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Species Composition and Structure of Habitats Exploited by Elephants (*Loxodonta Africana Cyclotis*) in the Campo Maan Forest, South Region, Cameroon

Ayemeley Betrand Ayuk[1*], Nkwatoh Athanasius Fuashi[1], Melle Ekane Maurice[2], Kamah Pascal Bumtu[2]

[1]Department of Environmental Science, Faculty of Sciences, University of Buea, Cameroon.

[2]Department of Forestry and Wildlife, Faculty of Agriculture and Veterinary Medicine, University of Buea, Cameroon.

[*]Corresponding Author Email: ayembeto@yahoo.com

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Abstract

Purpose: The main objective of this study was to determine the species composition and structure of habitats exploited by elephants in the Campo Maan Forest.

Methodology: Using the transect methods, purposively, 1km transects were laid along identified feeding tracts in various habitats. 15 transects with each having 4 quadrates of 30x30m were established at interval of 220m summing up to a total of 5.4 hectares of land covered for the study within which data was collected. In the quadrates, all vascular plants with dbh ≥10cm (diameter at breast height about 1.3m above the ground) were measured and identified. In each quadrate, four subplots of 15mx15m were placed at the corners to sample understory and herbs.

Findings: Results reveal a total of 1113 individual trees with DBH of ≥ 10 cm identified and measured belong to 49 species from 24 families. Fabaceae was the most dominant family of plants with 425 individual trees counted with Caesalpinioideae being the dominant specie type (116); followed by *Calpocalyx heitzii* (92). Lowland evergreen forest (Casalpinioideae) recorded the highest number of tree species counted (462, 41.5%) of the total tree species. Trees DBH varies between 10 and 64 cm with mean values of 29.45±11.48 cm, 23.3±7.759 cm, 27.69±9.189 cm and 25.75±14.056 cm for Lowland evergreen forest (Casalpinioideae), Lowland evergreen forest (mixed), Coastal forest (Sacoglotis gabonensis) and Coastal forest (mixed) respectively. A large number of trees recorded heights of above 30m though it was higher for Lowland evergreen forest (mixed), Coastal forest (Sacoglotis gabonensis) and the Coastal forest (mixed). For the understory, the dominant specie types are Scaphopetalum blackii, Palisota ambigua, Asystasia macrophylla, Podococcus barteri, Microdesmis puberula, Heistera pavifora, Haumania danckelmaniana, Alchornea floribunda all counting 9 and 10 individual Trees). Results revealed highly positive and significant correlations between trees DBH and height ($r=0.84$, $p=0.000$). The Shannon's diversity index indicates that the tree diversity for all habitats are fairly even with Coastal forest (Sacoglotis gabonensis) having a value of 4.73. The Coastal forest (mixed) shows the highest rate of basal area (76.39); followed by Coastal forest (Sacoglotis gabonensis) (41.50) and Lowland evergreen forest (Casalpinioideae) (32.26), all indicating high basal areas.

Recommendation: Further studies on habitat fragmentation are needed to assess its effects on elephant movement within the area.

Keywords: *Specie composition, habitat structure, elephants, campo maan, Cameroon*

1.0 INTRODUCTION

There is great variation in the; structure, species composition and diversity in the world ecological setup. Globally, Forests covers 31 percent of the total land area which are unequally distributed around the globe with total forest area of 4.06 billion (FAO, 2020). Ecological diversity is the degree at which life forms varies within the context of a particular ecosystem, biome, or entire planet (Uno *et al.,* 2001). Rawat and Agarwal (2015) defined biodiversity as the variety of different forms of life on earth, including the different plants, animals, micro-organisms, the genes they contain and the ecosystem they form. The variation in the different ecological, geographic and geological zones of the world supports various types of floristic composition.

Studies of the main tropical forest ecosystems have shown that African rainforests have relatively poor diversity compared to the highest diversity regions of Asia and the Americas (Parmentier *et al.,* 2007). However, based on this overall pattern of diversity, current understanding of the local scale community-assembly mechanisms for tropical African tree communities is very limited and complicated by previous sampling designs. Most inventories focus on large trees with diameter at breast height (dbh) from 10 cm (Hall et al., 2004, Hardy and Sonke, 2004) and in some cases only include selected taxa (Hall *et al.,* 2004). These small plots limit the identification of habitats at scales that could provide meaningful inferences on plant populations. It also precludes comparisons of degrees of habitat specificity with other tropical forests thus having the misconception of poor diversity of the African rainforest.

Besides other African countries, Cameroon is one of the most diverse countries in terms of plants, with over 7,850 plant species (Onana, 2011). From these species, 815 species are endangered (Onana and Cheek, 2011). The Cameroon heterogeneous landscape presents different vegetation types among which are the Biafran forest with high rainfall, the Congolese forest, and the semi-deciduous forest with low rainfall (Letouzey, 1985). Thus, Cameroon encompasses an intricate mosaic of diverse habitats with moist tropical forest dominating the south and south-east and covering 54% of the country, mountain forest and savannah in the highlands and sub-Sahelian savannah and near desert in the far north (Sunderland *et al.,* 2003). The vegetation of Cameroon ranges from lowland evergreen rainforest, semideciduous, deciduous, savannah woodland, and savannah grassland forest, at different altitudinal gradient of lowland to sub-montane, alpine and montane forest (Letouzey, 1985; Achoundong, 2007). Similar studies equally confirmed the high diversity of endemism of plant species, as found in the 50ha plot in central Korup National Park, with close to 500 tree species (Thomas *et al.,* 2003) and over 250 liana species. Most of this high diversity is usually preserved in protected areas through gazettement. Though the flora is highly studied, new species are recorded every year (Lachenaud *et al.,* 2013). Following these features, the forest of the cross-border region of Cameroon and Nigeria are highly diverse with a high degree of endemism (Davis *et al.,* 1994). Further studies conducted by Barthlott *et al.,* (1996) ranked Cameroon among the top countries in tropical Africa for plant species diversity per degree square. Most of this high diversity is usually preserved in protected areas where many elephants forage. Though the flora is highly studied, new species are recorded every year (Lachenaud *et al.,* 2013).

