Tree Species Diversity And Density Pattern In Afi River Forest Reserve, Nigeria

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Abstract: Afi River Forest Reserves in Cross River State, Nigeria, was assessed for tree species diversity and density pattern. Multistage (3 stage) sampling technique was adopted for data collection. 10 tertiary plots were randomly established within the secondary plots and trees randomly selected for measurement within the tertiary plots (0.20 ha). Growth data including: diameter at breast height (dbh, at 1.3m); diameters over bark at the base, middle and top; merchantable height and total height were collected on trees with dbh ≥ 10 cm in all the 10 tertiary sample plots. The results indicate that an average number of trees per hectare of 323 (68 species) were encountered in the study area. Population densities of the tree species ranged from 1 to 29 ha^{-1}. This means, some tree species encountered translates to one stand per hectare. *Pycnanthus angolensis* was the most abundant with a total of 29 tree/ha. The basal area/ha in the study area was 102.77m^2 and the species richness index obtained was 10.444, which indicate high species richness. The value of Shannon-Wiener Index (H^l) is 3.827 which is quite high. The results show that the forest reserve is a well-stocked tropical rainforest in Nigeria. The high species diversity and the relative richness in timber species of the forest reserve does not correlate well with the abundance because the abundance of each of the species was quite low and density poor. However, the presence of higher percentage of the lower diameter tree in the forest reserve indicates that the forest reserve is vigour and healthy.

Index Terms: Afi River Forest Reserve, floristic composition, species diversity, tree density

Introduction

Afi River Forest Reserve is a tropical rainforest considered as biodiversity hotspot of global significance (Myers et al. 2000, Oates et al. 2004). The tropical rainforests are the most biodiverse of all terrestrial ecosystems (Turner 2001, Onyekwelu et al., 2008; Schmitt et al. 2009, FAO 2010, and IUCN 2010). For example, though accounting for only 7% of the earth's dry surface area, rainforests accommodate about 70% of all animal and plant species in world ecosystems (Lovejoy 1997). Between 100 and 300 tree species ha-1 are found in rainforests, a value that is much higher than the number of species found in temperate forests (Onyekwelu et al., 2008). Forests play important role in maintaining fundamental ecological processes, as well as in providing livelihoods and supporting economic growth (UNEP 2007, FAO 2009a). However, many tropical forests are under great anthropogenic pressure and require management intervention to maintain and/or improve their biodiversity conservation, productivity and sustainability (Kumar et al, 2002). Loss of biodiversity has been recognized as one of the main threats to world's forest estates. There are growing concerns for developing new global, regional and national programmes for conserving and managing forest biodiversity (Köhl et al, 1998). Species diversity and stand density measures have been widely used as indicators of ecosystem status, and they play critical roles in studies dealing with the assessment of human impact on ecological systems (Leitner and Turner, 2001). Knowledge of stand density in forest management is an essential apparatus to check crowdedness and competition of trees in a forest stand.

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Relative stand density measures and maximum size density relationship have been used to developed stand management density diagram for slash pine plantation in lower coastal plain (Dean and Jokela, 1992) and stocking charts for upland hardwood forest in central United States (Gingrich, 1967); hardwood stands in northern England (Solomon and Leak, 1986). Essentially, these tools are simple average stand models that graphically characterize growth, density and mortality at various stages of stand development (Solomon and Zhang, 1998). Stand density management diagram is a useful tool which not only allows estimation of stand stocking but also serve as a stand monitoring system in which stand development and treatment can be traced through the stand management history (Solomon and Zhang, 1998; Kumar et al., 2006). Stocking chart can be used by forest managers to rapidly design and evaluate alternative density regimes. This practice will help to maximize wood yield (Kershaw and Fischer 1991; Dean and Jokela, 1992) and to create favourable ecological conditions for vegetation (Barbour et al., 1997). Kershaw and Fischer (1991) developed a stand density diagram for saw timber-sized mixed upland hardwoods in the central United States. Understanding species diversity and density patterns is important for helping forest managers evaluate the complexity and resources of forest. Trees form the major structural and functional basis of tropical forest ecosystems and can serve as robust indicators of changes. The objective of this study is to assess tree species diversity and investigate tree density pattern in Afi River Forest Reserve in Cross River state, Nigeria, with a view to ensuring its sustainable management.

