Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 1, No. 6, p. 93-103, 2011
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Effect of catenary differentiation on vegetation in Obung forest, Cross River State, Nigeria

Raphael Ayama Offiong[1], Anthony Inah Iwara[2], Gertrude Nnanjar Njar[1], Joy Eko Atu[1], Horsfall Digieneni Eli[3]

[1]*Dept. of Geography & Reg. Planning, University of Calabar, Nigeria*

[2]*Dept. of Geography, University of Ibadan, Nigeria*

[3]*Dept. of Geog. & Environmental Magt., Niger Delta University, Bayelsa, Nigeria*

Received: 12 October 2011
Revised: 01 November 2011
Accepted: 02 November 2011

Key words: Catenary differentiation, Obung Forest, importance value index, tree species composition, family composition.

Abstract

The paper examined catenary differentiation of vegetation in Obung Forest, Cross River State of Nigeria. Specifically, it examined the effect of topographic variation on vegetation composition from the upper to the lower slope of the catena. Vegetation data basically tree density, tree species composition, family composition, stem diameter (dbh) and species dominance was obtained from 60 quadrats of 20m by 20m established across the three sections of the catena. Results showed that the number of trees encountered across the catena varied significantly, with the upper slope recording a high stand density of 349, followed by the lower slope of 298, then the middle slope of 243. This difference in stand density was attributed to topographic positions along the catena. Also, mean dbh of trees and basal area varied significantly. The Shannon-Weiner's Index equally varied with the lower slope (2.86) being most diverse and richest than other sections of the catena – upper slope (2.62) and middle slope (2.53). *Elaeis guineensis, Terminelia superba* and *Ficus exasperate* were the most ecologically dominant species across the catena. In the upper slope, *Khaya guineensis* was most dominant, in the middle slope, *Elaeis guineensis* was, while the most ecologically dominant species in the lower slope was *Anthocleista vogelii*. The study however advised that to conserve this species-rich ecosystem, the wanton destruction of the forest vegetation especially for fuel wood harvesting and illegal logging activities should be checked.

***Corresponding Author:** Anthony Inah Iwara ✉ iwaradream2010@yahoo.com

Introduction

The intensity and differences in environmental conditions exert tremendous influence on the assemblage as well as the distribution of flora species across the globe. Plant communities may be sharply or diffusely differentiated from each other, from one site to another as a result of variation in environmental conditions (soil, climate, soil moisture and topography as well as elevation). Plant distribution is therefore principally controlled by the interaction of climatic and edaphic factors (Wong, 1974; Aweto and Iyamah, 1993). Edaphic factors are those soil properties which affect plant growth and distribution and are most likely to show sharply defined patterns within small areas. Within fairly uniform climatic areas, major plant community groups are often closely correlated with the developed soil type and independent of individual parameters such as texture or chemical characteristics of the soil, though these are, of course, related to soil type (Wong, 1974).

In the tropics, vegetation is greatly influenced by climatic factors particularly annual rainfall and its temporal distribution. Nevertheless, another environmental condition observed (Aweto and Iyamah, 1993; Signell and Abrams, 2007; Tamarstash *et al*., 2010) to exert a strong influence on vegetation dynamics is topographic position of slope. This is because over limited areas, soil characteristics vary along the topography, and so do vegetation composition. The difference in soil properties in a sequence along a slope is referred to as catena. Catena therefore is a generic term that describes the sequence of different soils from the same parent rock on a slope. The role of catena in vegetation distribution cannot be overemphasized, as soils on steep slopes are the cause of active erosion, while those in the valley are thicker and heavier, and are more fertile for plant growth (Aweto and Iyamah, 1993). Soils across a catena are distributed largely according to topography and variation in climatic conditions. This difference in soil properties and climate has significant influence on the zonation of vegetation. Indeed, soil along the catena varies from the hill top to the valley bottom, giving rise to a succession of vegetation types with differences in structural and floristic patterns. Catenary differentiation of soils is therefore of pivotal importance to the distribution of vegetation in different topographic positions across the globe (Aweto and Enaruvbe, 2010).

