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Woody Species Composition, Distribution and Structural Characteristics in Yabo Area, Sokoto State, Nigeria

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Abstract: Woody species in the study area were assessed in order to determine their composition, distribution and structural characteristics. A total of 32 km^2 around Yabo town in Sokoto State, Nigeria was earmarked for the study within which, a total of 50 sample points were randomly generated using IDRISI ANDES Software. On each of the sample points, a quadrat of 50×50 m dimension was laid and all woody species thereon were identified and enumerated. The study examined the prevailing land use/land cover of the study area and also measured vegetation parameters which include height, diameter at breast height, basal area, density and biomass. In addition, dominance at both species and family levels were determined by the Importance Value Index (IVI). Seven major land use types were identified and a total of 671 woody stems which belonged to 40 species, 35 genera and 12 families were identified and enumerated. The highest number of stems (271) was recorded in the savannah woodland and the farmland (137) whilst the lowest was recorded over the built-up area (15) and bare ground (24). Analysis of the importance value index revealed that the dominant species in the area are *Azadirachta indica*, *Balanites aegyptiaca*, *Senna sieberiana*, *Combretum micranthum*, *Guiera senegalensis*, *Mimosa pigra*, *Parkia biglobosa* and *Piliostigma reticulatum* which together account for about 67.2% of the species. The extrapolation of the results obtained to the entire study area revealed that overall, 171,600 (54 stands per hectare) woody stands abound. Result of ANOVA and DMR tests show that biomass is the most variable parameter amongst the land uses while species density is the least. The observed species and actual number of tree stands in the area are generally low and are a reflection of severe land degradation going on in the area. Factors that affect the composition, distribution and structural characteristics of woody species in the area were primarily found to be human activities that include unsustainable use of natural resources as manifested in agricultural and grazing activities and wood extraction. However, poor physical conditions in terms of soils, vegetation and inherent extreme variability of climate also play contributory roles. The urgent need to halt the degradation trend and improve upon the state of woody species in the area was stressed.

Key words: IDRISI ANDES, land use types, IVI, frequency, dominance, Sokoto State

INTRODUCTION

Woody species are a very important component of the plant community and of biodiversity. They provide free ecosystem services such as enhancing the hydrological cycle, erosion protection, carbon sequestration, modification of micro-climate, providing food and building materials for man and fodder for his animals (Kalema, 2010). Plants such as shrubs and trees, act as biological filters and cleanse the environment of pollutants. They also act as sinks for oxides of carbon, toxic gases and heavy metals (Chakraverty and Jain, 1984). Beyond their economic value, woody species also have ecological functions. They play stabilizing role to landform and soils and also maintain the cycling of oxygen and other elements essential for life. Many wildlife species also depend on woody plants for an essential component of their habitats.

It is a known fact however that woody species especially in the developing countries are under intense pressure. Rands *et al.* (2010) asserted that the key pressures driving biodiversity loss in general include the global increase in human population which is accompanied by increased economic activities, industrialization, overexploitation of species, invasive alien species, pollution, climate change and especially the degradation, fragmentation and destruction of habitats. In most developing countries, the rate of forest clearing and tree felling is so rapid that it is feared more species may be lost eventually. It is estimated that by the year 2025, the world population will be about 8.5 billion. The increase in population will demand higher exploitation of the natural resources for the production of food, fibre and shelter. On the other hand, the state of the world's natural resources especially those associated with agricultural production appears to be declining in many areas at far

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higher rate. Moreover, there is concern that the capacity of the natural resources to play their broader environmental role might be threatened. These situations imply the need for more attention to the management of natural resources and for the development of sustainable production options (ISC, 1995). Woody species in Nigeria are cheaply exploited for fuel wood for use in herbal medicinal preparations and as animal feed. Similarly, expansion of human settlements and construction of infrastructures such as roads, schools, hospitals and/or industries continue to impinge on the wellbeing of woody species.

Knowledge of the composition and structure of woody species in a given geographical entity is therefore necessary to the understanding of the complexity and dynamics of the relationship that exists and continues to exist between man and these species (Nalini *et al*., 1995) and in identifying important elements of plant diversity, protecting threatened and economic species and monitoring the state of reserves among others (Tilman, 1988; Addo-Fordjour *et al*., 2009). It also services the need for an efficient resource management which requires the ecological, economic, social and cultural values of biological resources to be explored and brought to the attention of decision makers and the general public (Kalema, 2010). Similarly, understanding the distributions of the largest and most abundant woody species will lead to an understanding of plant communities as a whole (Duelli, 1997) especially in the face of the ever increasing threat to the forest ecosystem (Klinge *et al*., 1995; Addo-Fordjour *et al*., 2009).