Methodology

Study Area

Afi River Forest Reserve lies approximately between latitudes 6^o 08′ and 6^o 26′N and longitudes 8^o 50′ and 9^o 05′E and covers a total land area of 383.32 km^2 including the area known as Afi Mountain (Figure 1).

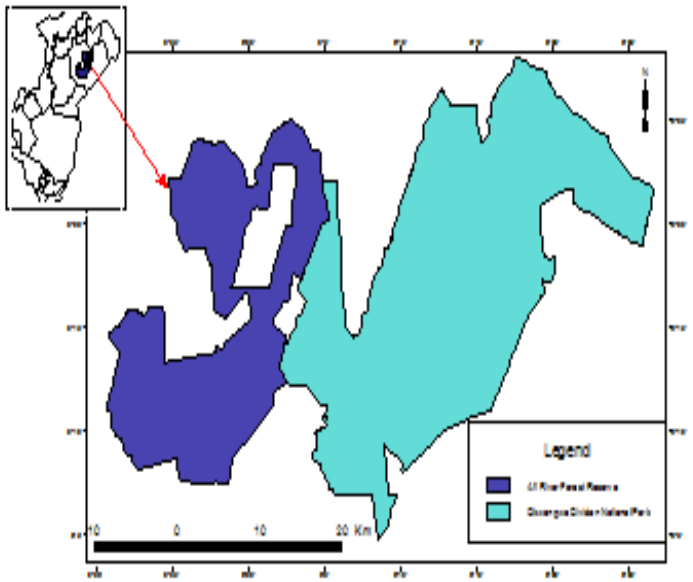

Fig. 1: Map of Afi River Forest Reserve

The topography of the study area is extremely complex with many connected ridge systems, isolated peaks and outcrops, with altitude ranging from 200m to 1200m above sea level. The reserve is characterized by large tracts of rock outcrops especially on the North-East axis. The hills of the reserve are extension of the Cameroon Mountains geological formation. The fast moving and high gradient streams drain the Afi River Forest Reserve, constituting an important watershed. Crustaceous sedimentary sandstone occupies a significant area of the study site, with volcanic eruptions that sometimes comprises columnar basalt in some places (Nsor, 2004). Old sedimentary soils tend to be sandy with structure less profiles and incipient laterite. Generally, the soils vary from clayey-loam to loamy-clay and normally red with high content of iron oxide. They are acidic and low in nutrient status, which makes them unsuitable for arable crop production (Agbor, 2003). Annual rainfall varies from 3,000 mm to 3,800 mm (Agbor, 2003) while average annual mean temperature 22.2^{o}C and 27.4^{o} C on Afi mountain and lowland, respectively. Balogun, (2003) indicated that the mean annual relative humidity is 78% at 7.00 Hr. The vegetation of Afi River Forest Reserve generally falls within the tropical high forest vegetation zone. The rainforest occupies the foot of the mountain. At about 700m above sea level, the forest structure changes gradually into sub-montane vegetation, while above 500m, the vegetation have been changed into grassland as a result of annual bush fire (Agbor, 2003).

Data Collection

Multistage sampling technique was used to establish primary (1000 m x 1000 m), secondary (1000 m x 50 m) and tertiary (40 m x 50 m) sample plots. Ten tertiary sample plots were randomly chosen within the secondary plots and all trees above 10 cm diameter were considered for measurement within the tertiary plots (0.20 ha). Tree growth data collected on trees with dbh ≥ 10 cm in all tertiary sample plots includes: diameter at breast height (dbh); diameters over bark at the base, middle and merchantable top; merchantable height (which is the point between ground level and point of the first surviving whorl of branch) and total height. In addition, all trees with dbh greater than or equal to 10 cm within each sample plot were identified by their botanical and family names through an experience forest taxonomist. Where a tree's botanical name was not immediately known on the field, such tree was identified by its common name.