The differences in soil properties, climate and topographic positions across the catena give rise to the speciation of species with peculiar adaptive capacity. For instance, water loving tree/shrub species otherwise referred to as hydrophytes are usually dominant at the valley-bottom of the catena; while the middle slope is usually dominated by tree/shrub species that can tolerate harsh climatic conditions. According to David (2000), steep slopes (in this case, the middle slope) as a result of its characteristic gravitational pull, have little or no soil except at their base where alluvial plains or cones may develop and the angle of slope affects drainage and soil depth as well as vegetation composition. Several studies have been conducted by researchers across the globe in the past to analyse soil and vegetation distribution along the catena. Studies abound on soil property variations in relation to topographic aspect (Ben-Shahar, 1990; Lopez *et al*., 2003; Yimer *et al*., 2006; Aweto and Enaruvbe, 2010); studies have also been carried out on vegetation variations in relation to topographic positions (Enoki *et al*., 1996; Signell and Abrams, 2007). However, in Nigeria, studies on the characterization of vegetation components across the catena have not received wide attention and coverage, as there are scanty documented studies. The only available study is that by Aweto and Iyamah (1993). Topography according to Tamarstash *et al*., (2010) has direct and indirect effects on plant distribution. Thus, understanding the relationship between vegetation distribution and topography can be effective on the estimation of species kind for ecological management in different ecosystems. In this paper, attempts are made to characterize vegetation components across the catena – from the hill top to the valley bottom as well as suggest conservative approaches in order to reduce the unsustainable use of the catena's rich forest resources.

Materials and method

Study area

This study was carried out in Obung Community in Akamkpa Local Government Area between the 12th and 15th of July, 2008. Obung lies between latitude 080 10' and 080 32'E and longitude 050 20' and 050 25' North. The area is characterized by double maxima rainfall with annual rainfall of about 2000-3000mm. The vegetation is typical of tropical rainforest with structural characteristics of three layer canopy and emergent trees. The vegetation is a closed canopy forest and has large broad-leaf. Relative humidity is over 80% while temperature rarely falls below 190 C and average about 270 C all year. The soil varies with terrain gradient, with dark-brown soils at the bottom slope.

Sampling procedure and data collection

Caternary differentiation of soil and vegetation according to Aweto and Iyamah (1993) is mostly marked or determined along transect running from the valley bottom/floor to the crest interfluves. For this study, four transects measuring 1680m (420m each) were laid with distance of 5m in between. Each transect was 420m long and ran from the upper slope to the bottom slope (lower slope). In each transect, twenty-one quadrats of 20m by 20m were laid (7 each in the upper slope, middle slope and bottom slope). In all, a total of 60 sample guardats were randomly selected and studied (20 from each section of the catena) out of the 28 established. In each quadrat, tree density, number of tree species and stem diameter were determined. All living trees with dbh > 0.30m were identified, measured and counted regardless of tree or shrub species. Tree species were identified as far as possible on site and those of unknown identity, parts of their leaves including the branches were pressed in newspapers for latter identification by a taxonomist at the herbarium, Department of Botany, University of Calabar.

Data analysis

Vegetation components obtained from the field were further analysed using the following formula:

Basal Area (BA) for each plot was calculated using the formula given by Cintron and Novelii (1984) as:

Basal area (BA) (m2) = 0.7857 x D2

Where D =Diameter at breast height (in meters)

Species Diversity Index for the slopes was calculated using Shannon-Wiener's Diversity Index given by Price (1997) as:

$$H1 = -\sum_{I=1}^{S} Pi \log_e Pi$$

Where: H1 = Shannon Diversity Index; S = Total number of species in each slopes; Pi = Proportion or relative abundance of individual species; loge = Natural logarithm.

Species Evenness (E) was calculated using Shannon's equitability (EH) as given by Adekunle and Olagoke (2008).

$$EH = \frac{H1}{Ln(S)}$$

Where H1= Shannon-Wiener's Diversity Index; S =Total number of species in each slope; Ln = Natural logarithm and EH = Species evenness.

The Importance value index (IVI) of every species and family was calculated using the equation given by Cintron and Novelii (1984) given as:

IVI = Relative density + Relative frequency + Relative dominance

$$Rd = \frac{\text{No of trees of a species}}{\text{Total No of all species}} \times 100$$

$$Rf = \frac{\text{No of points f occurrence of species}}{\text{Total occurrence of all species}} \times 100$$

$$RD = \frac{\text{BA of all trees/shrubs of species A}}{\text{Total BA of all species}} \times 100$$

Test of significance using One-Way analysis of variance (ANOVA) was employed for significant difference among selected tree growth variables such as basal area, tree species composition and family composition. The analysis was done using SPSS (17.0) for windows