MATERIALS AND METHODS

The study area: The study area is a total of 32 km^2 (12°41'45"N to 12°45'00"N and 4°58'00"E to 5°00'20"E) around Yabo town in Yabo Local Government Area of Sokoto State. Yabo Local Government is located between latitudes 12°28'00"N to 13°00'00"N and longitudes 4°44'58"E to 5°11'50"E. It has a total land area of 789 km^2 and a population of 115,011 according to the 2006 census Fig. 1. The area is geologically located in the Taloka formation belonging to the broad cretaceous Rima group which is part of the extensive Sokoto basin (Kogbe, 1979). The Taloka formation has a maximum thickness of 180 m and consists of fine to coarse sand, silty sands, shales and sandstones with many layers of clay/shale within the latter (Maduabuchi, 2002).

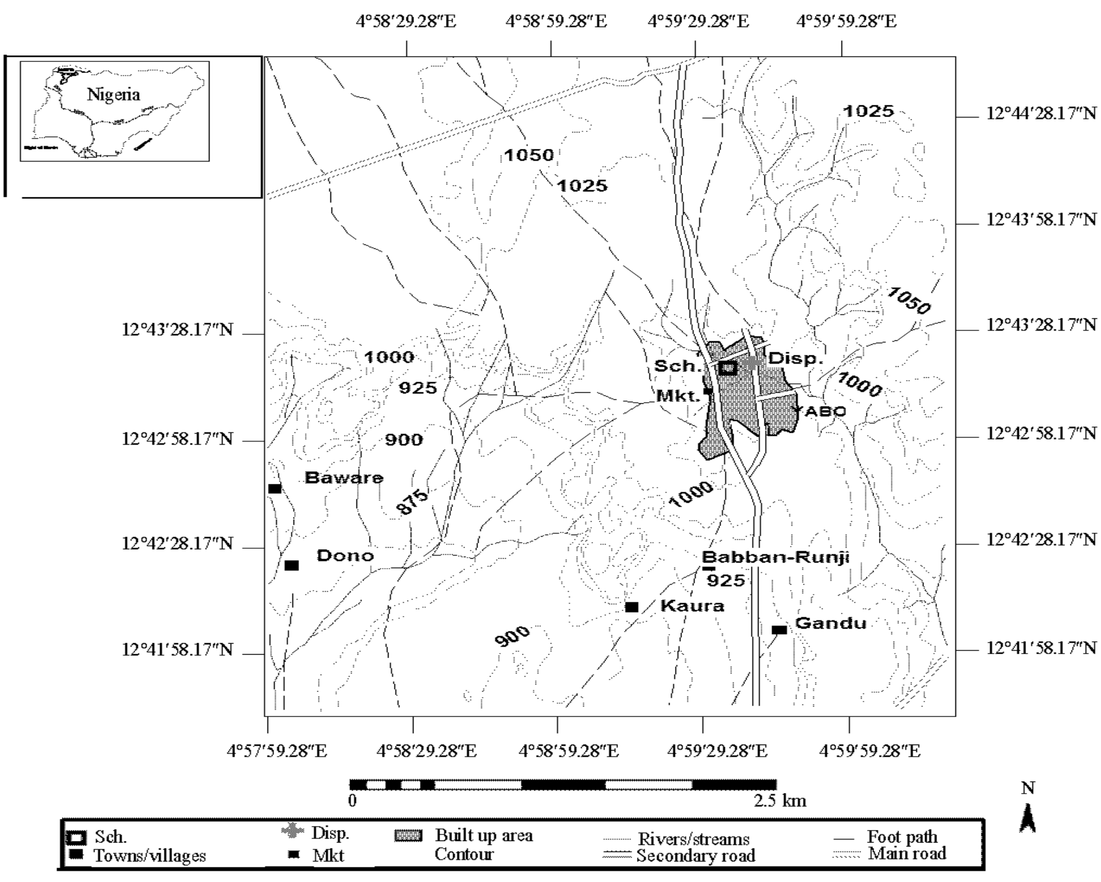

Fig. 1: The study area

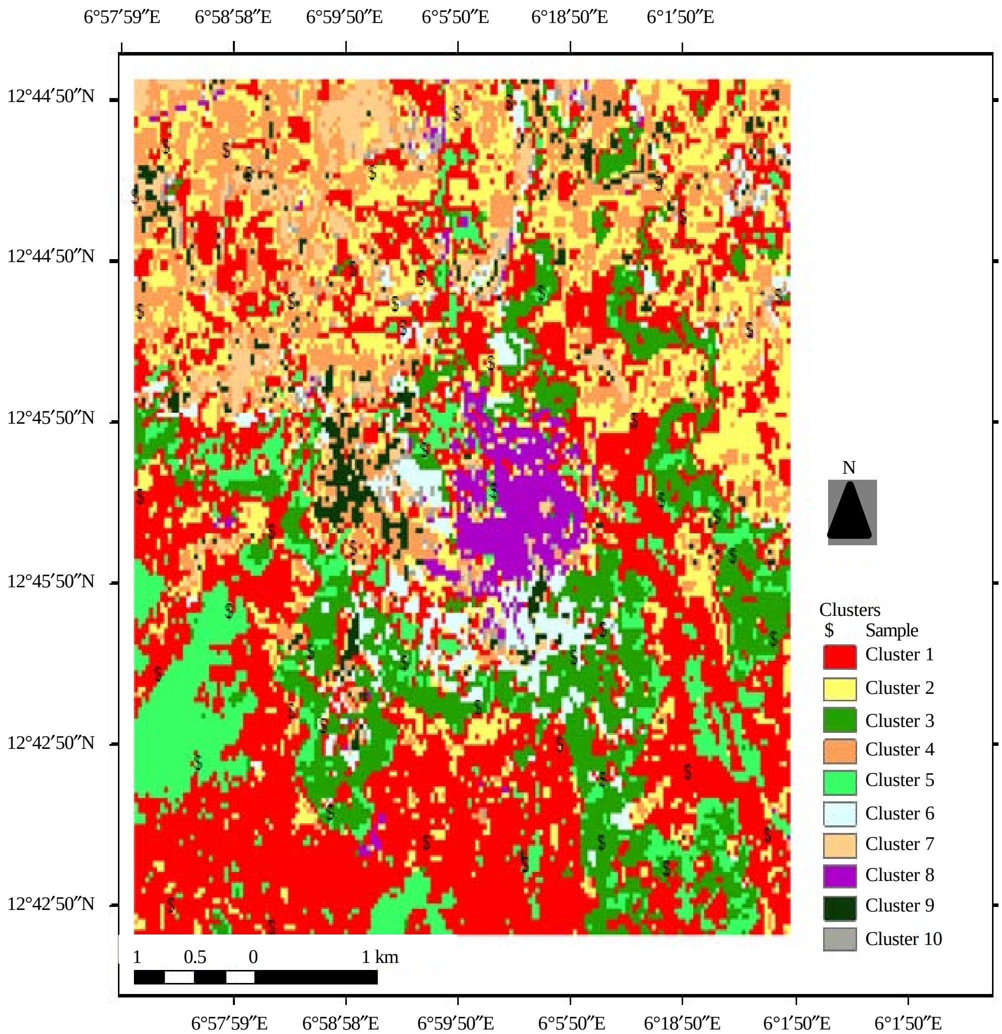

Fig. 2: Unsupervised classification of the LANDSAT imagery of the study area

The climate of the area is that of the sudano-sahelian ecological zone which is a semi arid type characterized by three distinct seasons: the cool, dry; the hot, dry and the hot, wet. Temperature in the area ranges from 22-40°C while rainfall with emphasis to the annual totals, incidence and distribution is highly variable from year to year. While some years may be relatively dry, some are relatively wet. Some months also experience more rainy days than others but most rains occur during the relatively short but intense thunderstorms usually at the beginning and end of the rainy season. Days without rainfall are common and also their number and frequency vary from year to year (Swindell, 1986). The mean annual rainfall however is 814.33 mm (Sokoto State Government, 2004). Vegetation of the area is mostly the short feathery grasses with some trees and other woody species most of which are deciduous, dotting the area. The species in the area are mostly those that have a low water requirement, those that can adapt to dry conditions and the fire resistant ones (SARDA, 1992). The pattern of vegetation distribution is to a large extent, influenced by human activity though physical factors may assume local importance (Abdu *et al*., 1982).

Sampling and data collection: Reconnaissance survey was the first major activity that was carried out in the course of the study. This was to familiarize with the area while ground truthing exercise was carried out to verify the true nature and location of points as well as areas and objects as they appear on the downloaded imagery. Information collected during the ground truthing exercise also provided the basis for image editing and supervised classification (Fig. 2).