Data Analysis

Basal Area Estimation

The basal area for each tree was computed using equation (1):

$$BA = \pi D^2/4 \quad \text{---------- (1)}$$

Where BA = basal area (m^2)

π = 3.142 (a constant)

D = dbh (m)

Basal area per plot was obtained by adding the basal area of all individual trees within the plot. Mean plot basal area were computed by summing the total plot basal areas of the sample plots and dividing it by the number of sample plots. Basal area per hectare was then obtained by multiplying the mean plot basal area by the number of sample plots per hectare.

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Volume Estimation

The volumes of individual trees in each plot were computed using Newton's formula (Husch *et al*., 2003) (equation. 2)

$$V = h/6(A_b + 4A_m + A_t) \quad - \ - \ - \ - \quad (2)$$

Where:

V = tree volume (m^3)

h = tree height (m)

A_b = Cross –sectional area at the base (m^2)

A_t = Cross –sectional area at the top (m^2)

A_m = Cross –sectional area at the middle (m^2)

Volume per plot was obtained by adding the volume of all individual trees within the plot. Mean plot volume were then computed by summing the total volumes of the sample plots and dividing it by the number of sample plots. Volume per hectare was obtained by multiplying the mean plot volume by the number of sample plots per hectare.

Diversity analysis

The Shannon-Wiener diversity index (H'), species evenness (E) and species dominance index were all calculated to determine the tree species diversity.

Shannon-Wiener Diversity Index (H'): The Shannon-Wiener diversity index is the most widely used index in community ecology. The values of Shannon-Wiener diversity index is usually found to fall between 1.5 and 3.5 and only rarely surpasses 4.5 (Magurran, 1988). It is given by (eqn 3):

$$H^I = -\sum P_i InP_i \quad - \ - \ - \ - \ - \ - \ - \ - \ - \ - \ - \quad (3)$$

Where P_i is the proportion of individuals found in the ith species

$$P_i = n_i / N$$

N being the total abundance

n_i **=** number of individual in the ith species

Evenness Index (E)

The ratio of the observed diversity (H) to the maximum diversity (H_{max}) is taken as a measure of evenness (E).

$$\text{Evenness} = \frac{H}{H_{max}} = \frac{H}{logs} \text{ - - - - - - - - - - - - - (4)}$$

Where S is the total number of species. E is constrained between 0 and 1.0 with 1.0 representing a situation in which all species are equally abundant.

Simpson's dominance Index

Simpson's dominance index is weighted towards the abundance of the commonest species.

$$\text{Simpson Index (C)} = \sum P_i^2 \text{ - - - - - - - - - - - - - (5)}$$

Where P_i is the proportional abundance of the ith species ($P_i = \frac{n_i}{N}$)

Simpson's index varies from 0 to 1 and gives the probability that two individuals drawn at random from a population belong to the same species. If the probability is high, then the diversity of the community sample is low. The higher the dominance index the lower the Shannon diversity. In addition, the Margalef's index (d) was used to calculate the species richness. The Margalef's index (d) is independent of sample size. It is based on the relationship between total number of species (S) and total number of individuals (N). Margalef's index is given by:

$$\text{Margalef' Index (d)} = \frac{S-1}{In(N)} \text{ ---------- (6)}$$

Where S is the total number of species; N is the total number of individuals and *ln'* is the natural logarithm ($\log_e$).

