buck, 1995; Ruitenbeek and Cartier, 1998) but most often the economic benefits supersede the rest. It is expected that tree plantations will play an increased role as a sustainable, energy efficient, environmentally and socially friendly source of world roundwood, fibre, fuelwood, non-wood forest products and other social and environmental values (Gelsenan, 2003).

Tree species composition studies are critical in the context of understanding the extent of plant diversity in various ecosystems (WCMC, 1992; Addo-Fordjour et al., 2009). They are important for the assessment of sustainability of ecotypes since various ecotypes play a vital role in the conservation of plant species, and ecosystem management (Tilman, 1988; Ssegawa and Nkuutu, 2006). The general objective of the study is to evaluate the various land cover types and tree species diversity in a heavily degraded tropical semi-deciduous forest which is planned for conversion into a forest plantation. The specific objectives of the study are; (1) To stratify the remaining natural forest into defined land cover types using satellite imagery, (2) To assess the level of canopy cover and (3) To assess tree species richness of the degraded forest.

MATERIALS AND METHODS

Study area

The study was carried out in a privately owned degraded forest, foreseen for conversion into a forest plantation. 100 km north of Kumasi, in the Ejura - Sekyedumase district of the Ashanti region of Ghana. The site is located in the forest-savanna transition zone which is characterized by the co-existence of the two distinct ecosystems forest and savanna. The ecosystems occur in an intertwined structure referred to as the "forest-savanna mosaic" (Hopkins, 1963). The district is marked by two rainfall patterns; the bi-modal pattern in the south and the uni-modal in the north. The main rainy season is between April and November. The annual rainfall varies between 1, 200 and 1, 500 mm. The proposed plantation site is approximately 17 km from the Ejura Township and is bordered to the north by the Nkrama and Bisiu, Boami is located to the south, while to the west it is bordered 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 Aibic Plinthosols/Typic Plinthustalf. The soil-texture comprises 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).

Pre-processing and processing of satellite images on the proposed plantation

A pan-sharpened IKONOS-2 satellite image clipped to the area of the proposed plantation site (recorded on October 10th, 2000) was purchased from European Space Imaging in 2006 (Figure 1). The IKONOS-2 satellite is a commercial satellite which is able to collect pan-chromatic images of 1 m resolution and multi spectral color images of 4 m resolution. Images from both sensors were merged by the process of pan-sharpening to create color imagery with 1 m resolution. Pan-sharpened satellite images are commonly used for presentation purposes, due to the high resolution, which in case of Ikonos corresponds to 1 m^2 per pixel. The satellite image was geo-referenced with Ground Control Points (GCPs) which were taken with Global Positioning System (GPS) in 2006 - and the satellite image was mapped with existing Geographic Information System (GIS) data, that is, boundaries of the proposed plantation site, already planted area, infrastructure, etc. (Figure 1).

The pan-sharpened IKONOS-2 satellite image was stratified - according to the parameter vegetation cover - with a supervised classification procedure, which belongs to the spectrally oriented classification procedures for land cover mapping (Lillesand et al. 2004). In this case the three bands for red, green and blue light (RGB-bands) were used for the pixel-based classification process. The assessed canopy cover of the sample plots was used as input to compile a numerical "interpretation key" for the description of spectral attributes. The stratification classes used were "forest" and "savanna ", assuming a normal distribution. The "Minimum-Distance-to-Means" algorithm was used for the comparison of the spectral information between known and unknown pixels (Wulder and Franklin, 2003; Lillesand et al., 2004). Due to the high resolution (1 m^2 per pixel) and the high cloud cover of the satellite image, image pre-processing procedures had to be carried out prior to the supervised classification. The low pass filter was used to modify the satellite image prior to the supervised image classification. Low pass filter belong to the category of spatial filters which emphasize low spatial frequency features and deemphasize high spatial frequency components of an image (Lillesand et al., 2004). In this case, a 25 × 25 low pass filter (based on the "moving window" algorithm) was used to modify the satellite image.

