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TREE SPECIES DIVERSITY IN A NIGERIAN MONTANE FOREST ECOSYSTEM AND ADJACENT FRAGMENTED FORESTS

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ABSTRACT
The study was conducted at Ngel Nyaki Forest Reserve to capture the tree species composition, diversity and richness in a Nigerian montane forest ecosystem, and to compare same between a protected natural forest - Main Forest (MF), and unprotected forest fragments (A, B, and C) within the buffer zone. Vegetation sampling was carried out using the Point-Centred Quarter (PCQ) method. Alpha diversity was measured using both Simpson and Shannon-Wiener indices while similarity or otherwise dissimilarity in species composition between the sites was measured using Sorenson's index. A total of 22 tree species were encountered in MF while 19, 18, 17 species were encountered in fragments A, B, and C respectively. Only 5, 3 and 4 tree species were common to MF and A, MF and B, and MF and C, respectively. A total of 10 tree species were common to fragments A and B, while 11 species were common to each of fragments A and C and B and C. Tree density (per hectare) was higher in the fragments than MF except for fragment C; though, individuals with larger diameter classes were more in MF. Tree diversity was higher in MF than in the fragments with C being the least diverse. Considering the importance of fragment C as a corridor within a buffer zone, and a source of livelihood to the rural community, the need for its restoration, protection and the introduction of stringent measures to ensure sustainable resource utilization was emphasized.

Keywords: tree diversity, montane forest, forest fragmentation, ecosystem management, Ngel Nyaki.

INTRODUCTION
The diversity of tropical forest ecosystems is known to be high; however, tropical forests are being deforested at an alarming rate. Deforestation has been described as the planet's most significant environmental and economic problem (FAO, 2001; NASA, 2003). As human populations continue to grow, land use intensity increases, and the negative effects of deforestation are likely to worsen (Chazdon, 2003). Degraded landscapes are expanding extensively in area, as forests are on daily basis converted to unsustainable pasture or cultivation, and then abandoned (Nepstad *et al*., 1991; Brown and Lugo 1994). Forests located in difficult terrains, like the montane zones, are not left out in this ugly trend.

Stretched along the Nigerian/Cameroon border are most of the Nigeria's Montane/sub-montane forests. Historically, these forests were located in expansive sweeps along escarpment edges in the Gotel Mountains and Mambilla Plateau (Taraba State), and on Vogel Peak and the Kirri Plateau (Adamawa State). Montane forest also occurred as stream fringing forest meandering across the Jos (Plateau State), Obudu (Cross River) and Mambilla plateaus. Almost all the stream fringing forest has been lost from Jos Plateau, and it is now confined to small fragments on Obudu and Mambilla Plateaus.

On Mambilla, there remains one significant sub-montane forest, Ngel Nyaki. The forest (approximately 7.2 km^2) falls within Ngel Nyaki Forest Reserve which is 46 km^2 in area. The reserve is located on the western escarpment of Mambilla Plateau, in the bowl of an old volcanic crater from 1400-1600m elevation. It was gazetted a Local Authority Forest Reserve in 1969. Outside the reserve boundary is an unofficial 'buffer zone', comprising grassland and stream fringing forest. The forest reserve is known for its high diversity in fauna and flora (Chapman and Chapman, 2001). If properly managed, an ecologically diverse montane forest like Ngel Nyaki will ensure watershed protection, perennial water supply to plants and animals, support for traditional livelihood, conservation of potentially valuable genetic resources, support for rural development, and provide a natural laboratory for research and education. However, Ngel Nyaki Forest Reserve is currently beset with problems of fragmentation (especially in the riverine forest strips of the buffer zone) which portrays danger to its biological resources.