Results and Discussion

Afi River Forest Reserve has an average number of 323 trees per hectare (Table 1), which is higher than the values reported by Adekunle *et al.* (2004) and Jimoh *et al.* (2012) for some tropical forests in Nigeria. The density of trees in this study is also higher than the 152 and 171 trees per hectare reported for tropical Barro Island, Panama by Hubbell and Foster (1983) and Thorington *et al.* (1983), respectively as well as the 104 trees per hectare for tropical Jengka Reserve, Malaysia (Ho *et al.* 1987). However, Afi River forest reserve has lower tree density than Wain River, East Kalimantan with 385/ha and 535/ha (Sidiyasa, 2001). And tropical Amazonia forest with 1420/ha (Campbell *et al*, 1986) and 1720/ha (Campbell *et al*, 1992). The minimum and maximum dbh of trees at Afi River Forest Reserve were 11.1 cm and 180.0 cm, respectively. The forest reserve was characterized by abundance of trees with small dbh, which is not unusual for tropical rainforests (figure 2). Similar results have been reported by previous workers in other tropical rainforests of Nigeria (Adekunle *et al.,* 2004; Adekunle and Olagoke, 2008). The reason for relatively fewer number of tree individuals with large dbh values greater than 0.50m (Dbh > 0.50m) can be attributed to forest degradation activities which may have removed large individuals as well as the fact that some large-sized trees would have been removed through logging operation for some uses in the past (Hadi *et al.,* 2009). The minimum and maximum merchantable heights obtained were 2.7 m and 55.0 m, respectively while the minimum and maximum total tree heights were 12.0 m and 62.2 m, respectively (Table 1). The average basal area/ha recorded in this study is 102.77m^2 (Table 1). The basal area value for Afi River Forest Reserve is higher than the values reported by Adekunle *et al*, (2004) and Kumar *et al*, (2002) for some tropical forests of the world. The stand basal area for Afi River forest reserve is far higher than the 15 m^2 suggested for a well-stocked tropical rainforest in Nigeria by Alder and Abayomi (1994). This is to be expected since the logging operation in the study area is well regulated from excessive timber operation and the high number of trees per hectare could also be attributed for the high tree basal area. The skewness in dbh distribution is positive because there are more trees in the lower dbh classes than in the upper classes (figure 2). This is consistent with the reports of Boubli *et al.* (2004) and Bobo *et al.* (2006) for two tropical rainforests. The implication of this is that the forests are still undergoing regeneration and recruitment, which are vital indicators of forest health and vigour (Jimoh *et al.* (2012).

Table 1: Summary of stand growth characteristics for Afi River Forest Reserve, Nigeria

Number of trees/hectare	323			
	Min	**Max**	**Mean**	**Std Error**
Dbh(cm)	11.1	180.0	57.7	0.0125
D_{st}(cm)	12.7	180.0	64.0	0.0131
MTH(m)	2.7	55	25.40	0.373
THT(m)	12	62.2	31.86	0.399
Basal Area/ha(m^2/ha)	59.14	157.03	102.77	0.015
Merchantable Vol/ha(m^3/ha)	586.50	1536	2570	0.470
Total Stem Vol/ha(m^3/ha)	1692	4317	3154	0.554

Dbh- diameter at breast height; Dst- stump diameter; MTH- merchantable height; THT- total height; Vol- volume