The error matrix in accordance to Lillesand et al., (2004) revealed two classification errors; 1) exclusion of forest vegetation and 2) other inclusion of forest vegetation. The overall accuracy of the supervised classification was 89.5%. Forest vegetation is classified in relation to FAO (2005) as land with trees higher than 5 meters and a canopy cover of more than 10%, or trees able to reach these thresholds *in situ* (it does not include land that is predominantly under agricultural land use).

Sampling design

Long term research is intended for this proposed plantation site which resulted in the use of reconnaissance forest inventory with the general objectives of indexing the location and extent of forested areas, as well as registering accessibility, species composition, tree dimensions, the distribution of various forest types, and initial data on timber quality (Kohl et al., 2006). A systematic sampling methodwas used because the systematic distribution of sample plots is more efficient for a given number of sample plots and detecting phenomena such as variations in species composition and stand structure (Synnott, 1979). A total of 55 circular sample plots (Figure 2) were laid on the intersections of the 600 m UTM-grid. Each plot of 15 m radius (706.5 m^2) was set up on the field with the use of the ultra sonic device Vertex III. Smaller circular sub-sample plots of 5 m radius (78.5 m^2) were set up using the same centre point for the assessment of regenerating trees with a height < 1.30 m (seedlings and small saplings).

Canopy covers

The crown position of all trees ≥ 1.3 m was assessed according to Dawkins and Field (1977). The crown diameter was measured by projecting the exterior shape of the crown to the ground and measuring the diameter with the Vertex III from north to south and from east to west. The mean diameter was used for calculating the crown projection area assuming a circular crown shape. To assess