Results and discussion

Species diversity, evenness and stand density

A total of 62 tree species (≥0.30m) belonging to 16 families were recorded along the catena. The number of tree species encountered varied significantly ($p<0.05$) along the catena (table 2). The Shannon-Wiener's indexes also vary along the catena with the lower slope being the highest (2.86); followed by the upper slope with index value of 2.62 then the middle slope of 2.53. This result corroborates those of Poulos and Camp (2010) when they reported high-diversity vegetation types at the valley bottoms, while hotter and drier mid-slopes and ridge tops supported lower tree diversity. They further argued that mountain ranges with high topographic complexity also had higher species richness, suggesting that geographical variability in environmental conditions was a major influence on tree diversity. The species evenness result was slightly similar in all the sections with the lower slope having the highest of 0.50, followed by the middle slope. This shows that the lower slope is more even, diverse and heterogeneous in species composition (Table 1). The stand density of tree species along the catena is depicted in table 1. The stand density varied significantly across the catena due mostly to changes in evaluation which influenced the rate of infiltration and the length of time a given section of the catena was flooded. Similar study by Hegazy *et al.* (1998) also reported variations in species richness, diversity and evenness among the different altitudinal belts. These variations were attributed to the climatic differences, substrate discontinuities and mountainous escarpment along the altitudinal gradient. The differences in stem density along the catena may be attributed to topographic settings, as differences in slope angles influence soil distribution, water availability and intensity of erosion. The same line, Lan *et al.*, (2011) in their study identified convexity and elevation as important topographic variables contributing to the distribution patterns of tree species richness along the catena.

Table 1. Summary of vegetation components obtained along the catena.

Variables	Slope sequence		
	Upper slope	Middle slope	Lower slope
Species composition	21	20	21
Number of trees/stand density	349	243	298
Average no of trees	16±12.2	11±11.2	14±18.4
Family composition	16	15	15
Mean dbh (m)	6.00	4.12	4.81
Shannon-Wiener's Diversity Index	2.62	2.53	2.86
Shannon Species evenness	0.45	0.46	0.50
Basal Area (m^2/ha)	46.27	21.85	29.70

However, because all sections of the caterna according to Aweto (1976) are influenced by a high water table, water living species like *Mitrigyna stipulosa, Musanga cecropioides, Alstonia boonei, Lophira alata,* and *Raphia hookeri* occurred in all the slopes but with high relative frequency in the lower slope. In similar way, Aweto and Iyamah (1993) reported that due to the closeness of ground water table to the surface, swamp-loving species, especially *Lophira alata Oxystigma mannii* and *Symphonia globulifera* occur in the upper, middle and lower slope units of the catena. *Lophira alata* and *Mitrigyna stipulosa* dominated the stand density across the catena with 7.6% and 7.3% respectively followed by *Alstonia boonei* with 3.3%. Nevertheless, in the lower slope, *Lophira alata, Mitrigyna stipulosa* and *Raphia hookeri* dominated the water loving tree species with 9.4%, 7.7% and 6.7% respectively (Table 4). The high stand density of *Elaeis guineensis, Anthocleista vogelii* and *Uapaca guineensis* across the catena with 7.4%, 6.3% and 5.3% respectively revealed the degrading effect of this rich forest ecosystem as a result of man's wanton destruction of vegetation for timber and fuelwood gathering. Thus, a number of tree species like *Khaya senegalensis, Terminalia* Spp, *Pycnanthus angolensis, Irvingia gabonensis* and *Baphia nitida* increased upslope as they were not adaptable to areas with high water table and associated water logging (Table 3); while water loving species such as *Raphia hookeri, Alstonia boonei* and *Lophira alata* increased down slope.

Table 2. One-Way ANOVA of some selected vegetation components along the catena.

Variables	Source of Variation	Sum of Squares	DF	Mean square	F-cal	F-tab
Basal Area	Between Samples	15.53	2	7.73	5.84*	3.15
	Within samples	75.85	57	1.33		
	Total	91.38	59			
Trees/stand density	Between Samples	281.03	2	140.52	23.26*	3.15
	Within samples	344.47	57	6.04		
	Total	625.50	59			
Mean dbh of trees	Between Samples	0.09	2	0.05	5.20*	3.15
	Within samples	14.68	57	0.26		
	Total	14.77	59			

*Difference between means is significant at 5% alpha level

Table 3. Density of tree species encountered along the Catena.

Species	Upper slope	Middle slope	Lower slope
Raphia hookeri	0	6	20
Elaeis guineensis	16	18	32
Anthoclesta vogelii	18	9	31
Lophira alata	19	21	28
Anthocleista djatonensis	21	10	22
Mitrigyna stipulosa	26	16	23
Musanga cecropioides	10	6	16
Khaya senegalensis	19	11	0
Melicia excelsa	16	4	6
Irvingia gabonensis	22	9	4
Terminelia superba	23	12	19
Nauclae diderrichi	6	10	5
Baphia nitida	10	11	4
Terminelia ivorensis	19	0	10
Pycnanthus angolensis	20	11	7
Poga oleosa	15	16	6
Diospyros elliotic	13	0	8
Brachystegia eurycoma	12	10	3
Astonia boonei	4	8	17
Ficus exasperata	24	20	19
Uapaca guineensis	22	17	8
Celtis zenkeri	14	18	10
Total	349	243	298