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Biodiversity assessment is recognized globally as a fundamental activity to sustainable biodiversity conservation, management and planning (Humphries *et al.,* 2003; Margules & Pressey 2000; Williams *et al.,* 1993). This makes available data necessary to understand species diversity and distribution within ecosystems. However, its application is often neglected particularly in tropical countries, including Cameroon, where a substantial fraction of the world's unique species are found (Gordon & Newton, 2006). Limitations on technical and financial capacity, presence of aggravating threats, and scarcity of information in biologically– rich countries have placed the conservation efforts to languish (Gordon & Newton, 2006).The study aims at examining species composition and structure of habitats exploited by elephants in the Campo Maan Forest.

2.0 MATERIAL AND METHODS

2.1 Location of the Study Area

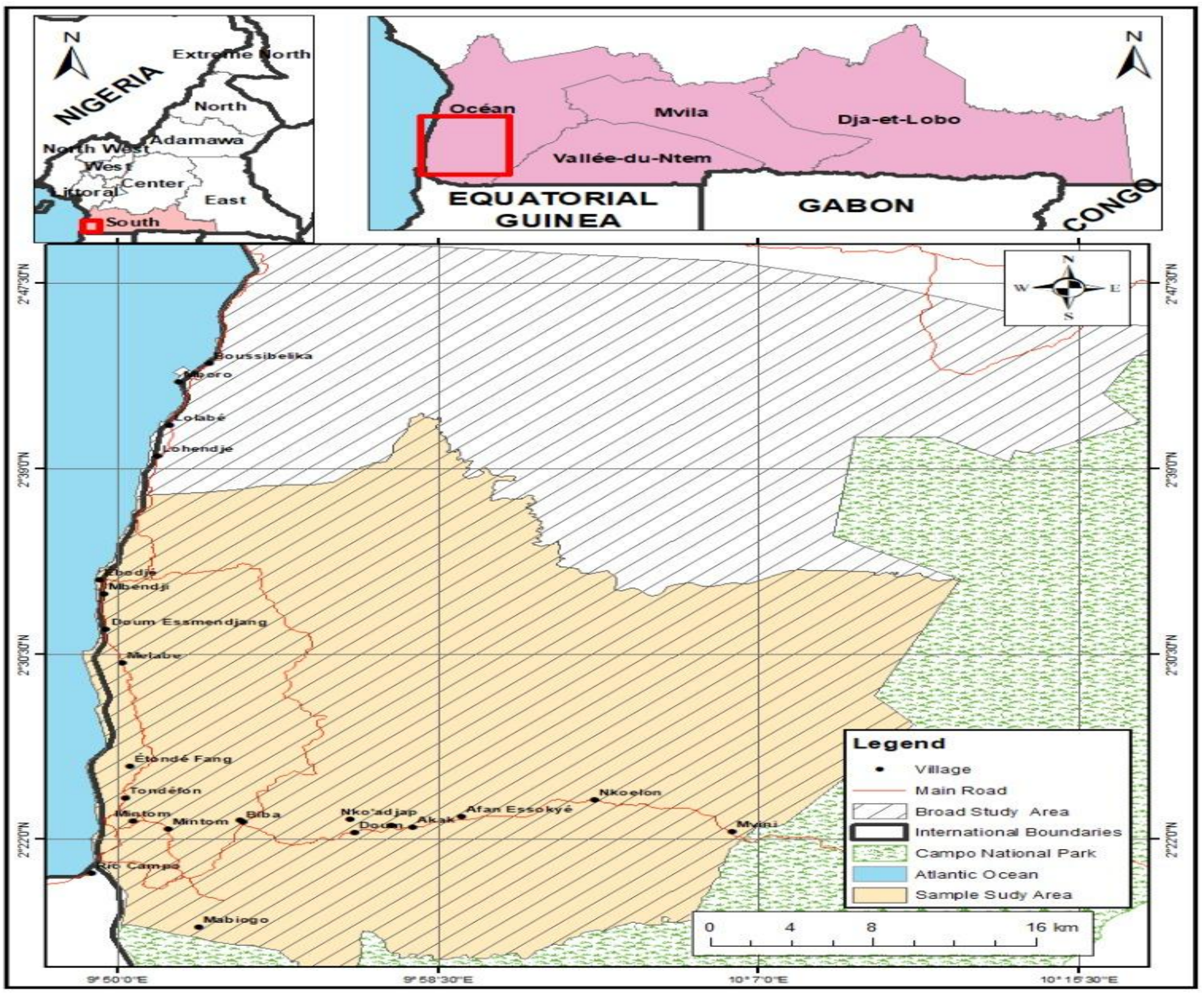

Figure 1: Study area map

Source: Adopted from US Geological survey (UGS)

The CMNP adjacent forest has been divided into three broad zones which includes; the Forest Management Unit (FMU 09-21) covering 3,6476 hectares, the FMU 09-24 covering 74,762 hectares and the FMU 09-25 covering 88,215 hectares (MINFOF, 2015). From reconnaissance survey, the FMU 09-25 found in the Western section of the park has the second largest number of elephants within the Technical Operation Unit (TOU) of the Campo Ma'an national park (MINFOF, 2015). Some of the fauna diversity in the FMU 09-25 forest zone includes: the African elephant (*Loxodonta africana cyclotis*), the lowland gorilla (*Gorilla gorilla*), the chimpanzee (*Pan Troglodytes*), the buffalo (*Synerus caffernanus*), the panther (*Panther apardus*), and the mandrill (*Madrillus sphinx*). Following the Food and Agricultural Organization (FAO) classification system, soils in this area are generally classified as Ferrasols and Acriso. It also has a tropical equatorial climate with two distinct dry seasons and two wet seasons.

2.2 Data Collection

Data collection on the flora took place in two different phases; December 2019 to February 2020 for the dry season and July to September 2021 for the wet season**.** Pilot survey was conducted wherein we first interviewed wildlife guards, foresters and local committees working for the conservation and the management of the Campo Maan National Park to get the exact location of the habitats where elephants occur at different periods of the year. We then conducted a quick field control on the indicated habitats and proceeded on the selection of the research sites. The identification of trees and grasses were done in the field using various methods. The trees were identified using a combination of standard botanical characters such as the general form of the tree (buttresses, roots systems, bark texture; slash colour, smell and exudates, leaf type and shape) as well as the flowers, and fruits of the trees. The dbh of all trees were measured using the dbh metal tape. The heights of trees were measured using the hypsometer (Vitax) and also by using expert estimation. Manuals, field books, text books all on plants were used to help in the identification of all plants/trees where plants species consumed by elephants were sorted. The identification of these plants was from literature, hunters and from feeding signs of the elephants. The Geographic coordinates of each plot or specimen was recorded with the help of the Global positioning system (GPS). We used the recommended GPS (Global-Positioning-System) Garmin 60CSx, which is very accurate in the forest, inexpensive and works adequately under forest canopy Condit (2008).

