Original Research Article

Floristic Checklist and Conservation Status of Woody Species in Relation to Gradient in Osomba Hills in Oban Forest of Cross River National Park, Nigeria.

Abstract

In a bid to provide an updated checklist of woody species in the Osomba Hills in Oban Forest of Cross River National Park and also determine the conservation status of species within the range and highlight the alpha diversity trend at different altitudes, standard inventory sampling methods were employed in the floristic checklist and conservation status of woody species as it relates with the elevation gradient in Osomba hills in Oban Forest. A total of 78 species of woody plants in 31 families were enumerated. The family Fabaceae recorded the highest number of species (13) followed by Malvaceae with 8 species, Annonaceae and Euphorbiaceae had 6 species each, Apocynaceae had 5 species, Irvingiaceae, Ochnaceae, and Olacaceae had 3 species each, Buseraceae, Clusiaceae, Combretaceae, Ebenaceae, Moraceae, Myristicaceae, Rubiaceae and Sapotaceae had 2 species each, Anacardiaceae, Anisophylleaceae, Asteraceae, Bombacaceae, Cecropioaceae, Gentianaceae, Hyperiaceae, Lecythiddaceae, Meliaceae, Passifloraceae, Polygalaceae, Rhizophoraceae, Rutaceae, Simaroubaceae and Violaceae had 1 species each. The investigation of the conservation status of the species in IUCN redlist revealed that 1 species (*Berlinia korupensis* Mackinder& Burgt) is critically endangered (CR), 6 species are near threatened (NT), 7 species are vulnerable (VU), 7 species are not evaluated (NE) and 54 species are of least concerned (LC). The vegetation analyses reveal the habits to be 14 shrubs and 64 tree species in the study area. In the dry season, a total of 29 species including 5 shrubs and 24 trees were enumerated, in the rainy season, a total of 57 species including 10 shrubs and 47 trees were enumerated. Plant diversity along elevation gradient was generally heterogeneous and could be influenced by many factors such as climate, spatial heterogeneity, biotic processes, and evolutionary history. Overall species richness of both shrubs and trees decreased along the elevation gradient whereas the tree species increased with the elevation. Anthropogenic factors and accessibility to the mountainous terrain and could also contribute to the patterns of the plant diversity and tree community structure in the study area. Common anthropogenic activities observed were timber harvesting, firewood collections, and harvesting of plants for food and medicinal uses.

Keywords: *Berlinia korupensis*, Critically Endangered, Osomba hills, Redlist, Richness, woody plants,

Introduction

The tropical rainforest has been identified as the most biologically diverse terrestrial ecosystem on earth [1,2,3,4,5]. The rainforest acts as the main repository of the genetic diversity of both flora and fauna, with trees often the most conspicuous plant life form in the forest [6]. Forests generally provide important ecological goods and services that equip adjourning communities livelihoods leading to economic growth [7, 8].

Trees species are critical constituents of forest ecosystems, in addition to solidifying the crucial structural and practical foundation of tropical rainforests, are essential as carbon sinks, watersheds, provide shades and homes for several life forms in the ecosystem [9]. Trees diversity is vital to tropical forest biodiversity, since trees provide habitats and resources to a wide array of plant and animal species. For that reason, they control the design and affect the make-up of forest communities. The size and degree of the biodiversity of an ecosystem impacts the total health of the ecosystem [10]. The firmness or permanence and task of the ecosystem are controlled by the variability of vegetation [11]. There is also compelling proofs on the good effect of elevated species variability in a physical surrounding task such as controlling the gradual wearing off of land surface materials by the action of water, winds, waves, etc.) [12].