Forest structure

The structure of the vegetation was not uniform along the catena, as there was substantial difference in basal area across the catena (Table 2) with the upper slope showing more growth index in basal area of 46.27m2/ha, followed by the lower slope with 29.7m2/ha, then the middle slope with 21.85m2/ha (Table 1). This variation in basal area was because, the upper slope was well drained and suffered less from topographic influence compared to the middle slope. Also, it could be attributed to the more relatively favourable climatic condition (as it suffers less from erosion intensity) compared to the middle slope; and it is not flooded as in the lower slope). This result is contrary to earlier findings like those of Aweto and Iyamah (1993) when they observed that there were no marked variations in vegetation structure along the catena, except near the river bank where trees are shorter, and tree density lower. Whereas, Pickering and Green (2009) in their study of vascular plant distribution in relation to topography observed differences among summits in species composition/abundance

An average of 15 stems/ha was obtained across the catena. The upper slope has the highest tree density of 349, and an average of 16±12.2, followed by the lower slope with 298 tree density with an average of 14±18.4, while the middle slope recorded the least of 243 with an average of 11±11.2 (Table 2 and 3). There was however, significant difference in the number of trees encountered per hectare across all sections of the catena. This study recorded more tree stands or density in the upper slope than the lower slope reported by Lawson *et al.* (1968). In addition, tree density was lower in the middle slope and higher in the lower slope (Table 3). This difference may be attributed to the less erosive nature of the lower/bottom slope. Similar, a study by Aweto (1976) though in a swampy forest, recorded a low tree density in the lower slope and attributed it to the prolonged effects of water logging which could have affected plant growth and immunity status.

Dominance of tree species

Dominance which is usually estimated *as the importance value index (IVI) (Adams et* al., 2007) varied across the catena. In the upper slope, Khaya *senegalensis* was the ecologically dominant species in the 0.04 hectare plot (Table 4a). It had the highest relative frequency of 8.1%, relative density of 5.4% and relative dominance of 7.8%. The second ranked ecologically dominant species was *Terminelia superba* with relative density of 6.6%, relative frequency of 7.1% and relative dominance of 6.8%. The third ecologically dominant tree species was *Melicia excelsa* with relative density of 4.6%, relative frequency of 7.6% and relative dominance of 7.3%. This however shows a wide range of growth and adaptability of these tree species throughout the upper slope. In the middle slope, the most ecologically dominant species was *Elaeis guineensis* with relative density of 7.4%, relative frequency and density of 8.0% respectively. The dominance of *Elaeis guineensis* represents a degrading forest. The second ranked tree species was *Ficus exasperata* with relative density of 8.2%, relative frequency of 8.7% and relative dominance of 5.5%. The third ranked tree species was *Uapaca guineensis* with relative density of 7.0%, relative frequency of 6.5% and relative dominance of 6.1%.

Table 4a. Ecological-dominance ranking of the 21 woody species (n=349) within the 0.04 hectare catena in the upper slope.

Rank	Species	No of stems	Rel. Dens (%)	Rel. Freq. (%)	Rel. Dom (%)	IVI
1	*Khaya senegalensis*	19	5.4	8.1	7.8	21.3
2.	*Terminelia superba*	23	6.3	7.1	6.8	20.5
3	*Melicia excelsa*	16	4.6	7.6	7.3	19.5
4	*Ficus exasperata*	24	6.9	7.1	5.4	1.4
5	*Pychanthus angolensis*	20	5.7	6.1	6.8	18.6
6	*Uapaca guineensis*	22	6.3	5.6	6.3	18.2
7	*Irvingia gabonensis*	22	6.3	6.6	4.9	17.8
8	*Terminelia ivorensis*	19	5.4	5.6	5.9	16.9
9	*Diospyros elliotii*	13	3.7	5.1	7.8	16.6
10	*Mitrigyna stipulosa*	26	7.4	4.5	2.9	14.8
11	*Elaeis guineensis*	16	7.4	4.5	4.4	13.5
12	*Poga Oleosa*	15	4.6	4.5	3.9	12.7
13	*Anthocleista djatonensis*	21	4.3	4.5	2.0	12.5
14	*Lophira alata*	19	6.0	5.1	1.5	12.0
15	*Anthocleista vogelii*	18	5.4	4.0	2.4	11.6
16	*Celtis zenkeri*	14	5.2	3.0	3.9	10.9
17	*Brachystegia eurycoma*	12	4.0	3.5	3.4	10.3
18	*Baphia nitida*	10	3.4	1.5	5.4	9.8
19	*Astonia boonei*	4	1.1	1.5	6.3	8.9
20	*Musanga cecropioides*	10	2.9	2.5	2.0	7.4
21	*Nauclea diderrichi*	6	1.7	2.0	2.9	6.6
	Total	**349**	**100**	**100**	**100**	**300**