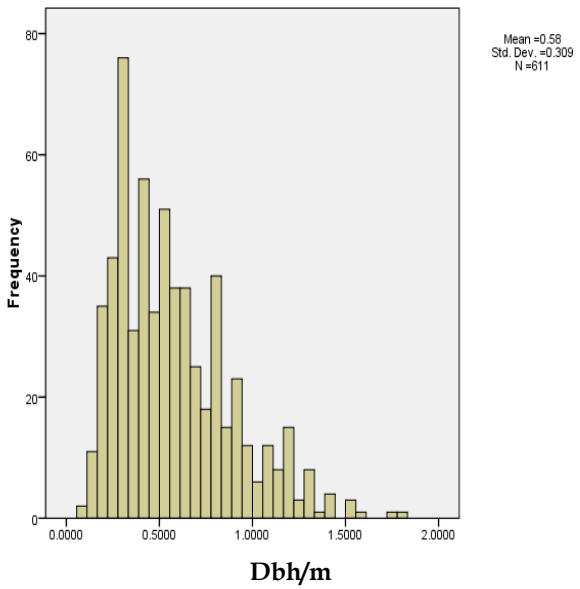

Figure 2: Dbh Distribution Pattern of Afi River Forest Reserve

Floristic Composition

A total of 68 species distributed into 28 families and 62 genera were identifiesd in the study area (Tables 2 and 3). The following tree species: *Berlinia grandiflora, Piptadenastium africanum, Brachystegia eurycoma, Irvingia gabonensis, Albizia zygia, pycnathus angolensis, Staudtia stipitata, Pterocarpus osun and Mamea africana* are more prevalent in the study area with average trees per hectare of greater than or equal to nine. *Pycnathus angolensis* and *Staudtia stipitata* are the richest individual species with 29 and 18 trees per hectare, respectively, which represent 9.5% and 5.7% of the total trees per hectare, respectively (Table 2). However, some species (e.g. *Canarium schweinfurthi, Detarium macrocarpum, Cloaxylum hexadrum, Drypetes gossweileri, Drypetes preussi, Petersianthus macrocarpus, Lophira alata, Anopysis klaineana, pausinystalia macrocera, Baillonella toxisperma, Sterculia oblonga* and *Vitex gradifolia*) were only represented by one tree species per hectare, which may imply that they have low conservation status and that they are currently threatened and may go into extinction in Afi River Forest Reserve, except measures are put in place to ensure their regeneration. The following families: Apocynaceae, Caesalpinioideae, Combreteceae, Euphorbiaceae, Guttifera, Irvingiaceae, Meliaceae, Mimosoideae, Moraceae, Myristicaceae, Papilionoideae and Steculiaceae have more than ten trees per hectare. Caesalpinioideae is the most dominant family being represented by 9 species and 9 genera (Table 3). The second most dominant family is Mimosoideae with 7 species and 5 genera, followed by Euphorbiaceae consisting of 6 species and 5 genera. Results on Table 2 indicate a generally low tree population density in the study area, which may partly be attributed to some conditions within the forest reserve, coupled with the possibility of paucity of viable seeds to sustain regeneration. For instance, a tree species that is not shade tolerant would find it difficult to regenerate in a rainforest with closed canopy, which definitely would affect the population density of such species. Christie and Armesto (2003) reported very low population densities of quite a number of economically valuable tree species occasioned by dearth of viable seeds and poor micro-sites for regeneration. Also, abundance or rarity of a timber tree species in rainforest is a function of the intensity and pattern of its exploitation. This would also cause gross inadequacy of seeds for regeneration, as a lot of mother trees must have been felled. It is a fact that there is a positive relationship between low population densities of some tree species and the mortality of their mother trees (Olajide, 2004).

Table 2: Family and density of tree species identified in Afi River Forest Reserve