2.2.1 Sample size

Since data collection was to provide a general idea of the flora in habitats exploited by elephants, a purposive sampling technique was used where only habitats exploited by elephants were measured. In these habitats, a total of fifteen transects were laid in specific areas known to be exploited by elephants. An average distance of 1.1km separates one feeding tract from another from calculations within sampled habitats, hence purposively, 1km transects were laid along identified feeding tracts in various habitats as described by Tchouto (1999, 2004), and Buckland *et al.* (2007). In each transect, four (04) quadrates of 30x30m were established at interval of 220m. The 30x30m was adopted taking into account the minimum area covered by a herd of elephants foraging in a given habitat (Lackmann, 2011). The quadrates along transects were placed in alternate or zigzag manner (ie, if quadrate one is on the left of the transect, quadrate two is placed at the right). A total of sixty (60) 30x30m quadrates on fifteen (15) transects were sampled giving a total of 5.4 hectares of land covered.

In the quadrates, all vascular plants with dbh $\geq$10cm (diameter at breast height about 1.3m above the ground) were measured and identified. In each quadrate, four subplots of 15mx15m were placed at the corners to sample understory and herbs (Oosting, 1956; Condit, 2008). For unknown species, a voucher specimen was collected and a data sheet was filled out describing it vegetative or botanical characteristics (Tchouto, 2004). These transects cut across four major vegetation types (lowland evergreen forest rich in *Casalpinioideae*, lowland evergreen forest rich in *Casalpinioideae* with *Calpocalyx heitzii* and *Sacolglottis gabonensis*; coastal forest rich in *Sacoglotis gabonensis* and coastal forest rich in *Sacoglottis gabonensis* and *Calpocalyx hetzii*).

2.2.2 Data analysis

The analysis was done with respect to specific objectives of the study.

Species Composition

Diversity of plants

The Shannon's Diversity Index (H', in bits) is computed using the following formula:

$$H' = -\sum_{i=1}^{S} pi \log_2 pi$$

Where H = total number of species in the community (species richness); Pi = abundance of the ith species expressed as a proportion of total number of trees inventoried in a given vegetation type (habitat). Values of the index usually lie between 1.5 and 3.5, although in exceptional cases, the value can exceed 4.5 (very high diversity).

Dominant species

The Simpson's dominance index (D') was calculated as follows:

$$D' = \sum_{i-1}^{S} pi^2$$

Where pi is the relative abundance based on number of individuals per species. D ranges from 0 to 1 in case of complete dominance.

Evenness index

The Evenness index of Smith and Wilson (Evar) were used as a measure of equitability (Smith & Wilson, 1996; Biaou, 2009). It is independent from species richness and has equal sensitivity to rare and abundant species. Evar ranges from 0 to 1, with 1 indicating equal abundance of all species and values close to 0 indicating dominance of one or few species.

Habitat Structure

Tree density

The tree-density of the stands (N), i.e. the average number of trees per plot was computed in trees/ha as $N = \frac{n}{s}$

Where n is the overall number of trees in the plot, and s the area (s = 0.283 ha).

Basal area of stands

The basal area of the stand (G), i.e. the sum of the cross-sectional area at 1.3 m above the ground level of all trees in a plot, expressed in m2/ha: G = $G = \frac{\pi}{40000S} \sum_{i-1}^{n} di^2$

di is the DBH (in cm) of the i-th tree of the plot; s = 0.283 ha.

Mean diameter

The mean diameter of the trees (D, in cm), i.e. the diameter of the tree with the mean basal area in the stand:

$$D = \sqrt{\frac{1}{n}\sum_1^n di^2}$$

Where n is the number of trees recorded in the plot, and di the diameter of the i^{th} tree in cm.

Mean height

The Lorey's mean height (H, in meters), i.e. the average height of all trees found in the plot, weighted by their basal area (Philip, 2002), will be computed as follows:

$$H = \frac{\sum_1^n gihi}{\sum_1^n gi} \quad \text{with } g_i = \frac{\pi}{4} di^2$$

Where gi and hi are the basal area (in m2/ha) and the total height (in m) of tree i.

Kruskal–Wallis tests

The Kruskal–Wallis tests followed by the multiple comparison rank test of Mann-Whitney were performed to verify significant differences in trees' DBH and height of habitats calculated as follows.

$$H = (N-1)\frac{\sum_{i=1}^{g} n_i(\bar{r}_{i\cdot} - \bar{r})^2}{\sum_{i=1}^{g}\sum_{j=1}^{n_i}(r_{ij} - \bar{r})^2},$$

- N is the total number of observations across all groups
- g is the number of groups
- n_i is the number of observations in group i
- r_{ij} is the rank (among all observations) of observation j from group i
- $\bar{r}_{i\cdot} = \frac{\sum_{j=1}^{n_i} r_{ij}}{n_i}$ is the average rank of all observations in group i
- $\bar{r} = \frac{1}{2}(N+1)$ is the average of all the r_{ij}.

3.0 RESULTS

3.1 Species Composition

Table 1: Family and species richness per habitat

Families and Species	Lowland forest (Casalpinioideae)	Lowland evergreen forest (Mixed)	Coastal forest (Sacoglotis	Coastal forest (Mixed)	Total	Families and Species	Lowland forest (Casalpinioideae)	Lowland evergreen forest (Mixed)	Coastal forest (Sacoglotis gabonensis)	Coastal forest (Mixed)	Total
Acanthaceae	10				10	*Leonardoxa africana*			4		4
Asystasia macrophylla	10				10	*Mucuna flagellipes*		4	4		8
Annonaceae	28	20	8	4	60	*Odyendeya gabonensis*			4		4
Greenwayodendron suaveolens	17	8		4	29	*Piptadeniastrum africanum*	9	13	19		41
Meiocarpidium lepidotum	11	12	8		31	*Pterocarpus soyauxii*	6			2	8
Apocynaceae	14	11	5	3	33	*Tetraberlinia bifoliolata*	2		4		6
Alstonia boonei	14	11	5	3	33	*Xrythrophleum ivorene*	13	6	7		26
Arecaceae		4	3		7	Humiriaceae	37	24	9	14	84
Cocos nucifera		4	3		7	*Sacoglottis gabonensis*	37	24	9	14	84
Burseraceae	15	13	9		37	Icacinaceae	4				4
Canarium schweinforthii	6	7	9		22	*Lasianthera africana*	4				4
Santiria trimera	9	6			15	Irvingiaceae	48	27	13	4	92
Caesalpiniaceae	14		6		20	*Desbordesia glaucescens*	40	15	9	4	68
Brachystegia cynometroides	14		6		20	*Irvingia gaboninsis*	8	12	4		24
Calophyllaceae		2	3		5	Ixonanthaceae	12	24	19	2	57
Calophyllum inophyllum		2	3		5	*Ochthocosmus calothyrsus*	12	24	19	2	57