When ecosystems are pushed to the point of failure, they convert into unpredictable state and human communities that depend on them convert as well. By understanding the status of the natural forest and the riverine forest fragments in terms of tree species composition, richness and diversity, recommendations can be made for the restoration and future management of the reserve. The study was a step in that direction. It aimed at ascertaining the status of the vegetation in the montane forest ecosystem. Specifically, the objectives of the study were: (1) to capture the composition, diversity and richness or otherwise rarity of tree species in a Nigerian Montane forest ecosystem; and (2) to compare the tree species composition, diversity and richness between unprotected forest fragments and the protected climax vegetation - the main forest (MF) within the same environment.

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Description of the study area

The study was conducted at Ngel Nyaki Forest Reserve, located towards the western escarpment of the Mambilla plateau, Taraba State, Nigeria (Figure-1). The plateau is located between longitude 11^0 00^1 and 11^0 30^1 East and latitude 6^0 30^1 and 7^0 15^1 North. It is drained by numerous water courses which unite to form the main rivers to discharge eventually into the Benue River. Ngel Nyaki Forest Reserve can be reached on foot from Yelwa village past the Mayo Jigawal, from where it is less than an hour's walk to the upper edge of the forest. It comprises approximately 46km^2 of impressive sub-montane to mid-altitude forest, lying between 1400 - 1500m (Chapman and Chapman, 2001). The forest vegetation is continued to the South-west facing slope where mist may lie for days, and sometimes a week at a time, during the rainy season. Heavy rainfall is recorded from April to October while the dry season is from approximately November to March.

Ngel Nyaki Forest Reserve and Game Sanctuary, is the most species diverse forest on Mambilla plateau (Chapman and Chapman, 2001). Over 146 vascular plant species have been recorded, many of which are trees, and (near-) endemic to the Afromontane Region (White, 1983; Dowsett - Lemaire, 1989). Four tree species are Red Data listed, and several, such as *Anthonotha nolddii* are new to West Africa and others new to Nigeria (Chapman and Chapman, 2001). This high floristic diversity is reflected in the high number of primates and other animal species in the forest (Hall, 1970; Dunn, 1993). There is a small, but thriving population of the Red Data listed Chimpanzee (*Pantroglodytes subsp vellerosus*), as well as the Putty-Nosed monkeys (*Cercopithecus nicitans*) and the black and white colobus (*colobus guereza occidentalis*). The forest is also rich in bird life, more than 200 species were documented in 2003 (Disley, personal communication). Ngel Nyaki was formally gazetted a local authority Forest Reserve under Gashaka - Mambilla Native Authority Forest order of April 1969, but at present it is under the management of the Taraba State Government and the Nigerian Conservation Foundation (NCF), with the Nigerian Montane Forest Project (NMFP) as a project partner.