Family	Species name	Average tree/Hectare	Relative Density/ Hectare
Anisophylleaceae	*Poga oleosa*	5	0.01471
Annonaceae	*Monodora myristica*	4	0.01307
Annonaceae	*Xylopia aethiopica*	2	0.00654
Apocynaceae	*Alstonia boonei*	3	0.00817
Apocynaceae	*Alstonia congensis*	3	0.0098
Apocynaceae	*Futumia elastica*	7	0.02124
Bombacaceae	*Bombax buonopozense*	4	0.01307
Bombacaceae	*Ceiba pentandra*	2	0.00654
Burseraceae	*Canarium schweinfurthii*	1	0.00327
Caesalpinioideae	*Afzelia Africana*	5	0.01634
Caesalpinioideae	*Berlinia grandiflora*	10	0.03268
Caesalpinioideae	*Brachystegia eurycoma*	15	0.04902
Caesalpinioideae	*Daniellia ogea*	3	0.00817
Caesalpinioideae	*Detarium macrocarpum*	1	0.00163
Caesalpinioideae	*Distemonathus benthamianus*	4	0.01144
Caesalpinioideae	*Erythrophleum suaveolens*	2	0.0049
Caesalpinioideae	*Gossweilerodendron balsamiferum*	2	0.0049
Caesalpinioideae	*Oxystigma manni*	5	0.01634
Combretaceae	*Terminalia ivorensis*	5	0.01471
Combretaceae	*Terminalia superba*	6	0.01961
Ebenaceae	*Diospyros crassiflora*	6	0.01961
Euphorbiaceae	*Claoxylon hexandrum*	1	0.00163
Euphorbiaceae	*Drypetes gossweileri*	1	0.00163
Euphorbiaceae	*Drypetes preussii*	1	0.00163
Euphorbiaceae	*Klainedoxa gabonensis*	4	0.01307
Euphorbiaceae	*Ricinodendron africanum*	3	0.0098
Euphorbiaceae	*Uapaca*	8	0.02451

	heudelotii		
Flacourtiaceae	*Homalium spp.*	3	0.00817
Guttiferae	*Allanblackia floribunda*	5	0.01634
Guttiferae	*Mamea Africana*	9	0.02778
Irvingiaceae	*Irvingia gabonensis*	11	0.03595
Lecythidaceae	*Petersianthus macrocarpus*	1	0.00327
Loganiaceae	*Anthocleista djalonensis*	4	0.01144
Meliaceae	*Carapa procera*	7	0.02288
Meliaceae	*Entandrophragma cylindricum*	3	0.0098
Meliaceae	*Khaya ivorensis*	5	0.01471
Meliaceae	*Lovoa trichilioides*	2	0.0049
Mimosoideae	*Albizia ferruginea*	4	0.01307
Mimosoideae	*Albizia gumifera*	2	0.0049
Mimosoideae	*Albizia zygia*	13	0.04085
Mimosoideae	*Cylicodiscus gabunensis*	4	0.01144
Mimosoideae	*Parkia bicolor*	6	0.01961
Mimosoideae	*Piptadeniastrum africanum*	10	0.03105
Mimosoideae	*Tetrapleura tetraptera*	2	0.00654
Moraceae	*Antiaris welwitschii*	3	0.00817
Moraceae	*Ficus mucuso*	4	0.01144
Moraceae	*Milicia excelsa*	4	0.01144
Moraceae	*Treculia obovoidea*	3	0.00817
Myristicaceae	*Coelocaryon preussii*	3	0.00817
Myristicaceae	*pycnathus angolensis*	29	0.09477
Myristicaceae	*Staudtia stipitata*	18	0.05882
Ochnaceae	*Lophira alata*	1	0.00327
Olacaceae	*Strombosia pustulata*	1	0.00163
Papilionoideae	*Amphimas pterocarpoides*	5	0.01634
Papilionoideae	*Pterocarpus osun*	9	0.02941
Papilionoideae	*Pterocarpus soyauxii*	2	0.00654
Rhizophoraceae	*Anopyxis Klaineana*	1	0.00327
Rubiaceae	*Mitragyna stipulosa*	4	0.01144
Rubiaceae	*Nauclea diderrichii*	4	0.01307
Rubiaceae	*Pausinystalia macrocera*	1	0.00163
Rutaceae	*Zanthoxylum zanthoxyloides*	3	0.00817
Sapotaceae	*Baillonella toxisperma*	1	0.00163
Sterculiaceae	*Pterygota macrocarpa*	8	0.02451
Sterculiaceae	*Sterculia oblonga*	1	0.00163
Sterculiaceae	*Triplochiton scleroxylon*	5	0.01634
Ulmaceae	*Celtis zenkeri*	8	0.02451
Verbenaceae	*Vitex gradifolia*	1	0.00163