Data on woody species composition, distribution and structural characteristics was collected from 50 randomly

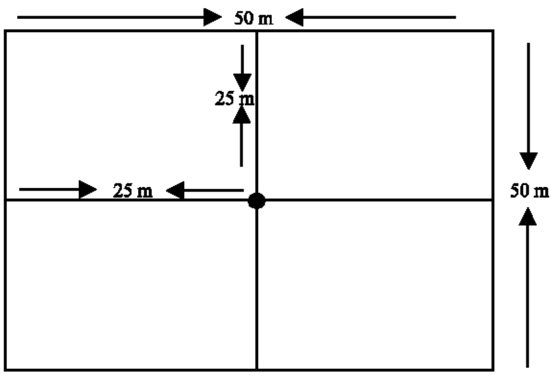

Fig. 3: The 50×50 m quadrat used for species' data collection

generated sample plots during the detail field survey. The sample plots were generated from the satellite imagery of the study area using the IDRISI ANDES Software. Using the software, 50 points were randomly (but proportionately) selected and from which quadrats of 50×50 m dimension were developed to form the basis for data collection (Fig. 3).

All woody species of ≥2.5 cm diameter in the quadrats were identified and enumerated these were then recorded according to their scientific and vernacular names. Secondly, species' physical characteristics were measured in all the sample plots and recorded accordingly. Species' height was measured with a Haga's altimeter while the diameter was measured at breast height (1.3 m above the ground) using a diameter tape the Diameter (DBH) determined species' basal area. The accompanying basal area was determined thus:

$$BA = \left(\frac{1}{2}d\right)^2 \times \pi$$

Where:
d = Tree diameter
π = 3.142 (constant)

Data analysis: From aggregate of the data collected, composition and distribution of woody species was determined. Species' structure was determined by analyzing the vertical, horizontal and quantitative structures of woody species (Kershaw, 1973). Similarly, species' density was calculated as the sum of all the individuals of respective species in the study area and expressed per hectare. Species' diversity was determined by the use of the Shannon Weiner's Index (H). The Shannon-Wiener index has probably been the most widely used index in community ecology (Meerman, 2004). It combines both species abundance and richness and is usually found to fall between 1.5 and 3.5 and is rarely above 5.0 (Magurran, 2004). The Shannon index is given as:

$$H = -\sum_{i=1}^{k} pi \log pi$$

Where:
k = Number of species
pi = number of individual species

Species biomass is the amount of organic matter, such as animal and plant tissue, found at a particular time and place. It was determined in this study based on a regression equation developed by Brown *et al.* (1989) and modified by Brown (1997) for calculating tree biomass in dry climates. The equation is given as:

$$Y = \exp\{-1.996+2.32\times \ln(D)\}$$

Where:
Y = Biomass per tree (kg)
exp = e−(the base of natural logarithms), raised to the power of (...)
ln(D) = Natural log of diameter at breast height

Frequency and dominance at both species and family levels were determined by calculating the Importance Value Index (IVI) which ranges from 0-300% (Savadogo *et al.*, 2007):

IVI = Relative Dominance (RD)+Relative Frequency (RF)+ Relative Basal Area (RBA)

Where:
RF = (a/b)×100 where, a is species frequency, b is Sum of all species frequencies
RD = (c/d)×100 where, c is number of individuals of a species, d is total number of individual species
RBA = (e/f)×100 where, e is Basal area of a species, f is total basal area of all species

While the dominant species was determined as the species with the highest IVI value, the dominant family was determined as the sum of IVI values of all the species belonging to a particular family (Mueller-Dombois and Ellenberg, 1974; Zimmerman *et al.*, 1999; Demisse, 2006; Asteggiano, 2008). IVI is used to determine the species dominance of an area where higher importance value index indicates more dominance of a particular species at the site (Koonkhunthod *et al.*, 2007).

RESULTS

Land use classification: Data collected during the ground truthing exercise was used to analyze and classify the