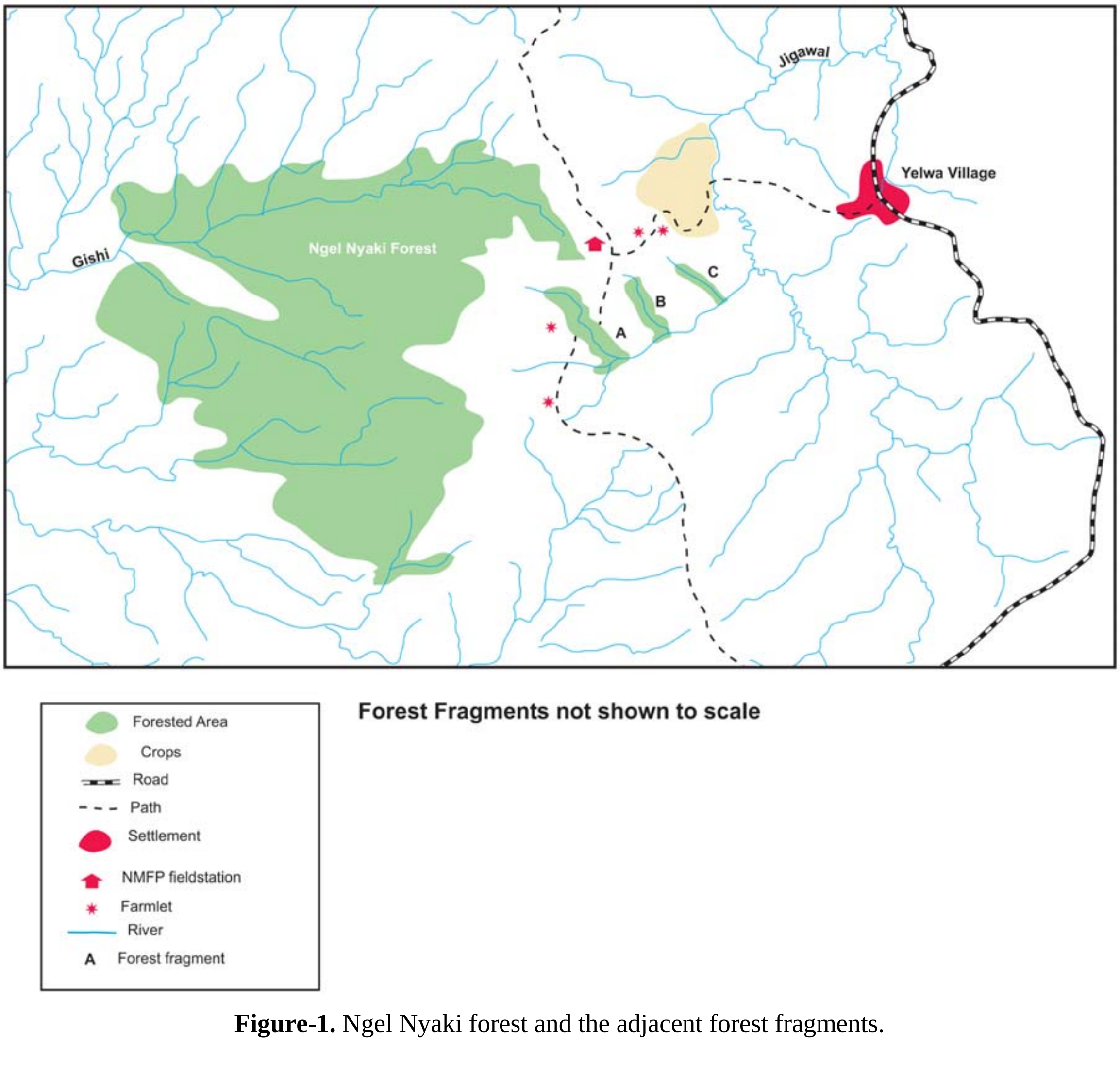

Figure-1. Ngel Nyaki forest and the adjacent forest fragments.

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MATERIALS AND METHODS

Materials / instruments used for data collection

The instruments used for data collection included: a telescope, calipers, measuring tapes, field data sheets, a clinometer, a Geographical Positioning system (GPS) and field guide book: The Nigerian Trees (Keay, 1964).

Experimental design

The study area comprised of four sites, the main forest, that is, Ngel Nyaki forest (hereafter referred to as MF), and forest fragments A, B and C (Figure-1). The study was designed to incorporate areas of forest at different locations from large, MF (> $8km^{2)}$, to small fragments A and B (>200 m^2) and very small fragment C (<$200m^2$); increasing distance from MF, 310m -1,590m (fragment A and C, respectively), and increasing habitat degradation from very little (MF) to extreme (fragment C).

Vegetation sampling

Vegetation sampling was conducted by Point-Centred Quarter (P.C.Q) method (Machange, 1985). P.C.Q was carried out by measurement of distances from randomly chosen points to the nearest woody plant species. Twenty random sampling points were located along a series of line transects passing through the stand (Compass direction). At each sampling point, 4 quarters (quadrants) were established using a cross. The individual nearest the point in each quadrant was located.