These three dominant tree species are adaptable to the harsh climatic condition of the middle slope (Table 4b). While in the lower slope, the ecologically dominant tree species was *Anthocleista vogelii* with relative density of 10.4%, relative frequency of 11.1% and relative dominance of 8.0%. The second ecologically dominant species was *Elaeis guineensis* with relative density of 10.7%, relative frequency of 7.6% and relative dominance of 10.3%. This was followed by Raphia hookeri with relative density of 6.7%, relative frequency of 9.7% and relative dominance of 6.9%. These dominate tree species are water loving plants and can conveniently adapt to water logged area (Table 4c).

However, across the catena, the most ecologically dominant species was *Elaeis guineensis* with relative density of 7.4%, relative frequency of 6.5% and relative dominance of 7.4%. The second ranked dominant species was *Terminelia superba* with relative density of 6.1% relative frequency of 7.1%and relative dominance 6.8%; while the third most dominant species was *Ficus exasperate* with relative density of 7.1%, relative frequency of 7.1% and relative dominance of 5.0%. The presence in large quantities of these tree species across the catena reveals a high floristic overlap in the forest vegetation (Table 4d).

Table 4b. Ecological-Dominance Ranking of the 20 Woody Species (n=243) within the 0.04 Hectare Catena in the Middle Slope.

Rank	Species	No of stand	Rel. Dens (%)	Rel. Freq. (%)	Rel. Dom (%)	IVI
1	*Elaeis guineensis*	18	7.4	8.0	8.0	23.4
2.	*Ficus exasperata*	20	8.2	8.7	5.5	22.4
3	*Uapaca guinensis*	17	7.0	6.5	6.1	19.6
4	*Lophira alata*	21	8.6	5.8	4.9	19.3
5	*Nauclea diderrichi*	10	4.1	6.5	8.6	19.2
6	*Celtis zenkeri*	18	7.4	5.1	5.5	18.0
7	*Poga Oleosa*	16	6.6	3.6	7.4	17.6
8	*Terminelia superba*	12	4.9	5.8	6.7	17.4
9	*Khaya senegalensis*	11	4.5	5.8	6.1	16.4
10	*Mitrigyna stipulosa*	16	6.6	7.2	1.2	15.0
11	*Pycnanthus angolensis*	11	4.5	4.3	5.5	14.3
12	*Baphia nitida*	11	4.5	3.6	6.1	14.2
13	*Astonia boonei*	8	3.3	4.3	6.1	13.7
14	*Brachystegia eurycoma*	10	4.1	5.1	3.1	12.3
15	*Irvingia gabonesis*	9	3.7	2.9	4.9	11.5
16	*Anthocleista vogelii*	9	3.7	4.3	2.5	10.5
17	*Anthocleista djatoensis*	10	4.1	3.6	2.5	10.2
18	*Melicia excelsa*	4	1.6	2.9	5.5	10.0
19	*Raphia hookeri*	6	2.5	2.9	3.1	8.5
20	Musanga cecropioides	6	2.5	2.9	0.6	6.0
	Total	**243**	**100**	**100**	**100**	**300**

Table 4c. Ecological-dominance ranking of the 21 woody species (n=298) within the 0.04 hectare catena in the lower slope.

Rank	Species	No of stems	Rel. Dens (%)	Rel. Freq. (%)	Rel. Dom. (%)	IVI
1	*Anthocleista vogelii*	31	10.4	11.1	8.0	29.5
2.	*Elaeis guineensis*	32	10.7	7.6	10.3	28.6
3	*Raphia hookeri*	20	6.7	9.7	6.9	23.3
4	*Lophira alata*	28	9.4	6.9	5.7	22.0
5	*Terminelia superba*	19	6.4	6.3	6.9	21.6
6	*Astonia boonei*	17	5.7	6.3	8.6	20.6
7	*Anthocleista djtonensis*	22	7.4	6.3	2.9	16.6
8	*Ficus exasperate*	19	6.4	5.6	4.0	16.0
9	*Mitrigyna Stipulosa*	23	7.7	5.6	2.3	15.6
10	*Diospyros elliotii*	8	2.7	4.2	6.9	13.8
11	*Musanga cecropioides*	16	5.4	4.9	3.4	13.7
12	*Khaya senegalensis*	6	2.0	4.2	6.3	12.5
13	*Terminelia ivorensis*	10	3.4	2.8	5.1	11.3
14	*Celtis zenkeri*	10	3.4	2.8	4.6	10.8
15	*Uapaca guineensis*	8	2.7	3.5	3.4	9.6
16	*Pycnanthus angolensis*	7	2.3	2.1	4.0	8.4
17	*Baphia nitida*	4	1.3	1.4	4.0	6.7
18	*Irvingia gabonensis*	4	1.3	2.8	2.3	6.4
19	*Nauclea diderrichi*	5	1.7	2.1	2.3	6.1
20	*Poga Oleosa*	6	2.0	1.4	1.7	5.1
21	*Brachystehia eurycoma*	3	1.0	0.7	0.6	2.3
	Total	**298**	**100**	**100**	**100**	**300**