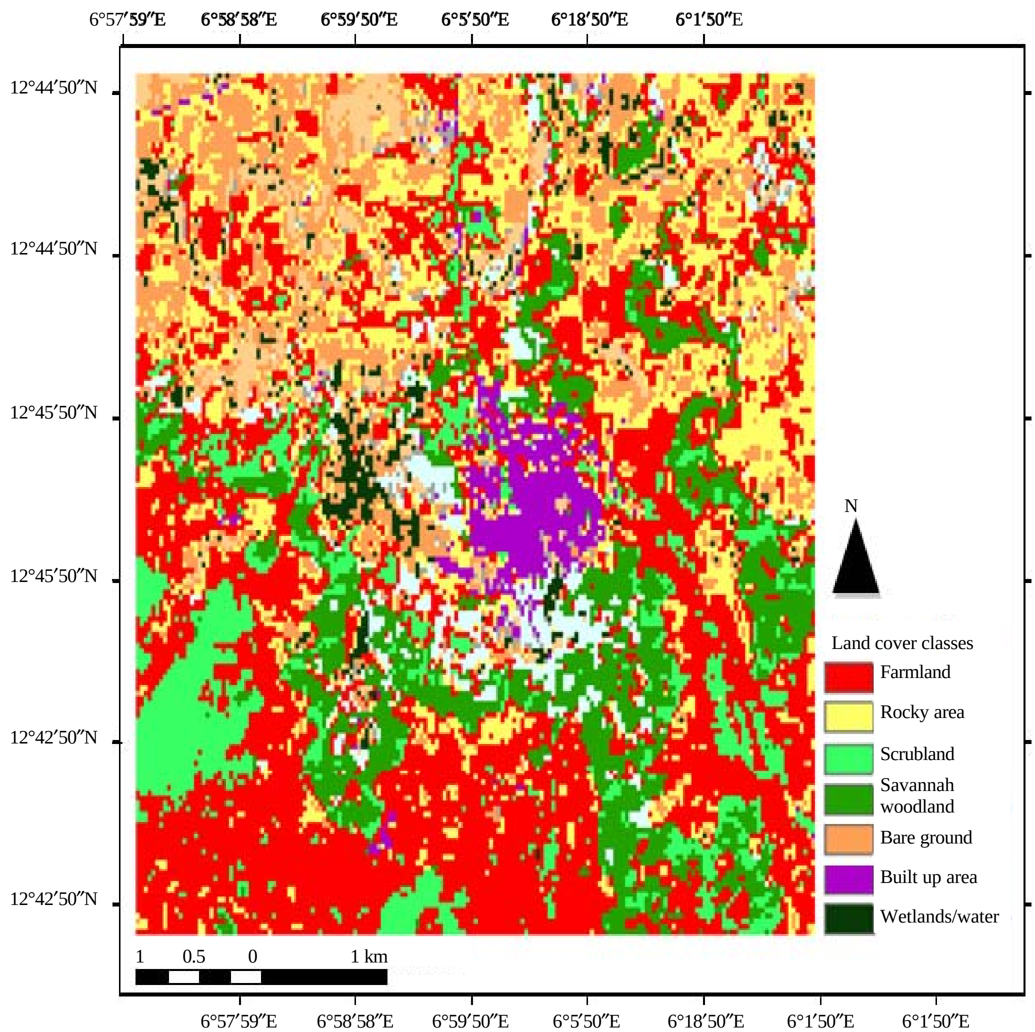

Fig. 4: Supervised classification of the landsat imagery of the study area

land use pattern of the study area. Seven major land use types were identified in the area; these include (in alphabetical order) bare ground, built-up area, farmland, rocky area, savannah woodland, shrubs and wetlands (Fig. 4).

Analysis of the land use/land cover of the area (Fig. 5) revealed that farmland which occupies 35% of the total study area is the dominant land cover and as such farming is the major land use in the area. This was followed by rocky area while the least land cover in the area is wetland; this occupies only about 4% of the study area.

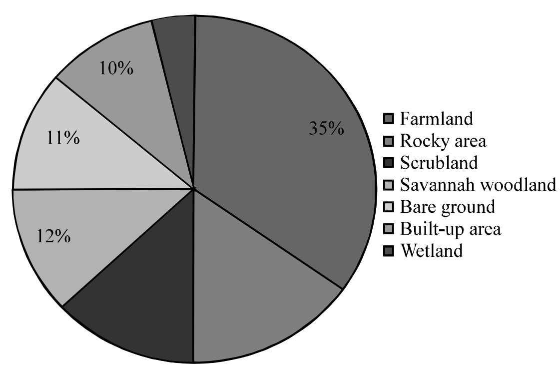

Fig. 5: Proportion of the land use/land cover in the study area

Floristic composition: A total of 671 woody stems (of ≥2 m height and ≥2.5 cm in diameter) belonging to 40 species, 35 genera and 21 families were identified and enumerated in the area (Table 1). Analysis of the species' importance value index (Table 1) revealed that *Azadirachta indica*, *Senna sieberiana*, *Combretum micranthum*, *Guiera senegalensis*, *Mangifera indica*, *Mimosa pigra*, *Parkia biglobosa* and *Piliostigma*

Table 1: Woody Species encountered in the study area and their percentage occurrence