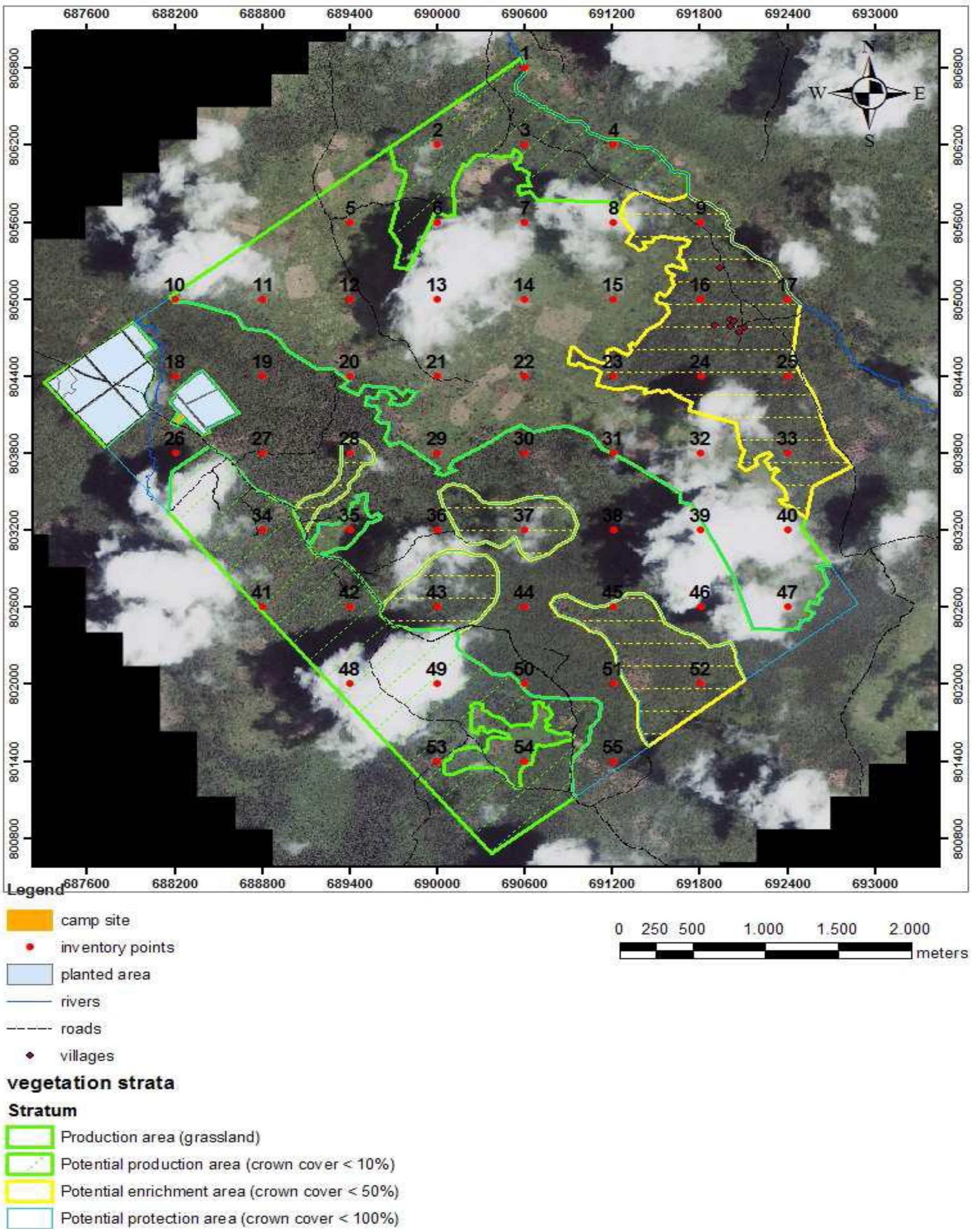

Figure 1. Manual delineation of the IKONOS-2 satellite image.

the crown projection area of trees with a DBH < 5 cm, a mean value was calculated. A total number of 170 trees with a DBH < 5 cm were measured resulting in an average value of 1.05 ± 0.08 m^2. The measured trees were distributed over 20 sample plots which were randomly chosen using the random number generator of Microsoft Excel 2007.

The canopy cover (in %) was calculated by dividing the accumulated crown projection area per sample plot with the area