Mountain ecosystems are characterized by steep environmental gradients, including temperature, pressure, and moisture [13, 14]. Abiotic and biotic factors influence the patterns of diversity and distribution of species along altitudinal gradients [15]. Along an elevation gradient, environmental variables directly affect species composition, growth patterns, and ecosystem functioning, which leads to a change in the vegetation composition [16, 17, 18]. The elevation regulates several abiotic factors (i.e., soil parameters, atmospheric pressure, humidity, cloudiness, solar radiation, light availability, pH, etc.) that control the composition of vegetation and the ecology of mountain forests [19]. Species from different taxa, families, and life forms respond specifically to these factors according to their eco-physiological properties and sensitivity [15, 20, 21]. Elevation and abiotic factors are the governing drivers for differences in species richness and composition in the Himalaya [22, 23]. The species composition depends directly on temperature and air pressure, which decrease along the elevation gradient [24, 25, 26]. It is well established that diversity declines linearly along the elevation gradient [27, 28]. However, recent studies highlight that plant diversity often peaks at mid-elevations [30, 31]. This may vary among taxa and mountain ranges [31, 32]. The Oban Forest Reserve harbours a significant portion of Nigeria's remaining tropical rainforest and the entire landscape is recognized internationally as a biodiversity hotspot [33]. However, in recent times there are evidence of resource exploitation around the park's buffer zone, which imperils extant vegetation and fauna life. Several studies on the park's fauna have been done, but there appears to be a deficit in the knowledge of lower and higher plants diversity. Hence, this project was to; provide an updated checklist of species with their parameters found in the forest; determine the

conservation status of species within the range and highlight the alpha diversity trend at different altitudes.

Methodology

Study Area

The Osomba Hills area is located between latitudes 05^0 32^1 and 04^0 27 North and longitudes 07^0 15 and 09^0 28^1 East. Osomba hills is a mountainous terrain and forms part of the Oban Division of the Cross River National Park (CRNP), Nigeria. The park was established under Decree 36 of 1991 with total land area of 4,000 km². and comprises of two divisions (Oban and Okwangwo). Oban Division lies within longitudes 8°20′ E and 8°55′ E and latitudes 5°00′ N and 6°00′ N; while Okwangwo Division is located on longitudes 9°02′ E and 9°27′ E and latitudes 6°04′ N and 6°28′ N [34]. The Oban Division was carved out of Oban group Forest Reserve in 1991. The total area is about 3,000 km^2 and it shares boundary with Korup National Park of Cameroon in the east. The vegetation of the park is characteristically moist tropical rainforest. In the less accessible areas, the forest has had little interference, but elsewhere the vegetation has been much influenced by human activities. Exploitation in the buffer zone has resulted in secondary regrowth. Tree height reaches 50 m to about 65 m and sometimes more [35]. The terrain is rugged and elevation rises from the river valleys to over 1,000 m in mountainous areas [34]. Most of the area is characterized by hilly terrain ranging from 100 to over 1,000m in height. The dominant rock types are ancient metamorphic rocks of the Basement Complex which covers 50% of Nigeria [36, 37]. Less sandy soils are found in areas with igneous rocks and deeper soils prevail in the plains of the southern part of the park whilst on steeper slopes they are increasingly stony, shallow and erodible [36]. Temperatures are generally high (average around 27ºC) and vary little throughout the year with the annual range of the monthly average temperature varying only between 3º and 3.5º C. Mean monthly relative humidity varies between 78% and 91% with an average of annual rainfall generally between 2,500mm-3,000mm. At times, it can be up to 4,000mm or 85%. [36, 37]. The mean annual temperature is between 22.3ºC and 30.0ºC and rainfall is 2000mm with mean relative humidity of 80 - 90%. The soil is rich in phosphorus and also highly acidic [38].

Sampling Method, Elevation and Conservation status of Samples

Vegetation sampling was carried out in five 100m transects. The rangers' tract was used as the line transect, each transect consisted of five 10m x 10m quadrats which were spaced at regular intervals of 10m [39, 40, 41]. In each quadrat, woody plant species were enumerated. The sampling was done within the study area during the dry season from 16th – 18th February 2022 and wet season from 29th – 30th July, 2022 using permanent sampling plots which were marked with the aid of a handheld Garmin ETrex 10 GPS Device. Elevation was determined using handheld Garmin ETrex 10 GPS device. The conservation status of species was validated using the IUCN [42] database (Table 2).