Species	Genus	Family	Local name	Total	Percentage
Acacia macrostachya	*Acacia*	Fabaceae	Gardaye	24	3.6
Acacia nilotica	*Acacia*	Fabaceae	Bagaruwa	5	0.7
Acacia sieberiana	*Acacia*	Fabaceae	Farar Kaya	8	1.2
Anogeissus leiocarpus	*Anogeissus*	Combretaceae	Marke	1	0.1
Aristida mutabilis	*Aristida*	Poacaea	Dashi	1	0.1
Azadirachta indica	*Azadirachta*	Meliaceae	Dogon Yaro	95	14.2
Balanites aegyptiaca	*Balanites*	Balanitiaceae	Aduwa	21	3.1
Boscia angustifolia	*Boscia*	Capparidiaceae	Anza	12	1.8
Cadaba farinosa	*Cadaba*	Capparaceae	Bagaye	1	0.1
Calotropis procera	*Calotropis*	Apocynaceae	Tunfafiya	3	0.4
Ceiba pentandra	*Ceiba*	Malvaceae	Rini	1	0.1
Combretum ghasalense	*Combretum*	Combretaceae	Taramniya	2	0.3
Combretum micranthum	*Combretum*	Combretaceae	Geza	71	10.6
Combretum nigricans	*Combretum*	Combretaceae	Tsiriri	1	0.1
Cordia africana	*Cordia*	Fabaceae	Alilliba	1	0.1
Delonix regia	*Delonix*	Fabaceae	Dorowar Turawa	9	1.3
Detarium microcarpum	*Detarium*	Caesalpiniaceae	Taura	6	0.9
Diospyros mespiliformis	*Diospyros*	Ebenacea	Kaiwa	1	0.1
Eucalyptus oblique	*Eucaliptus*	Myrtaceae	Zaiti	2	0.3
Faidherbia albida	*Faidherbia*	Fabaceae	Gawo	2	0.3
Ficus vallis-choudae	*Ficus*	Moraceae	Balgomi	8	1.2
Gardenia erubescens	*Gardenia*	Rubiaceae	Gaude	3	0.4
Guiera senegalensis	*Guiera*	Combretaceae	Sabara	84	12.5
Khaya senegalensis	*Khaya*	Meliaceae	Madacci	2	0.3
Lannea microcarpa	*Lannea*	Meliaceae	Faru	20	3.0
Lawsonia inermis	*Lawsonia*	Rubiaceae	Lalle	17	2.5
Maerua crassifolia	*Maerua*	Capparaceae	Jirga	3	0.4
Mangifera indica	*Mangifera*	Anacardiaceae	Mangoro	17	2.5
Mimosa pigra	*Mimosa*	Fabaceae	Gumbi	51	7.6
Moringa oleifera	*Moringa*	Moringaceae	Zogale	6	0.9
Parkia biglobosana	*Parkia*	Leguminosae	Dorowa	17	2.5
Piliostigma reticulatum	*Piliostigma*	Caesalpiniaceae	Kalgo	30	4.5
Prosopis africana	*Prosopis*	Fabaceae	Kirya	2	0.3
Psidium guajava	*Psidium*	Myrtaceae	Gwaiba	11	1.6
Rogeria adenophylla	*Rogeria*	Pedaliaceae	Loda	11	1.6
Senna sieberiana	*Senna*	Fabaceae	Malga	82	12.2
Tamarindus indica	*Tamarindus*	Fabaceae	Tsamiya	1	0.1
Vitex doniana	*Vitex*	Verbenaceae	Dunya	11	1.6
Ximenia americana	*Ximenia*	Olacaceae	Tsada	9	1.3
Ziziphus abyssiniaca	*Ziziphus*	Rhamnaceae	Magarya	19	2.8
			Total	671	100.0

Table 2: Dominant woody species

Species	RF	RD	RBA	IVI
Azadirachta indica	12.22	14.16	37.34	63.71
Combretum micranthum	5.88	10.58	1.18	17.65
Guiera senegalensis	7.24	12.52	0.75	20.51
Mangifera indica	1.81	2.53	5.45	9.79
Mimosa pigra	4.52	7.60	1.53	13.65
Parkia biglobosa	4.52	2.53	8.86	15.92
Piliostigma reticulatum	6.79	4.47	4.85	16.11
Senna sieberiana	9.95	12.22	14.47	36.64
Others	47.07	33.39	25.57	106.02
Total	100.00	100.00	100.00	300.00

RF = Relative Frequency; RD = Relative Density; RBA = Relative Basal Area; IVI = Importance Value Index

reticulatum are the most dominant species which together account for 67.2% of the species while the remaining 32 species account for 32.8%. The most dominant families on the other hand (Table 2) are Melieceae, Leguminosae, Caesalpiniaceae, Combretaceae, Fabaceae, Rhamnaceae and Anacardiaceae.