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Chrysobalanaceae		2	3		5	Lecythidaceae	12	12	5		29
Chrysobalanus icaco		2	3		5	*Pestersianthus macrocarpus*	12	12	5		29
Combretaceae	14	10	16	3	43	Meliaceae	8				8
Terminalia catappa		4	4		8	*Lovoa trchilioides*	8				8
Terminalia superba	14	6	12	3	35	Myristicaceae		2	14	7	23
Connaraceae	10				10	*Coelocaryon preussii*		2	9	5	16
Jollydora duparquetiana	10				10	*Scyphocephalium mannii*			5		5
Dilleniaceae		2	2		4	*Staudtia kamerunensis*				2	2
Tetracera alinifolia		2	2		4	Ochnaceae		13	14	2	29
Euphorbiaceae	24	5	12		41	*Lophira alata*		13	14	2	29
Dichostemma glaucescens	5				5	Olacaceae	25	21	27	2	75
Plagiostyles africana	9	1	6		16	*Coula edulis*		12	16		28
Uapaca guineensis	10	4	6		20	*Diogoa zenkeri*	12				12
Fabaceae	183	106	109	27	425	*Strombosia gradifolia*			2	2	4
Anthonotha fragrans	31	7	8		46	*Strombosia pustulata*			4		4
Aphanocalyx margininervatus	16				16	*Strombosiopsis tetrandra*	13	9	5		27
Caesalpinioideae	45	42	29		116	Rubiaceae	4				4
Calpocalyx dinklagei	33	8	2	2	45	*Massularia acuminata*	4				4
Calpocalyx heitzii	20	26	28	18	92	Sapindaceae		4	4		8
Dialium pachyphyllum	8				8	*Dodonaea viscosa*		4	4		8
Distemonanthus benthamianus				5	5						

Total: Families and Species (24); Lowland Forest (Casalpinioideae) (462); Lowland evergreen forest (Mixed) (302); Coastal Forest (Sacoglotis gabonensis) (281); Coastal Forest (Mixed) (68); Overall across Forest categories (1113)

A total of 1113 individual trees with DBH of ≥ 10 cm were identified and measured. This belongs to 49 species from 24 families. Fabaceae was overwhelmingly the most dominant family of plants with 425 individual trees counted belonging to this family. This was followed closely by Irvingiaceae, Humiriaceae, Olacaceae with 92, 84 and 75 individual trees counted under these families respectively. The least popular are Rubiaceae, Icasinaceae, Delliniaceae each having just 4 individual trees counted under these families. Based on the number of tree species in each family, Fabaceae is the most popular with 14 tree species. This is followed by Olacaceae, Euphorbiaceae, Myristicaceae with 5, 3 and 3 separate plant species under these families respectively. A total of 16 tree species fall under 16 different families. It is therefore evident that different tree species within the Campo forest fall under varieties of families. Though Fabaceae dominates, other families are very much visible in the area.

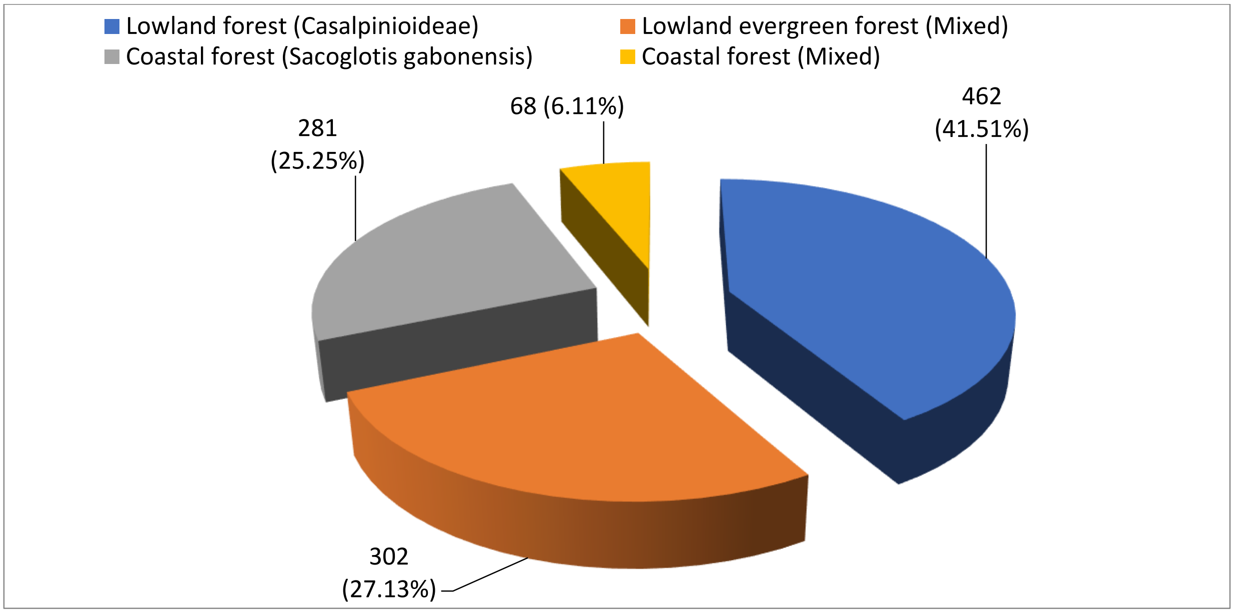

Figure 2: Total of individual per habitat

The total individual trees were segregated with respect to the various habitats identified (Figure 4). Lowland evergreen forest (*Casalpinioideae*) recorded the highest number of tree species counted with a total of 462 tree species making 41.5% of the total tree species counted in the area. Lowland evergreen forest (mixed) follows with 302 plant species making 27.1% of the total tree species in the area. Coastal forest (*Sacoglotis gabonensis*) with just 281 tree species making 25.3% of the total species while the zone around Coastal forest (mixed) makes just 6.1%.