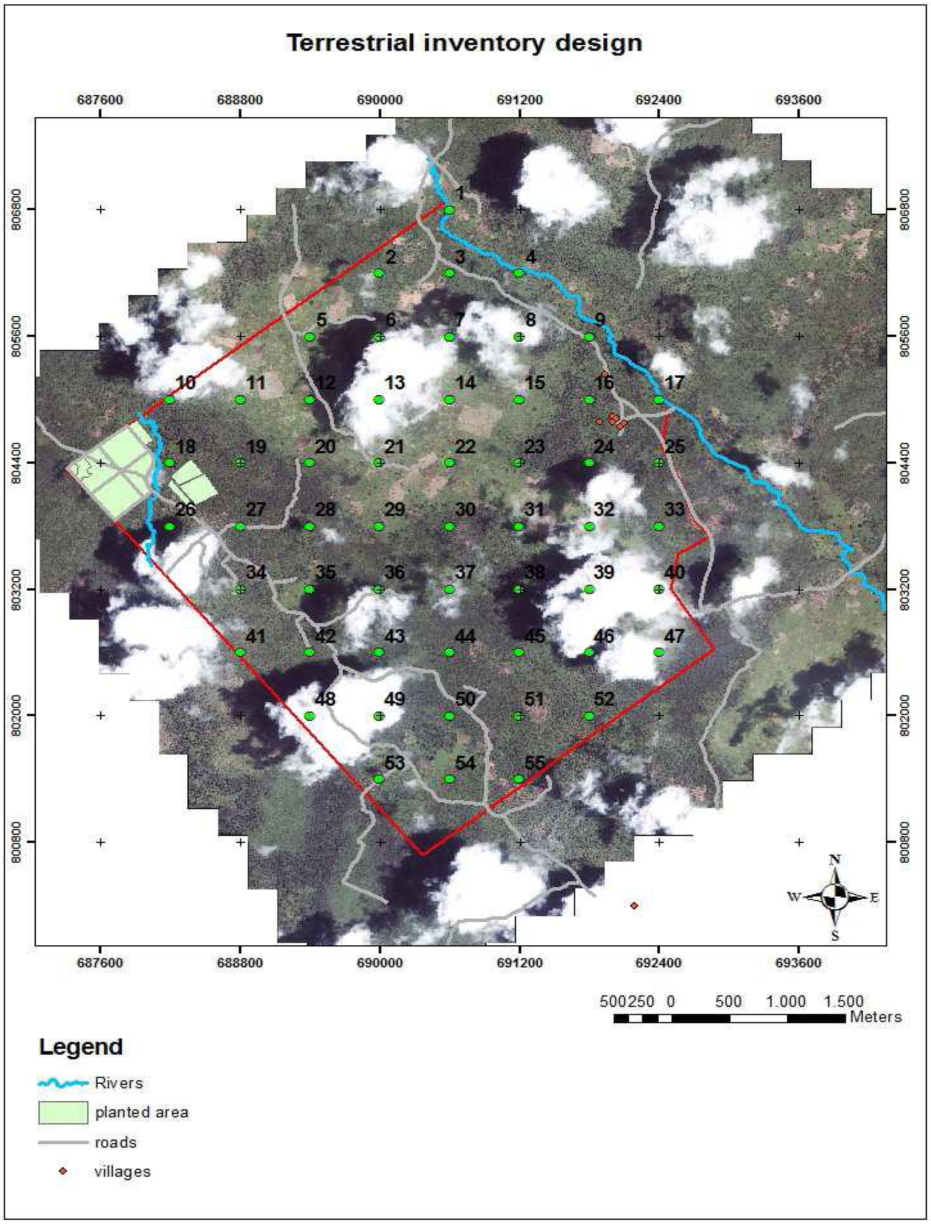

Figure 2. Inventory design of the planned Ejura plantation proposed site indicating sampling plots.

per sample plot. The crown projection area of trees of the crown positions 1 and 2 - that is trees which do not receive direct overhead light were excluded from the calculation of the canopy cover, since they were fully shaded by trees of the higher crown positions 3 to 5. The Kolmogorov-Smirnov test was used to test for differences in canopy cover of the vegetation types, forest and savanna.

Tree species inventory

Tree species were identified in a vegetative state, with the aid of a forest botanist from the Forestry Commission (Kumasi) following the identification key by Irvine (1961), Hawthorne (1990) and Hawthorne and Jongkind (2006). In cases of uncertainty specimen were taken to the herbarium of the Forestry Commission Department in Kumasi. The tree species were given vernacular names up to the point of identification by the herbarium. All trees with a height < 1.30 m - which occurred in the inner sub sample plot were identified and counted. Each specimen was assigned to one of the 3 height-classes; seedlings < 30 cm, small saplings 30 to 50 cm and big saplings 50 to 130 cm.

RESULTS

Vegetation mapping

The mapping of the foreseen plantation site according to vegetation cover, conducted as a supervised classification resulted in a ratio of land covered by forest vegetation to