Species frequency and distribution: Species frequency distribution which was obtained by grouping the species into 5 classes A (1-20%), B (21-40%), C (41-60%), D (61-80%) and E (81-100%), based on their percentage occurrences (Demisse, 2006) shows a reversed J shape similar to the observation of Upadhaya *et al.* (2004) and Asteggiano (2008). Class A has the highest number of individuals at 82.5% and class B has 12.5% while class C accounts for only 5%. No species was recorded to have a frequency class of >60% in the study area. Analysis of the distribution of woody species in the study area reveals that the study area is composed of diverse species belonging to different genera and families that are distributed across the different land use types. However, the highest number of individual species (271) was recorded in the savannah woodland this was followed by farmland and rangeland which have 137 and 93 species, respectively the lowest number of individual

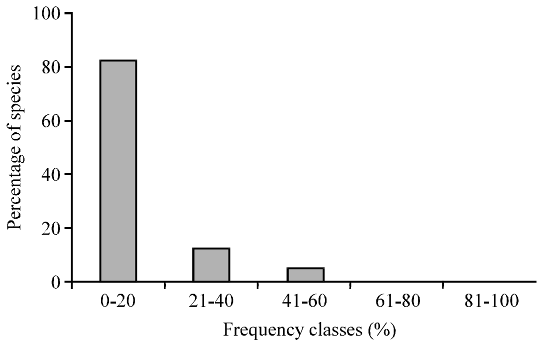

Fig. 6: Species frequency distribution

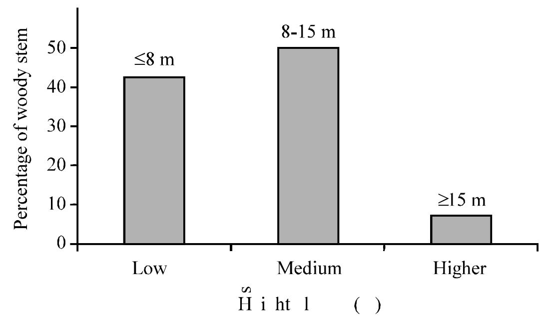

Fig. 8: Vertical structure of woody species

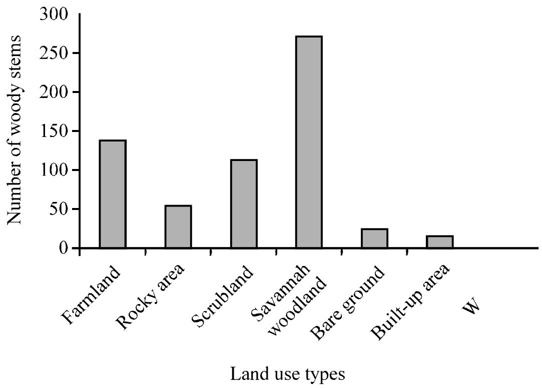

Fig. 7: Distribution of woody species

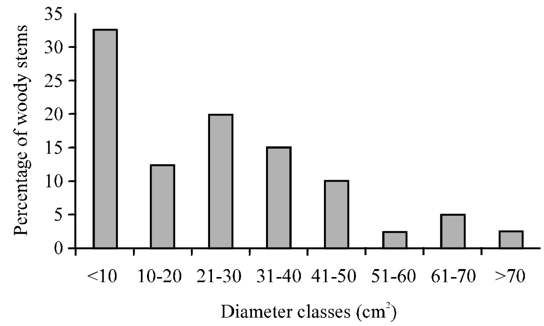

Fig. 9: Horizontal structure of woody species

species on the other hand was recorded at bare ground, shrubs and built-up area which have 24, 20 and 15 stems, respectively.

Species structure: Analysis of the vertical structure of woody species in the study area revealed that the species belonged to three height categories-lower height class (≤8 m), medium height class (8-15 m) and higher height class (>15 m). The analysis further revealed that 42.5% of the species belong to the lower height class; 50% belong to the medium height class while only 7.5% belong to the higher height class (Fig. 7).

Similarly, analysis of the horizontal structure of the species (Fig. 8) revealed that the species belonged to 7 diameter classes: >10, 10-20, 21-30, 31-40, 41-50, 51-60, 61-70 and >70 cm^2 in diameter (Asteggiano, 2008). The analysis further revealed that 32.5% of the species have a diameter of <10 cm^2, 12.5% have a diameter of between 10 and 20 cm^2 while only about 10% have a diameter of >50 cm^2.