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Table 2: Dominant species per habitat

Lowland forest (Casalpinioideae)	**Lowland evergreen forest (Mixed)**	**Coastal forest (*Sacoglotis gabonensis*)**	**Coastal forest (Mixed)**
Species (abundance)	**Species (abundance)**	**Species (abundance)**	**Species (abundance)**
Caesalpinioideae (45)	*Caesalpinioideae* (42)	*Caesalpinioideae* (29)	*Sacoglottis gabonensis* (14)
Desbordesia glaucescens (40)	*Calpocalyx heitzii* (26)	*Calpocalyx heitzii* (28)	*Calpocalyx heitzii* (18)
Sacoglottis gabonensis (37)	*Ochthocosmus calothyrsus* (24)	*Terminalia superb* (12)	
Calpocalyx dinklagei (33)	*Sacoglottis gabonensis* (24)	*Ochthocosmus calothyrsus* (19)	
Anthonotha fragrans (31)	*Desbordesia glaucescens* (15)	*Piptadeniastrum africanum* (19)	
Calpocalyx heitzii (20)	*Lophira alata* (13)	*Coula edulis* (16)	
Greenwayodendron suaveolens (17)	*Piptadeniastrum africanum* (13)	*Lophira alata* (14)	
Aphanocalyx margininervatus (16)	*Irvingia gaboninsis* (12)		
Alstonia boonei (14)	*Coula edulis* (12)		
Brachystegia cynometroides (14)	*Meiocarpidium lepidotum* (12)		
Terminalia superba (14)	*Pestersianthus macrocarpus* (12)		
Strombosiopsis tetrandra (13)	*Alstonia boonei* (11)		
Xrythrophleum ivorene (13)			
Diogoa zenkeri (13)			
Ochthocosmus calothyrsus (13)			
Pestersianthus macrocarpus (13)			
Meiocarpidium lepidotum (13)			

Dominant species here are those with total abundance greater than 10 individuals per corridor. Table 3 shows dominant tree species for each habitat. Species considered dominant are those with total abundance of 10 per habitat. Based on that, *Caesalpiniodeae* is the most dominant tree species with abundance of 45 individual trees in Lowland evergreen forest (*Casalpinioideae*), 42 individual trees in Lowland evergreen forest (mixed), 29 in Coastal forest (*Sacoglotis gabonensis*) and 14 in Coastal forest(mixed). *Sacoglottis gabonensis* is consistent in all habitats having abundance of 37, 24, and 14 in Lowland evergreen forest (*Casalpinioideae*), Lowland evergreen forest (mixed) and Coastal forest (mixed). *Calpocalyx heitzii* has abundance of 20 in Lowland evergreen forest (*Casalpinioideae*), 26 in Lowland evergreen forest (mixed), 28 in Coastal forest (*Sacoglotis gabonensis*) and 18 Coastal forest (mixed). *Ochthocosmus calothyrsus* was identified in all major corridors with abundance of 13 in Lowland evergreen forest (*Casalpinioideae*), 24 in Lowland evergreen forest (mixed) and 19 in Coastal forest (mixed). *Pestersianthus macrocarpus* is also popular specie found in both Lowland evergreen forest (*Casalpinioideae*) and Lowland evergreen forest (mixed) with abundance of 13 and 12 individual plants. *Piptadeniastrum africanum was* identified in Lowland evergreen forest (mixed) and Coastal forest (*Sacoglotis gabonensis*) with individuals of 13 and 19.

3.2 Understorey

A total of 21 species belonging to 17 families were identified.

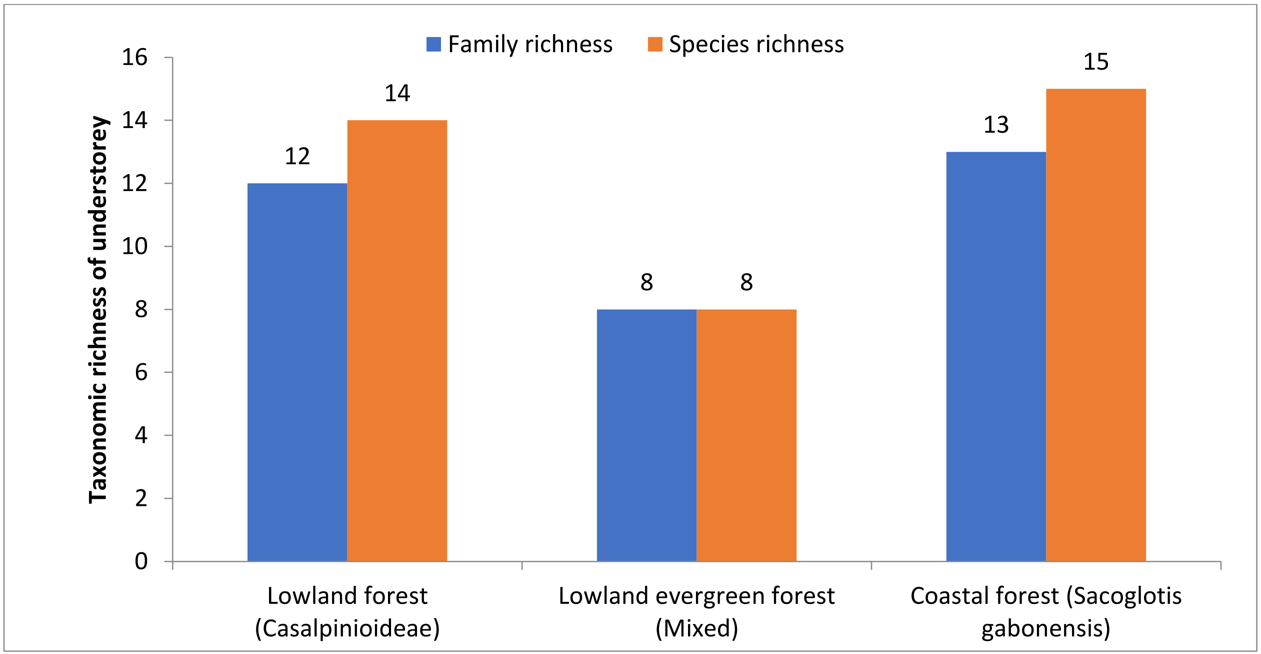

Figure 3: Taxonomic richness per habitat

Figure 3 indicates that the area has different species that constitute the understory with Coastal forest (*Sacoglotis gabonensis*) being the richest with 15 species identified belonging to 13 separate families. This was followed by Lowland evergreen forest (*Casalpinioideae*) with 14 species identified belonging to 12 families. A total of 8 different species were identified in Lowland evergreen forest belonging to 8 families.