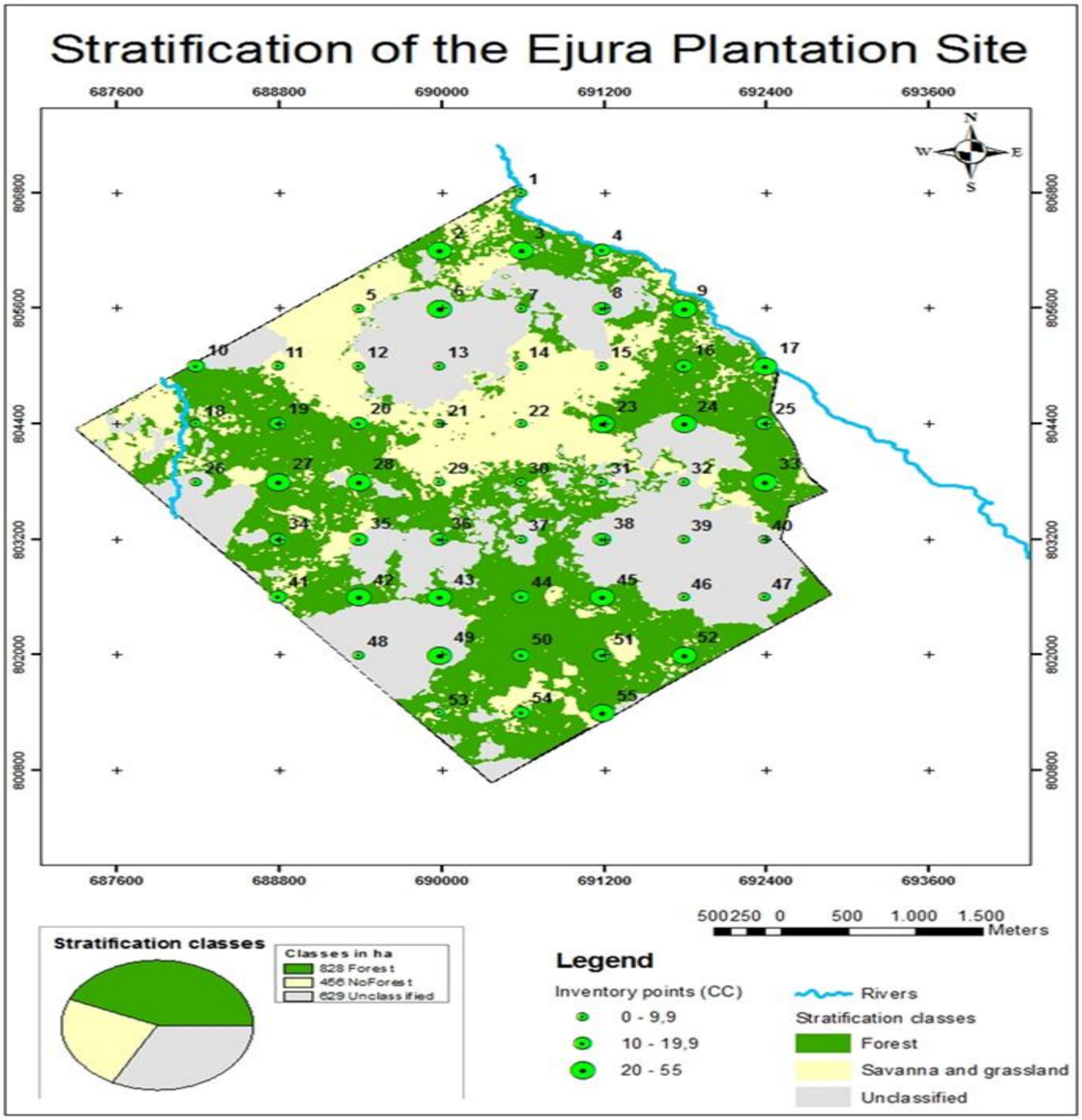

Figure 3. Stratification of the planned Ejura plantation site.

to land covered by savanna vegetation of 1.8 : 1.0. A map of the results is presented in the Figure 3. An area of 828 ha (43.3% of planned plantation area) is classified as forest. The forest vegetation is distributed over the entire proposed plantation site, divided by a large almost rectangular shaped area of savanna and grassland vegetation in the center with an area of 456 ha (23.8% of the planned plantation area).

Canopy cover

The forest vegetation has an open canopy structure with an estimated average canopy cover (cc = 0.05) of 21.6 ± 3.2%. The canopy cover ranges from a minimum of 10% (sample plot 36) to a maximum of 51.8% (sample plot 17). Only the sample plots 2 and 17 feature a canopy cover > 40%, while thirty sample plots (93.8% show a cc > 10%) feature a canopy cover between 10 and 40%. An area of 629 ha have (32.9% of the planned plantation area) could not be classified due to the high amount of areas covered and shaded by clouds (Figure 2). Fifty five sample plots were systematically distributed over the proposed plantation site, but due to the aforementioned, only 35 sample plots could be utilized for the mapping of the proposed plantation site. 25 sample plots contained forest vegetation (cc > 10%) and were used for the supervised classification of the forest vegetation stratum. 10 sample plots contained savanna vegetation (cc < 10%) and were used for the supervised classification of the savanna vegetation stratum. The Box-Whisker plot (Figure 4) for canopy