The overall density which represents the quantitative structure of the species in the study area was 2684, a value which shows low population of woody species in the area. However, *Azadirachta indica* has the highest per hectare density of 380 ha^{-1} and therefore has the most outstanding quantitative structure. This is followed by *Guiera senegalensis* and *Senna sieberiana* which have respective densities of 336 and 328 ha^{-1} while *Combretum micranthum* has a density 284 ha^{-1}. Species with the least density include *Anogeissus leiocarpus*, *Aristida mutabilis*, *Cadaba farinosa*, *Ceiba pentandra*, *Combretum nigricans*, *Cordia africana*, *Diospyros mespiliformis* and *Tamarindus indica* each of which has a density of 4 ha^{-1} (Fig. 9).

Species biomass: Species biomass was found to vary considerably over the land use types with the highest mean value of 3191.46 kg per tree recorded in the built-up area. The built-up area had the highest number of large trees and as such recorded the highest mean diameter at breast height and subsequently, higher biomass values (Fig. 10).

Bare ground and farmland also recorded relatively high values of mean biomass of 884.6 and 655.81 kg per tree, respectively. Although, the areas had few woody species, the ones found are big and matured compared to other land use types. Similarly, although there are big species in the wetland, the land use type had the least mean biomass value of 152.1 kg per tree. This may be explained by the ratio of very thin woody species such as

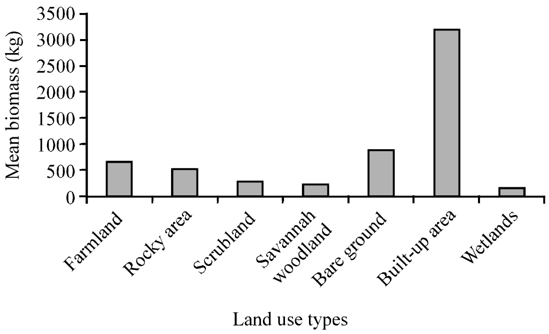

Fig. 10: Variation of woody species biomass over different land uses

Pteleopsis habeensis and *Moringa oleifera* in the composition of species in the area. Since, this analysis is based on mean values, the mean biomass would correspondingly.

DISCUSSION

Land use pattern in the study area follows a traditional distribution in most developing countries and especially the savannah regions where agricultural land use predominate all other land use types. Similarly, the study area is devoid of industries, large water bodies, natural forests, plantations or recreational areas that may have reduced the size of the farmlands. The vast landscape therefore cannot be put to any better use but agriculture. However, woody species are not many in this land use type as farmers see them as threats to crops. They are therefore minimized to as bearable as possible. The type and intensity of land use to a greater extent determines the availability of woody species in a given area (Upadhaya *et al*., 2004; Addo-Fordjour *et al*., 2009). The dominant species were found in relatively large number across the study area. This may not be unconnected with their level of adaptability to the environment their relative tolerance to disturbance as well as water, nutrient and/or other environmental requirements. This conforms to the findings of Fuhlendorf (1999) where it was asserted that many woody plants, especially on rangelands are capable of surviving in stressful environments.

Height, diameter at breast height, basal area and stem density were found to be generally low in the study area. The structure of woody species in a given area may be adversely affected by the degree of exploitation. It was found out that unsustainable agricultural practices, over grazing, exploitation for fuel wood and for herbal medicinal preparations as well as other construction activities are frequent in the area.

Species structure in the study area therefore portrays a disturbed ecosystem where except in the built-up area; woody species are hardly allowed to reach maturity. Tree density (Addo-Fordjour *et al*., 2009), decreased with increasing height in the study area. While only a few species belong to the higher height class, majority belong to the medium and lower height classes. Similarly while most of the species have a diameter of <50 cm^2 many also have a very low per hectare density.

CONCLUSION

Although, not much has been documented on the composition, distribution and structural characteristics of woody species in the study area, results from this study confirm that the area is diverse in woody species but their distribution is generally uneven. Similarly, many species were represented in very small numbers due to disturbance most probably caused by human activities as such therefore require considerable conservation attention.

Knowledge of the composition, distribution and structural characteristics of woody species is highly desirable and also necessary to the understanding of the complex man-species relationship for identifying important elements of plant diversity and for effective conservation of biological diversity. Measures should be taken to conserve the species as well as their ecological habitat for optimal productivity and enhanced ecosystem services production. To this end, environmental education, alternative domestic energy and propagation of economic trees will go a long way in ensuring the stability of woody species and also solving many environmental problems in the area.

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