Table 3: Understorey family per habitats

Understorey families	Habitats used by elephants			Total
	Lowland forest (Casalpinioideae)	**Lowland evergreen forest (Mixed)**	**Coastal forest (*Sacoglotis gabonensis*)**	
Acanthaceae	4	3	3	10
Araceae	2	0	0	2
Arecaceae	4	3	2	9
Commelinaceae	6	3	3	12
Connaraceae	0	0	1	1
Costaceae	2	0	0	2
Ebenaceae	0	0	1	1
Euphorbiaceae	3	3	4	10
Icacinaceae	0	0	1	1
Malvaceae	4	3	3	10
Marantaceae	6	3	2	11
Olacaceae	4	3	2	9
Pandaceae	4	3	2	9
Poaceae	2	0	0	2
Prosopistomatidae	2	0	0	2
Rubiaceae	0	0	2	2
Violaceae	0	0	1	1
Total	**43**	**24**	**27**	94
Chi-Square Test	$X^2 = 27.535$	*p-value = 0.692*		

Commelinaceae is the dominant family type with 12 species counted. This was followed by Marantaceae, Malvaceae, Euphorbiaceae, Acanthaceae, Arecaceae with 11, 10, 10, 10 and 9 species counted respectively. Families such as Violaceae, Ebenaceae, Connaraceae were the least identified counting just a single species.

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Table 4: Understorey species per habitats

Understorey species	Habitats used by elephants			Total
	Lowland forest (Casalpinioideae)	**Lowland evergreen forest (Mixed)**	**Coastal forest (*Sacoglotis gabonensis*)**	
Alchornea floribunda	3	3	3	9
Allexis cauliflora	0	0	1	1
Asystasia macrophylla	4	3	3	10
Costus englerianus	2	0	0	2
Crotonogyne manniana	0	0	1	1
Diospyros obliquifolia	0	0	1	1
Haumania danckelmaniana	4	3	2	9
Heistera pavifora	4	3	2	9
Jollydora duparquetiana	0	0	1	1
Lasianthera africana	0	0	1	1
Massularia acuminata	2	0	0	2
Microcalamus barbinoides	0	0	1	1
Marantochloa monophylla	2	0	0	2
Microdesmis puberula	4	3	2	9
Palisota ambigua	4	3	3	10
Palisota barteri	2	0	0	2
Podococcus barteri	4	3	2	9
Puella schumanniana	2	0	0	2
Rinoria albidiflora	0	0	1	1
Scaphopetalum blackii	4	3	3	10
Stylochaeton zenkeri	2	0	0	2
Total	**43**	**24**	**27**	**94**
Chi-Square Test	$X^2 = 34.056$	*p-value* = 0.734		

The dominant specie types are *Scaphopetalum blackii, Palisota ambigua, Asystasia macrophylla, Podococcus barteri, Microdesmis puberula, Heistera pavifora, Haumania danckelmaniana, Alchornea floribunda* all counting 9 and 10 individuals. The least recorded were *Rinoria albidiflora, Microcalamus barbinoides, Lasianthera Africana, Crotonogyne manniana, Allexis cauliflora* all recording a single individual.

3.3 Habitat Structure

Table 5: Analyzing vegetation characteristics

Plant's Metrics	Lowland forest (Casalpinioideae)	Lowland evergreen forest (Mixed)	Coastal forest (*Sacoglotis gabonensis*)	Coastal forest (Mixed)
Surface area (ha)	0.072	0.048	0.048	0.012
Total abundance of trees	462	302	281	68
Number of tree Species	32	30	35	14
Trees density	6417	6292	5854	5667
Shannon's Index (H')	4.67	4.45	4.73	3.31
Evenness (E)	0.93	0.91	0.92	0.87
Simpson's Index of diversity (1-D)	0.95	0.94	0.96	0.87
Stand basal area (G)	36.31	33.11	41.50	76.39
Mean diameter of trees (D)	32.26	25.98	26.93	28.88
Lorey's mean height (H)	28.99	21.89	20.94	29.76

From table 5, Lowland evergreen forest (*Casalpinioideae)* has the highest surface area (0.072) since it has the highest number of transects. Lowland evergreen forest (mixed) and Coastal forest (*Sacoglotis gabonensis*) has the same surface area of .048 each. With a larger surface area, Lowland evergreen forest (*Casalpinioideae)* counted up to 462 individual trees which were the highest in all three corridors. This was followed by Lowland evergreen forest (mixed) with 302 individual trees and Coastal forest (*Sacoglotis gabonensis*) with 281 individual trees counted. The Coastal forest (mixed) counted just 68 individual trees. The number of tree species counted for the habitats identifies were fairly even with Coastal forest (*Sacoglotis gabonensis*) having 35 different tree species counted, slightly different from Lowland evergreen forest (*Casalpinioideae)* and Coastal forest (*Sacoglotis gabonensis*) with 32 and 30 different species identified respectively. Just 14 species were identified around Coastal forest (mixed).

The Shannon's diversity index indicates that the tree diversity for all habitats are fairly even with Coastal forest (*Sacoglotis gabonensis*) having a value of 4.73 having the most diverse tree species for the study. This was followed by 4.67 and 4.45 for Lowland evergreen forest (*Casalpinioideae)* and Lowland evergreen forest (mixed) respectively showing highly diverse tree species in the area. Values of 0.93, 0.94, and 0.96 for Lowland evergreen forest (*Casalpinioideae),* Lowland evergreen

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forest (mixed) and Coastal forest (*Sacoglotis gabonensis*) respectively show a near complete evenness for tree species in the area. Lowland evergreen forest (*Casalpinioideae)* shows more evenness in tree species while the Coastal forest (mixed) shows the lowest evenness with 0.87. These values portray closeness in tree species in each plot. With high values of Evenness, diversity index shows very high values in all 3 major corridors (0.95, 0.94 and 0.96) indicating highly diverse tree species in the study area.