The distances from the sampling point to the mid-point of the nearest tree in each quadrant were measured and recorded. Single-stem woody perennials of up to 5m height and 7cm diameter at breast height (dbh) within the quadrants were identified to species level and counted. However, few individuals that could not be identified were counted and recorded against their respective sites of occurrence. Parameters obtained by this method include tree species composition, density, diameter and frequency. The following computations were made: (a) Plant species point to point distance (m); (b) Tree species mean point distance (m); (c) Mean area (M.A)/tree species (m^2); and (d) Total (absolute) density (Trees/hectare).

a) Plant species point to point distance (m) was obtained from the sum of the distances from the centre of the quadrant to each of the four plants per station. In each of the 20 stations, the distance of 4 points to the nearest tree distance taken in each 4 quarters i.e., D_1, D_2, D_3 and D_4 are summed. The sum of the total distance of the 4 quarters in the 20 stations gives the species point to point distance.
   Mathematically,
   $D_1 + D_2 + D_3 + D_4$ = Species distance (Spd) per station.
   Then, $Spd_1 + Spd_2 + \ldots\ldots + Spd_{20}$ = Point to point distance.
   D = Distance (m)
   Spd = Species distance
   Spd_{20} = the species point to point distance in the 20^{th} station.
b) Species mean point to point distance (m), was averaged to give plant species mean point to point distance. For instance, in the 20 stations, the tree species mean point to point distance was calculated by dividing Point to point distance (m) by the 20 stations.
c) Mean area/plant species (m2) represents the average area of ground surface on which one tree occurs.
   The mean area/tree (MA) = D2.
   Where D = the mean distance of 4 points to the nearest tree distances taken in each of four quarters i.e., D1, D2, D3 and D4.
d) Total (absolute) density (trees/hectare). The total density of trees in the area sampled was then obtained by dividing the MA/tree into the unit area on the basis of which density was expressed. Total density of all species = unit area divided by mean point to point distance squared. Unit area refers to the size of the area in the same units as those of MA/plant on the basis of which density (per hectare) was expressed.

Method of data analysis

Measurement of alpha diversity

Two common approaches for measuring alpha diversity are species richness and evenness/heterogeneity (Ojo, 1996). Species richness simply refers to the number of species in the community while evenness/heterogeneity refers to the distribution of individuals among the species. In this study, species richness was computed as the total number of tree species encountered in each site. For the measurement of evenness/heterogeneity, Simpson and Shannon-Wiener indices were computed for each of the sites using the PAlaeontological Statistics (PAST) software.

Measurement of beta diversity

Sorrenson's similarity index was used to measure beta diversity. Wolda (1983) suggested the use of similarity indices for measuring beta diversity. Jansen and Vegelius (1981) had earlier opined that, of the many similarity indices, only three of them (the Ochiai, the Jaccard and the Sorrenson) are worth considering.

Sorrenson's index is expressed as:

RI = 100 * a / a + b + c

Where

a = number of species present in both sites under consideration
b = number of species present in Site 1 but absent in Site 2
c = number of species present in Site 2 but absent in Site 1

RESULTS

Species composition and tree density

The species composition for the enumerated sites is presented in Table-1. A total of 70 individuals belonging to 22 species were encountered in MF; while 80 individuals belonging to 19, 18, and 17 species were

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encountered in each of fragments A, B and C, respectively. The similarity or otherwise dissimilarity in species composition between each pair of the enumerated sites is shown in Table-2. MF and fragment B are the most dissimilar, followed by MF and C and MF and A, respectively. A total of 19, 18, and 17 tree species found in MF were not found in fragments B, C, and A respectively. Only 5, 3, and 4 tree species were common to MF and A, MF and B, and MF and C, respectively. Fragments B and C are the most similar in terms of species composition, followed by fragments A and C and fragments A and B, respectively. A total of 10 tree species were common to fragments A and B, while 11 species were common to each of fragments A and C and B and C.

The tree density (per hectare) for each of the four sites is shown in Figure-2. Site B had the highest density, followed by Sites A and MF respectively while Site C had the lowest density. Although, more individuals were found in the fragments A and B than MF, more of the individuals in the fragments fall within the smallest diameter class (Figure-3).

Table-1. Tree species composition of the enumerated sites and number of individuals encountered.