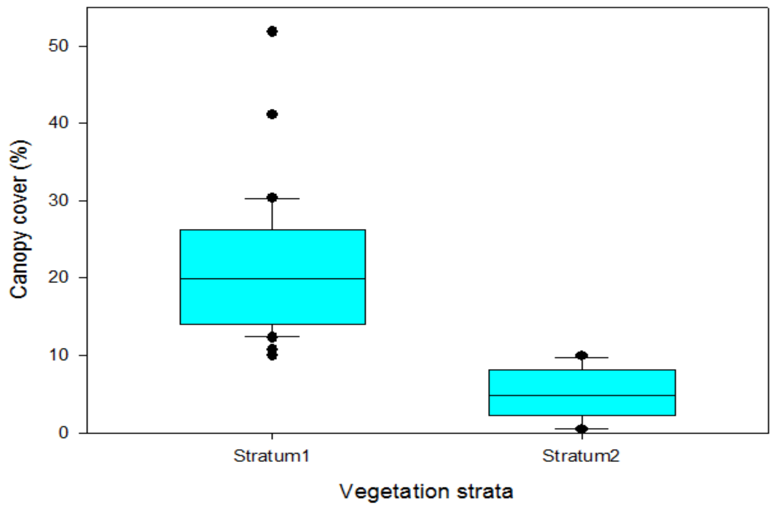

Figure 4. Box-Whisker plot of canopy over vegetation (Stratum 1 and 2 are forest and savanna vegetations respectively).

cover of the vegetation strata illustrates the distribution as being univariate with stratum 1 resembling the forest vegetation and stratum 2 being savanna. The one sample Kolmogorov-Smirnov the test (Table 1) illustrates test distribution as normal and no significant change in canopy cover of the vegetation types, forest and savanna.

Tree species diversity

A total number of 65 tree species (Table 2) were encountered belonging to 49 genera and 23 families. Leguminosae is the biggest family represented by 63% followed by Moraceace and Rubiaceae both with 25%. The remaining 21 families are represented with an abundance of less than 5 tree species. Two important trends were identified during the assessment of the species composition. 32 tree species (48.5%) show an average abundance of only 1 individual per hectare or less, out of which 28 tree species (42.4%) occurred in only 2 sample plots (= 4.3% of sample plots) or less. This indicates that the majority of the remnant tree vegetation comprises of a relatively homogeneous species composition. The species composition may vary on a small scale, since almost half of the encountered tree species recorded a low abundance in combination with a limited range of distribution. About 30.3% of encountered species (20 tree species) recorded an abundance of at least 5 individuals per hectare. Six tree species (9.1%) recorded an abundance of 20 individuals per hectare and more. A total of 47.7% of all tree species (Table 2) recorded in the study belong to the biome "forest" while 36.9% are savanna species. However 15.4% of encountered species exist in both forest and savanna (Table 2). *Bridelia ferruginea*, *Vitellaria paradoxa*, *Terminalia laxiflora.* The most abundant tree species with 30 individuals per hectare and more. *Pterocarpus erinaceus*, *Daniellia oliveri, Ficus sur* recorded abundance of at least 20 individuals per hectare. The relative abundance of these six tree species accounted for 45.8% of the total number of surveyed trees.

DISCUSSION

The current extent of vegetation distribution is only inferred because the classification was carried out with a precision of 89.5% and a wide time lapse of more than ten years between taking the satellite images and the implementation of the forest reconnaissance inventory. In this time lapse, the rate of deforestation could not be estimated and it can be assumed that the forest area has rather decreased than increased. Therefore, it is presumed that the ratio of forest to savanna has shifted towards savanna due to ongoing transformation of vegetation to different anthropogenic activities, mainly wild fires, swidden agriculture and charcoal production. 32.8% of the satellite images (629 ha of the planned plantation site) were not classified due to cloud cover and areas shaded by clouds. Field observations revealed that the large coherent area of savanna vegetation extends almost to the southeastern boundary of the proposed plantation site, but the actual extent of the vegetation stratum cannot be presented. It can be concluded from the forest reconnaissance inventory,that the extent and distribution of the savanna vegetation stratum is underestimated, but by how far cannot be estimated at this point. A GPS – assessment of the major forest savanna boundaries was not carried out which could have provided relevant information on the current extent and distribution of the vegetation strata. According to FAO (2006), forest vegetation with a

Table 1. Analysis of the distribution pattern of the parameter canopy cover.