The Coastal forest (mixed) shows the highest rate of basal area (76.39). This is followed by Coastal forest (*Sacoglotis gabonensis*) (41.50) and Lowland evergreen forest (*Casalpinioideae)* (32.26), all indicating high basal area. Lowland evergreen forest (*Casalpinioideae)* had the highest mean diameter of 32.26cm. Lowland evergreen forest (mixed) and Coastal forest (*Sacoglotis gabonensis*) also had high values of 25.98cm and 26.93 respectively while the Coastal forest (mixed) has mean diameter of 28.88cm. The study area equally has very tall trees with values above 20m in height. Lowland evergreen forest (*Casalpinioideae)* has above 28m in average height while Lowland evergreen forest (mixed) and Coastal forest (*Sacoglotis gabonensis*) have average heights of 21m and 20m respectively. Very tall trees do exist around the Coastal forest (mixed) averaging about 30m in height.

3.4 Analyzing Habitat Structure

Table 6: DBH classes per habitat

DBH Classes	**Habitats used by elephants**				**Total**	**Chi-Square Tests**
	Lowland forest (Casalpinioideae)	**Lowland evergreen forest (Mixed)**	**Coastal forest (*Sacoglotis gabonensis*)**	**Coastal forest (Mixed)**		
[10-20]	105	85	44	24	258	X^2 = 127.183
[20-30]	150	171	128	23	472	
[30-40]	92	37	78	11	218	
[40-50]	91	7	24	5	127	p-value = 0.000
≥50	24	2	7	5	38	
Total	**462**	**302**	**281**	**68**	**1113**	

The distribution of plants according to DBH classes shows that DBH class [20-30] is the most represented with 472 individuals followed by the classes [10-20[, [30-40[, [40-50[and ≥50 with 258, 218, 127 and 38 individuals respectively. The Chi-Square test reveals that there is a significant difference (p = 0.000) in trees DBH across the habitats used by elephants.

Table 7: Height classes per habitat

Height Classes	Habitats used by elephants				Total	Chi-Square Tests
	Lowland forest (Casalpinioideae)	Lowland evergreen forest (Mixed)	Coastal forest (*Sacoglotis gabonensis*)	Coastal forest (Mixed)		
[5-10]	34	35	12	0	81	X^2 = 149.380
[10-15]	154	136	80	18	388	
[15-20]	66	67	58	18	209	
[20-25]	22	27	61	14	124	p-value = 0.000
[25-30]	63	18	29	3	113	
≥30	123	19	41	15	198	
Total	**462**	**302**	**281**	**68**	**1113**	

The distribution of plants according to height classes shows that height class [10-15[is the most represented with 388 individuals follows by the classes [15-20[, ≥30, [20-25[, [25-30[and [5-10[with 209, 198, 124, 113 and 81 individuals respectively. The Chi-Square test reveals that there is a significant difference (p = 0.000) in trees height by habitats used by elephants.

Table 8: Descriptive statistics on trees DBH and height

	Habitats	Mean	Std. Dev	Min	Max	Shapiro-Wilk Tests of Normality			Kruskal-Wallis Test (H)
						Statistic	df	P-value	
Trees DBH (cm)	Lowland forest (Casalpinioideae)	29.45	11.48	10	58	0.957	462	0.000	H = 57.331
	Lowland evergreen forest (Mixed)	23.3	7.759	10	64	0.922	302	0.000	
	Coastal forest (*Sacoglotis gabonensis*)	27.69	9.189	10	55	0.953	281	0.000	p = 0.000
	Coastal forest (Mixed)	25.75	14.056	10	75	0.864	68	0.000	
Trees Height (m)	Lowland forest (Casalpinioideae)	21.66	11	5	46	0.896	462	0.000	H = 65.045
	Lowland evergreen forest (Mixed)	15.81	7.06	6	45	0.859	302	0.000	

	Coastal forest (*Sacoglotis gabonensis*)	20.33	8.871	7	48	0.928	281	0.000	p = 0.000
	Coastal forest (Mixed)	22.45	10.832	10	51	0.845	68	0.000	

Trees DBH varies between 10 and 64 cm with mean values of 29.45±11.48 cm, 23.3±7.759 cm, 27.69±9.189 cm and 25.75±14.056 cm for Lowland evergreen forest (*Casalpinioideae*), Lowland evergreen forest (mixed), Coastal forest (*Sacoglotis gabonensis*) and Coastal forest (mixed) respectively. Concerning Trees height, values recorded during the study period range from 5 to 51 m with the highest mean (22.45±10.832) being observed in Coastal forest (mixed). In Lowland evergreen forest (*Casalpinioideae)*, Lowland evergreen forest (mixed) and Coastal forest (*Sacoglotis gabonensis*) trees height mean values are respectively 21.66±11 m, 15.81±7.06 m and 20.33±8.871 m. The non-parametric Kruskal-Wallis test shows that the variations of trees DBH and height according to corridors are significant ($p<0.05$).

The mean DBH for Lowland evergreen forest (*Casalpinioideae)* is about 29cm, Lowland evergreen forest (mixed) about 23cm and Coastal forest (*Sacoglotis gabonensis*) about 28cm. A low standard deviation of DBH for all habitats indicates that the data was widely spread and not concentrated around the mean. Based on the Krustal Wallis test conducted, with a P value of 0.000, indicates a significant difference in DBH between the major corridors. The mean tree height of Lowland evergreen forest (*Casalpinioideae)* is close to 22m, Lowland evergreen forest (mixed) close to 16m and Coastal forest (*Sacoglotis gabonensis*) about 20m. With respect to the tree height, analyses reveal a low standard deviation for all habitats, which indicates a widely spread out data set which is not concentrated around the mean. With a P value of 0.000, there is a significant difference in tree heights between the various habitats.

Table 9: Spearman correlation between DBH and height

			DBH	**Trees Height**
Spearman's rho	DBH	Correlation Coefficient	1.000	0.843**
		Sig. (2-tailed)	.	0.000
		N	1113	1113
	Trees Height	Correlation Coefficient	0.843**	1.000
		Sig. (2-tailed)	0.000	.
		N	1113	1113

***. Correlation is significant at the 0.01 level (2-tailed).*

The Spearman correlation test shows highly positive and significant correlations between trees DBH and height ($r=0.84$, $p=0.000$).