Table 1. Coordinates and Elevation of the Sampling Points

Sampling Plots		Coordinates
1.	Latitude	5.444366 - 5.455375
	Longitude	8.637177 - 8.633327
	Elevation.	170m - 175m
2.	Latitude	5.455358 - 5.458294
	Longitude	8.6333055 - 8.629719
	Elevation.	178m - 205m
3.	Latitude	5.458399 - 5.46426
	Longitude	8.629556 - 8.62523
	Elevation.	232m – 240m
4.	Latitude	5.46421 - 5.46632
	Longitude	8.62509 - 8.62406
	Elevation	271m - 279m
5.	Latitude	5.46695 - 5.469033
	Longitude	8.62358 - 8.623697
	Elevation	295m - 297m

Quantitative Determination of Vegetation Parameters

Height:

The heights of the plant species were measured using a Haga altimeter. Readings was taken 15 m away from the base of the woody plant from where the crown was sighted through the eye piece of the altimeter and the upper reading taken. The base of the woody plant was similarly sited and the lower altimeter readings taken. The height of each species was calculated using:

Height (m) = Algebraic sum of the reading of the top and bottom of each plant × horizontal distance from observer to each species divided by the scale factor used on the altimeter.

Diameter/Girth Size:

Girth is a measurement of the distance around the trunk of a tree measured perpendicular to the axis of the trunk. It is measured at a height of 1.3 meters (4.3 ft), in this case the base of the tree is measured for both height and girth as being the elevation at which the pith of the tree intersects the ground surface beneath, or where the acorn sprouted. This is assumed to be at the centre of the trunk. Trees with normal form, slow tapering trunk on level ground was measured at 1.3 m above ground level but when trees with trunk split into two or more trunks below 1.3 m, measurement of the girth of the biggest trunk was taken at 1.3 m height.

Basal Area

This was calculated using:

$$\text{Basal Area} = \frac{C^2}{4\pi}$$

Where $4\pi = 4 \times 3.142 = 12.568$

C = girth size of the species at breast height

Density

The density of each plant species was estimated by enumerating all plants present in 100 m^2. The number of individuals of a species was taken as a proportion of the number of 10 transects to give a mean of species. The mean was then taken as a proportion of the area of the quadrat to give density in m^2 which was multiplied by 10,000 m^2 to give density per hectare [43].

Importance Value Index (IVI)

The Importance Value Index (used to determine dominance of tree/shrub species) for the enumerated plant species was determined as the sum of the Relative frequency (R_f), Relative density (R_d) and Relative dominance (R_D).

Relative frequency (R_f)

This was calculated thus:

$$R_f = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

Relative density (R_d)

This was calculated thus:

$$R_f = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$$

Relative dominance (R_D)

This was calculated thus:

$$R_D = \frac{\text{Basal area of a species}}{\text{Total basal area of all species}} \times 100$$

RESULT

In the vegetation sampling of the Osomba hills, a total 78 species of woody plants in 31 families were enumerated. The family Fabaceae recorded the highest number of species (13) followed by Malvaceae with 8 species, Annonaceae and Euphorbiaceae had 6 species each, Apocynaceae had 5 species, Irvingiaceae, Ochnaceae, and Olacaceae had 3 species each, Buseraceae, Cluisiaceae, Combretaceae, Ebenaceae, Moraceae, Myristicaceae, Rubiaceae and Sapotaceae had 2 species each, Anacardiaceae, Anisophylleaceae, Asteraceae, Bombacaceae, Cecropioaceae, Gentianaceae, Hyperiaceae, Lecythiddaceae, Meliaceae, Passifloraceae, Polygalaceae, Rhizophoraceae, Rutaceae, Simaroubaceae and Violaceae had 1 species each (Table 1). The investigation of the conservation status of the species in IUCN redlist data (IUCN, 2022) revealed that 1 species is critically endangered (CR), 6 species are near threatened (NT), 7 species are vulnerable (VU), 7 species are not evaluated (NE) and 54 species are of least concerned (LC) (table 1).

The vegetation analyses reveal the habits to be 14 shrubs and 64 tree species in the study area. In the dry season, a total of 29 species including 5 shrubs and 24 trees were enumerated, whereas in the rainy season, a total of 57 species including 10 shrubs and 47 tree were enumerated (table 3 and 4).