Table 3: Pattern of Families Distribution by Genera and Species

Families	Number of genera	Number of species	Average trees/Hectare
Anisophylleaceae	1	1	5
Annonaceae	2	2	6
Apocynaceae	2	3	13
Bombacaceae	2	2	6
Burseraceae	1	1	1
Caesalpinioideae	9	9	47
Combretaceae	1	2	11
Ebenaceae	1	1	6
Euphorbiaceae	5	6	18
Flacourtiaceae	1	1	3
Guttiferae	2	2	14
Irvingiaceae	1	1	11
Lecythidaceae	1	1	1
Loganiaceae	1	1	4
Meliaceae	4	4	17
Mimosoideae	5	7	41
Moraceae	4	4	14
Myristicaceae	3	3	50
Ochnaceae	1	1	1
Olacaceae	1	1	1
Papilionoideae	2	3	16
Rhizophoraceae	1	1	1
Rubiaceae	3	3	9
Rutaceae	1	1	3
Sapotaceae	1	1	1
Sterculiaceae	3	3	14
Ulmaceae	1	1	8
Verbenaceae	1	1	1

Tree Species Diversity Index

Table 4 shows the summary of tree species diversity indices for Afi River Forest Reserve. The species richness index measures the variety of species. It takes into consideration the total number of a particular species in relation to the total number of individuals within the forest stand (Gebreselasse, 2011). Based on the results of Margalef's index, the species richness indices obtained for this study is 10.444, which indicate high species richness when compare with the values (7.19-10.64) for Bwindi forest, (4.71-10.51) for Budonga forest, (6.36-8.08) for kibale forest and (7.54-8.20) for Kasyoha-Kitomi forest, all located in Albertine rift, Uganda (Eilu *et al.,* 2004) . The Shannon-Wiener diversity index (H') value of 3.83 obtained for Afi River Forest Reserve is higher than the 2.20–2.65 for tropical forests of Kodayar in Western Ghats, India (Sundaranpandian *et al*, 2000), compares favourably with the values (3.31 and 3.69) reported for tropical forests in Kalakad Reserved Forests in Western Ghats (Parthasarathy *et al*, 1992) and lower than the 4.8 for tropical forests of Barro Colorado Island in Panama (Knight, 1975). The H' value in this study is similar to what has been reported (3.1 – 3.7) for various rainforest sites in south-western Nigeria (Adekunle, 2006; Onyekwelu *et al*., 2008). However, it should be noted that effective quantitative comparisons of species diversities between forest communities depend on sample size, plot size, environmental conditions, and other site factors.

Table 4: Summary of tree species diversity indices for Afi River Forest Reserve

Characteristic	Afi River Forest Reserve
Margalef's index (d) (species richness)	10.444
Shannon-Wiener diversity index(H')	3.827
Evenness Index(E)	0.907
Dominance Index(C)	0.030
Simpson's Index(D^{l})	34.931

Conclusion

Afi River Forest Reserve which has an estimated number of 323 trees species per hectare is reasonably rich in tree species when compare to tree densities of other tropical rainforest reserves. Some tree species encountered had only one stem per hectare. *Pycnathus angolensis* and *Staudtia stipitata* were the most abundant with a total of 29 and 18 stand/ha respectively in the Afi River Forest Reserve. The basal area of 102.77m^2 estimated suggest a well-stocked tropical rainforest in Nigeria. Generally, low tree population densities for each species in the study area were recorded but tree diversities were high. The dominant height of tree in the reserve is 62m. The prominent tree sizes in the reserve were dbh size class of 0.5m below, which tend to dominate. To prevent the extinction of some families and species, urgent steps therefore need to be taken to arrest the dwindling low density of some species and restock the forest reserve, particularly with the seedlings of species that were represented by only stem per hectare. Exploitation of timber resources should be well regulated to give room for sustainability.

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