Analysis		Forest (cc)	Savanna (cc)
N		32	15
Normal parameters	Mean	21569	5093
	Std. deviation	89957	30999
Most extreme differences	Absolute	0.114	0.109
	Positive	0.114	0.104
	Negative	-0.99	-0.109
Kolmogorov-Smirnov Z		0.646	0.42
Asymp. Sig. (2-tailed)		0.798	0.994

Table 2. List of encountered tree species, their abundance per hectare and the vegetation type in which they occur.

Species	Family	Abundance (Trees/ha)	Vegetation type
Afzelia Africana Sm.	Leguminosae	≤ 1	Forest
Albizia adianthifolia W.Wight	Leguminosae	≤1	Forest
Albizia ferruginea Benth.	Leguminosae	≤1	Forest
Albizia zygia J.F.Macbr.	Leguminosae	≤1	Forest
Anogeissus leiocarpus Guill.&Perr.	Combretaceae	15	Savanna
Anthocleista djalonensis A.Chev.	Loganiaceae	≤1	Forest
Baphia pubescens Hook.f.	Leguminosae	≤1	Forest
Borassus aethiopium Mart.	Arecaceae	≤1	Forest/Savanna
Bridelia ferruginea Benth.	Euphorbiaceae	37	Forest/Savanna
Bridelia grandis Pierreex. Hutch.	Euphorbiaceae	10	Forest
Burkea africana Hook	Leguminosae	2	Savanna
Ceiba pentandra Gaertn	Bombacaceae	≤1	Forest/Savanna
Cola chlamydantha K.Schum.	Sterculiaceae	≤1	Forest
Cola gigantea A.Chev.	Sterculiaceae	≤1	Forest
Cnestis ferruginea DC.	Connaraceae	≤1	Forest
Craterispermum caudatum Hutch.	Rubiaceae	≤1	Forest/Savanna
Crossopteryx febrifuga (Afzel.ex Guill.&Perr.)	Rubiaceae	13	Savanna
Cussonia barteri Seem.	Araliaceae	4	Forest
Daniellia oliveri (Rolfe.) Hutch. &Dalziel	Leguminosae	20	Savanna
Detarium senegalensis G.F.Gmel.	Leguminosae	≤1	Savanna
Elaeis guineensis Jacq.	Arecaceae	≤1	Forest
Ficus kamerunensis Warb.ex.Mildbr. &Burret	Moraceae	≤1	Forest
Ficus natalensis Hochst.	Moraceae	≤1	Forest
Ficus ovata D.Don.	Moraceae	≤1	Forest
Ficus spp.	Moraceae	≤1	Forest
Ficus sur Forssk.	Moraceae	18	Forest
Ficus vogeliana Miq.	Moraceae	2	Forest
Gardenia erubescens Stapf & Hutch.	Rubiaceae	≤1	Savanna
Gmelina arborea Roxb.	Lamiaceae	2	Forest
Grewia mollis Juss.	Tiliaceae	4	Savanna
Holarrhena floribunda T.Durand.& Schinz	Apocynaceae	7	Forest/Savanna
Hymenocardia acida Tul.	Euphorbiaceae	5	Savanna
Khaya anthotheca C.DC*	Meliaceae	≤1	Savanna
Khaya senegalensis A. Juss.*	Meliaceae	≤1	Savanna
Lannea acida A. Rich.	Anacardiaceae	8	Savanna
Lonchocarpus sericeus (Poir.)DC	Leguminosae	4	Forest/Savanna
Lophira lanceolata Tiegh.	Ochnaceae	4	Savanna