Table 10: Two ways ANOVA for DBH and height

Source	Dependent Variable	Type I Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	DBH	56833.293[a]	110	516.666	7.836	0.000
	Trees Height	52812.136[b]	110	480.110	8.776	0.000
Intercept	DBH	818086.815	1	818086.815	12406.719	0.000
	Trees Height	435711.107	1	435711.107	7964.217	0.000
habitats' effect	DBH	7147.270	3	2382.423	36.131	0.000
	Trees Height	6950.431	3	2316.810	42.348	0.000
Species effect	DBH	34363.876	48	715.914	10.857	0.000
	Trees Height	32412.402	48	675.258	12.343	0.000
Habitats * Species effect	DBH	15322.148	59	259.697	3.938	0.000
	Trees Height	*13449.303*	*59*	*227.954*	*4.167*	*0.000*

Two ways ANOVA test shows that trees DBH and height vary significantly (p=0.000) among species and form one habitat to another. This analysis also reveals that there is a significant interaction between tree's species and specific habitats. There was a significant relationship between tree height and habitats use. Meanwhile there was a significant variation in DBH and height with respect to habitats.

4.0 DISCUSSIONS

4.1 Species Composition

Campo Maan forest area has five distinct vegetation types: Lowland evergreen forest rich in *Caesalpinioideae*, the lowland evergreen forest rich in *Caesalpiniodeae* with *Calpocalyx heitzii* and *Sacoglottis gabonensis*, Lowland evergreen forest rich in *Caesalpinioideae* with *Sacoglottis gabonensis* and other coastal indicators, the Coastal forest rich in *Sacoglottis g*abonensis, Coastal forest rich in *Calpocalyx heitzii* and *Sacoglottis gabonensis*. This is consistent with Colligne (2010), Turner (2005) and Fischeret *et al.*, (2004) who all identified Lowland evergreen forest as the dominant forest types in the Congo Basin. It is slightly different from Canham and Marks (2016) who identified two forest types including coastal forest and lowland evergreen.

A total of 49 plant species were identified from 24 families of which Fabaceae is overwhelmingly the most dominant family of plants with 425 individual trees belonging to this family. A host of researchers identified Fabaceae as the most dominant family of plants in the area. This includes Smithet *et al.*, (2011), McGarigal (2010) in various forests in tropical Africa. The least popular in the CMNP adjacent forest includes Rubiaceae, Icasinaceae, Delliniaceae. This is consistent with Wagner (2012) in the Korobera forest who identified Icasinaceae as the least popular family.

A total of 1113 individual plants were counted along all habitats. This indicates that the study area is rich in diverse plant species foraged by elephants. Yackulicet et al. (2011) identified 1023 individual plants in his ecological study of Krugua National Park indicating plant species richness in the area. The dominant species identified in the CMNP adjacent forests is *Caesalpinioideae*, *Calpocalyx heitzii*, *Sacoglottis gabonensis*, *Desbordesia glaucescens*, *Ochthocosmus calothyrus*. This is consistent to Bennet and Saunders (2010) who identified *Calpocalyx heitzii* and *Sacoglottis gabonensis* as the dominant species. *Caesalpinioideae* is overwhelmingly the most dominant specie in all habitats similar to Achoundong (2007) in his study carried out in the Mosembe National Park. The Campo Maan Forest is therefore rich in many plants species.

4.2 Habitat Structure

All habitats recorded DBH of between 10cm to above 64cm with Lowland evergreen forest (*Caesalpinioideae*) recording the highest number of trees with DBH of 64cm. This is an indication that the study area had a blend of large and small trees. The distribution of trees in circumference classes was uneven. The study recorded 9 dbh classes indicating that, structurally, the forests are probably mature, stable and highly likely to continue perpetuating their constituent species. The smallest diameter trees (10-20cm dbh) were 258 abundant showing that the ecological importance of small-trees in the structure, diversity and biomass to tropical forests (Memiaghe et al., 2016). This means that the four community forests are much more supported by younger trees. Tree heights vary between 5m and 56m in all habitats. This indicates that the study area not only have large trees but also very tall trees which were consistent in all habitats with few anthropogenic activities. This scenario was also observed by Zeh et al, 2019 in their study of floristic composition of species in the Kimbi Fungom National park These results were similar to those of Savadogo et al. (2007) in Tiogo Forest who demonstrated that at dbh of > 10 cm, a great number of stems were recorded from the circumference class 10 - 30 to 30 - 50 cm, indicating the high number of small trees The Campo Maan forest is also rich in understorey with a total of 21 species belonging to 17 families were identified. Hoodeveent et al. (2013) in his study also identified large number of understorey. Commelinaceae was the dominant family type consistent with Erbet et al. (2012), Brashareset et al. (2004). The dominant specie was *Scaphopetalum blackii* which is similar to what Eillcox and Nambu (2007) explained in their study.

All habitats had an overlap of vegetation characteristics though Lowland evergreen forest (*Caesalpinioideae*) is quite distinct from the rest of the habitats identified. There is no significant relationship between DBH and elephant habitats. This means the selection and use of a particular habitat by elephants were not based on the size of trees. Elephants made use of areas small trees as well as large trees though they use large trees in scratching their skin. There was a significant relationship between tree height and habitats use. This means habitats use by elephants is dependent on heights of trees. Meanwhile there was a significant variation in DBH and height with respect to habitats. Different habitats had different DBH and heights classes of tree. Also, areas with taller trees had large DBH and therefore, there was a significant interaction between tree species and habitat use which means many plants were simultaneously present in all habitats. All habitats identified had a fairly even tree diversity. This indicates that no habitat was overwhelmingly dominant in terms of diversity of plant species.

5.0 CONCLUSION AND RECOMMENDATIONS

The Campo Maan adjacent forest is an Eco region with diverse plant species located in five distinct vegetation types. Plant species are not evenly distributed with plants such as *Caesalpinoideae* dominating all five vegetation types. All habitats identified had large trees of between 10cm to above 50cm DBH and very tall trees of between 5m to above 30m in height. Some vegetation characteristics are quite similar with all habitats though dense evergreen forest is distinct from the rest of the habitats. The taller trees in the area have larger DBH with many tree species simultaneously present in all habitats.

The management, preservation systems including local population and habitat regeneration will therefore be highly needed to save this protected area from destruction, save their flora and fauna species from local extinction and to maintain a viable population size in the face of growing anthropogenic activities. It should be noted that the Campo Maan Forest species richness and its diversity are under serious threats due to the anthropogenic pressure resulting from both cash crops and food crop production especially with the establishment of CAMVERT plantation. Serious habitat destruction and illegal logging are still very active in the forest management units which are a great problem for the area. Measures should therefore be taken toward good management and monitoring of this park through frequent patrol and the recruitment of more forest guards. Measures to support the regeneration of tree species should also be taken, in order to increase the main abundance of trees and threatened species.

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