MF		A		B		C	
Species	**No.**	**Species**	**No.**	**Species**	**No.**	**Species**	**No.**
Anthonotha noldeae	8	*Garcinia smeathmannii*	13	*Croton macrostachyus*	11	*Allophylus africanus*	8
Hannoa klaineana	2	*Bridelia micrantha*	4	*Maesa lanceolata*	7	*Syzygium guineense*	20
Pleiocarpa pycnantha	2	*Funtumia elastica*	5	*Psorospermum corymbiferum*	4	*Bridelia micrantha*	10
Synsepalum sp	3	*Albizia gummifera*	5	*Bridelia micrantha*	8	*Ficus spp*	6
Discoclaoxylon hexandrum	3	*Syzygium guineense*	22	*Syzygium guineense*	10	*Anthonotha noldeae*	2
Allophylus africanus	1	*Maesa lanceolata*	4	*Canthium Sp*	1	*Maesa lanceolata*	5
Isolona deightonii	3	*Anthonotha noldeae*	4	*Entenda*	2	*Musanga cecropioides*	1
Strombosia scheffleri	9	*Allophylus africanus*	6	*Anthocleista vogelii*	1	*Anthocleista vogelii*	2
Deinbollia spp	6	*Anthocleista vogelii*	2	*Allophylus africanus*	6	*Memecylon afzelii*	2
Ficus spp	4	*Psorospermum corymbiferum*	3	*Recinodendron africanum*	11	*Croton macrostachyus*	13
Carapa grandiflora	5	*Deinbollia spp*	2	*Ilex mitis*	5	*Canthium sp*	1
Garcinia smeathmannii	7	*Rauvolfia vomitoria*	1	*Ficus spp*	3	*Trema orientalis*	3
Pouteria altissima	1	*Clausena anisata*	2	*Pittospos*	5	*Unknown*	1
Voacanga bracteate	5	*Nuxia congesta*	2	*Rauvolfia vomitoria*	1	*Psorospermum corymbiferum*	2
Zanthoxylum leprieurii	2	*Dombeya ledermannii*	1	*Albizia gummifera*	2	*Albizia gummifera*	2
Rothmannia urcelliformis	1	*Croton macrostachyus*	1	*Anthonotha noldeae*	1	*Clausena anisata*	1
Unknown	1	*Ficus spp*	1	Unknown	1	*Synsepalum sp*	1
Newtonia buchananii	2	*Symphonia globulifera*	1	*Trema orientalis*	1		
Tabernaemontana contorta	1	*Ilex mitis*	1				
Chrysophyllum albidum	1						
Zymalos monospora	2						
Beilschmiedia mannii	1						

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Table-2. Sorenson's similarity indices for the different sites.

	MF	A	B	C
MF	*	13.89	8.11	11.43
A	13.89	*	37.04	44.00
B	8.11	37.04	*	45.83
C	11.43	44.00	45.83	*

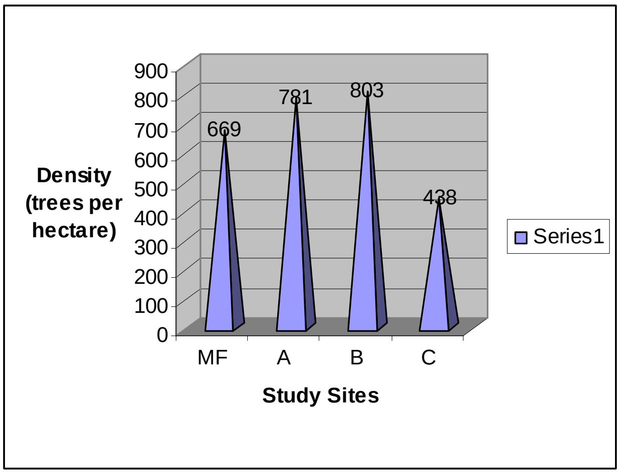

Figure-2. Tree density at the different sites.