Table 4d. Ecological-dominance ranking of 22 woody species (n=890) across the catena.

Rank	Species	No of stems	Rel. Dens (%)	Rel. Freq. (%)	Rel. Dom. (%)	IVI
1	*Elaeis guineensis*	66	7.4	6.5	7.4	21.3
2.	*Terminelia superba*	54	6.1	7.1	6.8	20.0
3	*Ficus exaperata*	63	7.1	7.1	5.0	19.2
4	*Lophira alata*	68	7.6	5.8	3.9	17.3
5	*Anthocleista vogelii*	58	6.5	6.3	3.5	16.3
6	*Uapaca guineensis*	47	5.3	5.2	5.3	15.8
7	*Melicia excelsa*	26	2.9	5.2	6.4	14.5
8	*Mitrigyna stipulosa*	65	7.3	5.6	1.5	14.4
9	*Pycnanthus angolensis*	38	4.3	4.4	5.5	14.2
10	*Astonia boonei*	29	3.3	3.8	7.0	14.1
11	*Khaya senegalensis*	30	3.4	5.0	4.8	13.2
12	*Celtis zenkeri*	42	4.7	3.5	4.6	12.8
13	*Anthocleista djatonensis*	53	6.0	4.8	1.7	12.5
14	*Irvinga gabonensis*	35	3.9	4.4	4.1	12.4
15	*Poga Oleosa*	37	4.2	3.3	4.2	11.7
16	*Diospyros elliotii*	21	2.4	3.3	5.2	10.9
17	*Terminelia ivorensis*	29	3.3	3.1	3.9	10.3
18	*Nauelea diderrichi*	21	2.4	3.3	4.4	10.1
19	*Baphia nitida*	25	2.8	2.1	5.2	10.1
20	*Raphia hookeri*	26	2.9	3.8	3.1	9.8
21	*Musanga cecropioides*	32	3.6	3.3	1.6	8.5
22	*Brachystegia eurycoma*	25	2.8	3.1	2.4	8.3
	Total	**890**	**100**	**100**	**100**	**300**

Family composition and dominance

A total of 16 families were encountered (Table 5b). Moraceae with 121 stands (13.6%) dominated the forest canopy of the catena; it was followed by Loganiaceae with 111 stands (12.5%), Palmae with 92 stands (10.3%) and Rubiaceae with 86 stands (9.7%). The least encountered families were Apocynaceae with 29 stands (3.3%), followed closely by Caesalpinaceae and Papilionoidae with 25 stands each (2.5%), then Ebenaceae with 21 stands (2.4%). However, the most ecologically dominant families across the catena were Moraceae with relative density of 13.6%., relative frequency of 15.6% and relative dominance of 13.4%. The second ranked family was Palmae with relative density of 10.3%, relative frequency of 10.2% and relative dominance of 10.5% while the third ecologically dominant family was Combretaceae with relative density of 9.3%, relative frequency of 10.2% and relative dominance of 10.7%. These families dominated the catena's forest canopy with closed canopy structure, as they were able to adapt to the varying site conditions along the catena (Table 5b).

Stem diameter distribution and density

Tree density across the catena consistently decreased with increasing stem diameters size from 1.51m – 3.50m across the catena. The decrease in stems with increasing tree size or girth classes due to various reasons has been emphasized by earlier studies of Reddy *et al.*, (2008); Attua (2003). Tree density however increased at stem diameter size of 0.00m – 1.50m. The lower diameter class (0.00 - 1.50m) captured 39.6% of the total catena's forest stand density, while the highest diameter size class (3.01 – 3.50m) captured 4.1% of the catena's forest vegetation (Table 5c). However, mean dbh of trees across the catena differed significantly, with the upper slope recording the highest dbh of 6.00 m/ha, followed by the lower slope then the middle slope with dbh values of 4.81m/ha and 4.12m/ha respectively (Table 1).

Table 5a. Family composition of tree species encountered along the catena.