Table 2. Contd**.**

Lychnodiscus dananensis Aubrev.& Pellegr.	Sapindaceae	6	Forest
Manilkara obovata (Sabine & G.Don) J.H. Hemsl	Sapotaceae	≤1	Forest
Margaritaria discoidea (Baill.)G.L.Webster	Euphorbiaceae	12	Forest/Savanna
Maytenus buchananii (Loes) Wilczek	Celastraceae	6	Forest
Millettia thonningii Baker	Leguminosae	≤1	Forest/Savanna
Millettia zechiana Harms	Leguminosae	≤1	Forest
Morinda lucida Benth.	Rubiaceae	≤1	Savanna
Nauclea latifolia Sm.	Rubiaceae	9	Savanna
Parkia bligobosa (Jacq.)R.Br.ex G.Don	Leguminosae	2	Savanna
Pauridiantha hirtella (Benth.)Bremek	Rubiaceae	5	Forest
Piliostigma thonningii (Schumach.) Milne-Redh	Leguminosae	13	Savanna
Pseudospondias microcarpa Engl.	Anacardiaceae	≤1	Forest
Pseudospondias spp.	Anacardiaceae	10	Forest
Pterocarpus erinaceus Fern. Vill.	Leguminosae	21	Savanna
Securidaca longipendunculata Frasen.	Polygalaceae	2	Savanna
Spathodea campanulata P. Beauv.	Bignoniaceae	≤1	Forest
Sterculia oblonga Mast.	Sterculiaceae	≤1	Forest
Sterculia tragacantha Lindl.	Sterculiaceae	2	Forest/Savanna
Stereospermum acuminatissimum K.Schum.	Bignoniaceae	4	Forest
Terminalia glaucescens Planch.ex Benth.	Combretaceae	3	Savanna
Terminalia laxiflora Engl.	Combretaceae	31	Savanna
Tetrapleura tetraptera Taub.	Leguminosae	≤1	Forest
Trichilia roka (Forssk) Chiov	Meliaceae	15	Forest/Savanna
Trichilia monadelpha (Thonn.)J.J. de Wilde	Meliaceae	≤1	Forest
Vitellaria paradoxa C.F.Gaertn*	Sapotaceae	34	Savanna
Vitex doniana Sweet.	Lamiaceae	≤1	Savanna
Vitex micrantha Guerke	Lamiaceae	2	Savanna
Zanthoxylum xanthoxyloides Hamm.	Rutaceae	≤1	Savanna

*Listed as vulnerable on the IUCN red list of threatened species.

canopy cover between 10 and 40% can be classified as open forest. Thus the surveyed forest vegetation is classified as open forest. Areas of closed forest (cc > 40%) are assumed to occur only as remnant forest patches, which are scattered within the open forest vegetation. A further stratification of the forest vegetation (Figure 5) into open and closed forest was not attempted, due to the limited number of sample plots. Forest canopy structure is a key determinant of forest ecosystem processes, and its measurement is essential for ecosystem monitoring, modeling, and management (Sexton et al., 2009).

The species recorded in this study are similar to those recorded recently by other studies in semi-deciduous forest of Ghana (Vordzogbe et al., 2005; Anning et al., 2008; Addo-Fordjour et al., 2009; Tom-Dery and Schroeder, 2011). Vordzogbe et al. (2005) which recorded a high number of 172 plants belonging to 67 families however this include herbs and grasses that were excluded from the current study. Addo-Fordjour et al. (2009) likewise recorded a higher number of 107 species belonging to 37 families which also included lianas, grasses and herbs. However, Tom-Dery and Schroeder (2011) recorded a lesser number of 46 tree species belonging to 14 families in two small semi-deciduous forest fragments in the same region.

The dominance of the families *Leguminosae*, *Moraceae* and *Meliaceae* in some semi-deciduous forests has been reported (Vordzogbe et al., 2005; Anning et al., 2008; Addo-Fordjour et al., 2009). FAO (2008) reviewed *D. oliveri*, *V. paradoxa* and *Terminalia* spp. as characteristic tree species of natural and derived Guinea woodland savannas. Interestingly the dominant family recorded in recent studies of the savanna was also *Leguminosae* (Asase and Oteng-Yeboah, 2007; Asase et al., 2009; Tom-Dery et al., 2012). This can be taken as further evidence that the planned planation site is located in the transition zone since its tree composition contains species of savanna and forest origins.

In view of the open nature of the classified forest canopy and the comparison of the tree species composition of the forest and savanna biomes vegetation strata revealing no obvious (significant) differences, a literature search of inventoried plant species was carried

Figure 5. Image of the vegetation classified as forest.

out. This revealed a majority of the tree species being forest but a substantial number being either savanna species or species that occur in both forest and savanna. It is therefore concluded that the planned plantation site can be classified as a transition zone. It is recommended that an inventory of soil-vegetation catena be implemented, to facilitate the identification of indicator species that will enable the categorization of site requirements of indigenous timber species for sustainable tree growth.

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