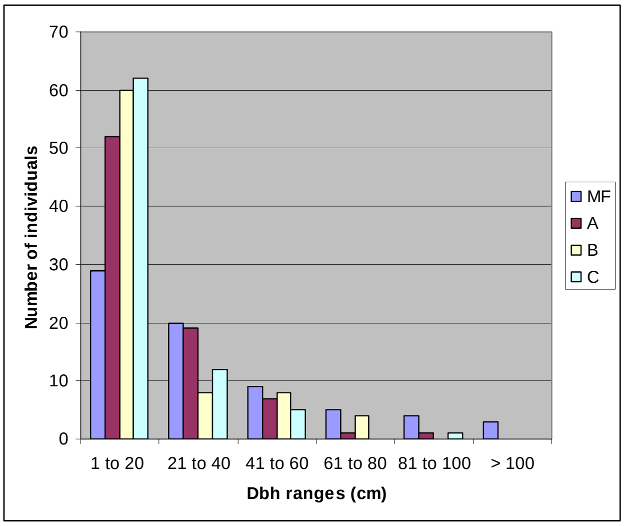

Figure-3. Diameter ranges for individual trees in different sites.

Species diversity

The alpha (within-site) diversity for the different sites is shown in Table-3. Both Simpson and Shannon-Wiener diversity indices show that MF is the most diverse of all the sites, followed by fragments B and A, respectively while fragment C is the least diverse.

Table-3. Alpha diversity indices for the different sites.

Variable	MF	A	B	C
Simpson index	0.9286	0.8722	0.9094	0.8706
Shannon-Wiener index	2.831	2.461	2.576	2.358
Species richness	22	19	18	17

DISCUSSIONS

In terms of species composition, MF was richer than each of the forest fragments. Although, there was not so much difference in the number of species encountered in MF and the fragments, a great dissimilarity was observed in the species composition between MF on one hand and the forest fragments on the other. MF was dominated by climax (shade-tolerant) tree species while the tree species composition of the fragments was dominated by the pioneers (light demanders). The very few pioneers recorded for MF were found at the edges (outliers). Habitat fragmentation and subsequent disturbance may have encouraged colonization by pioneers in the fragments, leading to variations in species composition. Williams-Linera (1990) noted that habitat fragmentation may change species composition due to the arrival of new species.

Higher tree density in fragments A and B than in MF could be attributed to increase in tree populations following the germination of seeds of pioneer tree species in the soil seedbank due to habitat disturbance and alteration. Considering studies in forest areas, it has been observed that forest fragmentation causes biotic changes, which may include increase in the number of populations in the case of shade intolerant species (Lovejoy *et al*., 1986). Hyde (2000) also observed that patches of a fragmented landscape may vary in their suitability as habitats for various organisms. However, the lowest tree density in fragment C could be as a result of over-exploitation due to non-protection and its proximity to settlements of local resource users.

The highest and the lowest tree diversity indices recorded for MF and fragment C respectively is indicative of the level of protection enjoyed by the two sites, and the consequent level of exploitation and resource utilization. While MF is the farthest from the settlements of the rural dwellers and enjoy full protection, fragment C which is the closest to the human settlements, enjoys no form of protection and serves as source of fuel wood, bush meat, drinking water and other non-timber forest products, for the rural dwellers. Harris and Silva-Lopez (1992) observed that habitat fragmentation is one of the most serious causes of diminishing biological diversity, while its main consequence - habitat loss- is responsible for biodiversity loss and ultimate extinction of species (IUCN, 2002).

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CONCLUSIONS

There was a great dissimilarity in tree species composition between MF and the fragments. MF was dominated by climax (shade-tolerant) species while the fragments were dominated by pioneer (light-demanding) species. Tree species richness and diversity compared better in MF than in the fragments; with fragment C being the least rich and diverse. Considering the importance of fragment C as a corridor within a buffer zone and source of livelihood (drinking water, fuel wood, herbs, etc.) to the rural community, there is an urgent need for its restoration and protection, and the introduction of stringent measures to ensure sustainable resource utilization.

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