Family	Upper slope	Middle slop	Lower slope
Anacardiaceae			
- *Irvingia gabonensis*	22	9	4
Apocynaceae			
- *Astonia boonei*	4	8	17
Caesalpinaceae			
- *Brachystegia eurycoma*	12	10	3
Combretaceae			
- *Terminelia superba*	23	12	19
- *Terminelia ivorensis*	19	0	10
Ebenaceae			
- *Diospyros elliotic*	13	0	8
Euphorbiaceae			
- *Uapaca guineensis*	22	17	8
Logeniaceae			
- *Anthocleista vogelii*	18	9	31
- *Anthocleista djatonensis*	21	10	22
Meliaceae			
- *Khaya senegalensis*	19	11	0
Moraceae			
Musanga cecropioides	10	6	16
Melicia excelsa	16	4	6
Ficus exasperate	24	20	19
Myristicaceae			
- *Pycnanthus angolensis*	20	11	7
Ochnaceae			
- *Lophira alata*	19	21	28
Palmae			
Raphia hookeri	0	6	20
Elaeis guineensis	16	18	32
Papilionoidae			
- *Baphia nitida*	10	11	4
Rhizophoraceae			
- *Poga Oleosa*	15	16	6
Rubiaceae			
Nauclea diderrichi	6	10	5
Mitrigyna stipulosa	26	16	25
Ulmaceae			
- *Celtis zenkeri*	14	18	10
Total	**349**	**243**	**298**

Table 5b. Ecological-dominance ranking of woody families (n=16) across the catena.

Rank	Species	No of stems	Rel. Dens (%)	Rel. Freq. (%)	Rel. Dom. (%)	IVI
1	Moraceae	121	13.6	15.6	13.4	42.6
2.	Palmae	92	10.3	10.2	10.5	31.0
3	Combretaceae	83	9.3	10.2	10.7	30.2
4	Rubiaceae	86	9.7	9.0	6.6	25.3
5	Loganiaceae	111	12.5	6.0	6.6	25.1
6	Ochnaceae	68	7.6	5.8	3.9	17.3
7	Euphorbiaceae	47	5.3	5.2	5.3	15.8
8	Myristicaceae	38	4.3	4.4	5.5	14.2
9	Apocynaceae	29	3.3	3.8	7.0	14.1
10	Meliaceae	30	3.4	5.0	4.8	13.2
11	Ulmaceae	42	4.7	3.5	4.6	12.8
12	Anacardiaceae	35	3.9	4.4	4.1	12.4
13	Rhizophoraceae	37	4.2	3.3	4.2	11.7
14	Ebenaceae	21	2.4	3.3	5.2	10.9
15	Papilionoidae	25	2.8	2.1	5.2	10.1
16	Caesalpiriaceae	25	2.8	3.1	2.4	8.3
	Total	**890**	**100**	**100**	**100**	**295**

Table 5c. Stem diameter distribution and density across the catena.

Diameter classes (m)	Upper slope	Middle slope	Lower slope
0.00 – 1.50	33	30	23
1.51 – 2.00	31	23	25
2.01 – 2.50	9	5	7
2.51 – 3.00	8	4	10
3.01 -3.50	2	2	5
Total	**83**	**64**	**70**

Conclusion

Changes in elevation along the catena evidently influence the variation in tree density. Tree species density such as those of *Khaya senegalensis, Terminelia spp, Pycnanthus angolensis, irvingia gabonensis* and *Baphia nitida* increased upslope while water loving tree species like *Raphia hookeri, Alstonia boonei,* and *Lophira alata* increased down slope. Also, the density of trees decreased with increasing stem diameter in all sections of the catena; across the catena. In similar manner, the number of trees encountered varied significantly, with the upper slope recording more stand density than other sections of the catena due principally to topographic positions. *Elaeis guineensis, Terminelia superba* and *Ficus exasperate* were the most ecologically dominant tree species. This is because these tree species are able to adapt to varying site conditions along the catena like topographic positions, climatic conditions (erosion and flooding) as well as elevation and water. The catena's forest canopy is completely dominated by the families of Moraceae, Palmae and Combretaceae. The presence of high species diversity and richness across different sections of the catena indicates the uniqueness and potentiality of the Obung catena for conservation of it unique biodiversity in totality, mostly in the face of climate change. The problem of recurrent forest disturbance as a result of illegal logging activities and felling of trees for fuel wood has been observed and should be checked to conserve this species-rich ecosystem of Obung's forest.

References

Adam JH, Mahmud AM, Muslim NE. 2007. Cluster Analysis on Floristic Composition and Forest Structure of Hilly Lowland Forest in Lok Kawi, Sabah State of Malaysia. International J. of Botany **3 (4),** 351 – 358.

Adekunle VAJ, Olagoke AO. 2008. Diversity and Biovolume of Tree Species in Natural Forest Ecosystem in the Bitumen-Producing Area of Ondo State, Nigeria: A baseline Study. Biodiversity Conservation, 17 (11), 2735–2755.

Attua EM. 2003. Land Cover Change Impacts on the Abundance and Composition of Flora in the Densu Basin. West Africa Journal of Applied Ecology **4,** 27 – 34

Aweto AO. 1976. Changes in Soil Characteristics Associated with Secondary Sucession in A Part of the Forest Zone of South-Western Nigeria. Postgraduate Students/Staff seminar, Dept. of Geography – University of Ibadan.

Aweto AO, Enaruvbe GO. 2010. Catenary Variation of Soil Properties under Oil Palm Plantation in South Western Nigeria. Ethiopian Journal of Environmental Studies and Management **3 (1),** 1 – 7

Aweto AO, Iyamah CC. 1993. Catenary Variation of Vegetation in a Swamp Forest in South-Western Nigeria. International Journal of Environmental Studies **43 (2-3),** 133 – 140.

Ben-Shahar R. 1990. Soil Nutrients Distribution and Moisture Dynamics on Upper Catena in a Semi-Arid Nature Reserve. http://www.jstor.org/stable/20038663.

Cintron G, Novelii YS. 1984. Methods for Studying Mangrove Structure in S. Snedakar and J.S. Snedakar (eds) The Mangrove Ecosystem Research Methods. UNESCO, United Kingdom. P. 91 – 114.

David W. 2000. Geography: An Integrated Approach. United Kingdom: Nelson Publishers.

Enoki T, Kawaguchi H, Iwatsubo G. 1996. Topographic Variations of Soil Properties and Stand Structure in a *Pinus thunbergii* Plantation. Ecological Research **11,** 229- 309.

Furley PA, Newey WW. 1979. Variations in Plant Communities with Topography over Tropical Limestone Soils. Journal of Biogeography **6,** 1-15.

Hegazy K, El-Demerdash MA, Hosni HA. 1998. Vegetation, Species Diversity and Floristic Relations along an Altitudinal Gradient in South-West Saudi Arabia. Journal of Arid Environments **38,** 3–13.

Lan G, Hu Y, Cao M, Zhu H. 2011. Topography related Spatial Distribution of Dominant Tree Species in a Tropical Seasonal Rainforest in China. Forest Ecology and Management **262,** 1507–1513.

Lopez IF, Lambert MG, Mackay AD, Valentine I. 2003. The Influence of Topography and Pasture Management on Soil Characteristics and Herbage Accumulation in a Hill Pasture in the North Island of New Zealand. Plant and Soil **255,** 421-434.

Pickering CM, Green K. 2009. Vascular Plant Distribution in Relation to Topography, Soils and Micro-climate at five Gloria Sites in the Snowy Mountains, Australia.Australian Journal of Botany **57(3),** 189–199

Poulos HM, Camp AE. 2010. Topographic Influences on Vegetation Mosaics and Tree Diversity in the Chihuahuan Desert Borderlands. Ecology **91(4),** 1140-51.

Price PW. 1997. Insect Ecology (Third Edition). New York: John Wiley and Sons Inc.

Reddy S, Babar S, Giriraj A, Reddy KN, Thulsi-Rao K. 2008. Structure and Floristic Composition of Tree Diversity in Tropical Dry Deciduous Forest of Eastern Ghats, Southern Andhra Pradesh, India. Asian J. of Scientific Research **1(1),** 57 – 64.

Signell SA, Abrams MD. 2007. Interactions between Landscape Features, Disturbance and Vegetation in Frequently Burned Appalachian Oak Forests in Nole C. Verne (ed) Forest Ecology Research. Nova Science Publishers, Inc. p. 147-166.

Tamartash R, Yousefian M, Tatian MZ, Ehsani M. 2010. Vegetation Analysis in Rangelands of Lasem, Iran. American-Eurasian J. Agric. & Environ. Sci. **7(4),** 397-401.

Wong M. 1974. Vegetation Pattern related to the Edaphic and Biotic Variables on Waldridge Fell, County Durham, UK. Department of Biology, New Asia College. The Chinese University of Hong Kong, Shatin, N.T., Hong Kong. p. 437 – 438.

Yimer F, Ledin S, Abdelkadir A. 2006. Soil Property Variations in Relation to Topographic Aspect and Vegetation Community in the South-Eastern Highlands of Ethiopia. Forest Ecology and Management **232(1-3),** 90-99.