TABLE 2: IUCN CONSERVATION STATUS OF THE SPECIES

S/N	FAMILY	SPECIES	CONSERVATION STATUS
1.	Anacardiaceae	1. *Antrocaryon micraster* A.Chev. & Guillaumin	VU
2.	Anisophylleaceae	*1. Poga oleosa* Pierre	LC
3.	Annonaceae	*1. Cleistopholis patens* (Benth.) Engl. & Diels	LC
		2. Hexalobus crispiflorus A.Rich.	LC
		3. Monodora crispata Engl.	LC
		4. Xylopia aethiopica (Dunal) A. Rich.	LC
		5. Xylopia quintasii Pierre ex Engl. & Diels	LC
		6. Uvariodendron fuscum var. fuscum R.E. Fr.	NT
4.	Apocynaceae	*1. Alstonia boonei* De Wild.	LC
		2. Funtumia elastica (Preuss) Stapf	LC
		3. Rauvolfia mannii Stapf	LC
		4. Rauvolfia vomitoria Wennberg	LC
		5. Tabernaemontana pachysiphon Stapf	LC
5.	Asteraceae	*1. Veronica pusilla var pusilla*	NE
6.	Bombacaceae	*1. Ceiba pentandra* (L.) Gaertn.	LC
7.	Burseraceae	*1. Canarium schweinfurthii* Engl.	LC
		2. Pachylobus edulis G. Don Syn *Dacryodes edulis* (G.Don) H.J.Lam	LC
8.	Cecropioceae	*1. Musanga cecropioides* R.Br.ex Tedlie	LC
9.	Clusiaceae	*1. Allanblackia floribunda* Oliv.	LC
		2. Garcinia kola Heckel	VU

10.	Combretaceae	*1. Terminalia superba* Engl. & Diels	LC
		2. Terminalia ivorensis A.Chev.	VU
11.	Ebenaceae	*1. Diospyros mespiliformis* Hochst ex A.DC.	LC
		2. Diospyros zenkeri (Gurke) F. White	LC
12.	Euphorbiaceae	*1. Alchornea cordifolia* (Schumach. &Thonn.) Mull. Arg.	LC
		2. Antidesma laciniatum Mull. Arg.	LC
		3. Maesobotrya barteri (Baill.) Hutch.	LC
		4. Bridelia micrantha (Hochst.) Baill.	LC
		5. Uapaca acuminata Pax & K.Hoffm	LC
		6. Uapaca guineensis Mull. Arg.	LC
13.	Fabaceae	*1. Albizia zygia* J.F.Macbr.	LC
		2. *Amphimas pterocarpoides* Harms	LC
		3. *Angylocalyx oligophyllus* (Baker) Baker f.	LC
		4. *Baphia nitida* G. Lodd.	LC
		5. *Berlinia korupensis* Mackinder& Burgt	CR
		6. *Berlinia bracteosa* Benth.	LC
		7. *Calpocalyx cauliflorus* Hoyle	VU
		8. *Hylodendron gabunense* Taub	LC
		9. *Isoberlinia doka* Craib & Stapf	LC
		10. *Millettia griffoniana* Baill.	LC
		11. *Pentaclethra macrophylla* Benth.	LC
		12. *Piptadeniastrum africanum* (Hook. f.) Brenan	LC
		13. *Pterocarpus osun* Craib	LC
14.	Gentianaceae	*1. Anthocleista vogelii* Planch.	LC
15.	Hypericaceae	*1. Harungana madagascariensis* Lam. Ex Poir .	LC
16.	Irvingiaceae	*1. Klainedoxa gabonensis* Pierre ex Engl.	LC
		2. *Desbordesia glaucescens* (Engl.) Tiegh.	LC
		3. *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill	NT
17.	Lecythidaceae	*1. Napoleonaea egertonii* Baker f.	VU
18.	Malvaceae	*1. Bombax buonopozense* P. Beauv.	LC
		2. Cola gigantea A. Chev.	LC
		3. Cola lepidota K. Schum.	LC
		4. Cola rostrata K. Schum.	LC
		5. Pterygota macrocarpa K. Schum.	VU
		6. Sida cordifolia L.	NE
		7. Sterculia tragacantha Lindl.	LC
		8. Cola hispida Brenan & Keay	NE
19.	Meliaceae	*1. Carapa procera* DC.	LC
20.	Moraceae	*1. Ficus sur Forssk. SYN F. capensis Thunb.*	NE
		2. Milicia excelsa (Welw.) C.C.Berg	NT
21.	Myristicaceae	*1. Pycnanthus angolensis*(Welw.) Warb.	LC
		2. Staudtia kamerunensis var. gabonensis (Warb.) Fouilloy	LC

22.	Ochnaceae	*1.* *Lophira alata* Banks ex C.F.Gaertn.	VU
		2. *Ouratea calophylla* Engl.	NE
		3. *Rhabdophyllum calophylum* Tiegh.	NE
23.	Olacaceae	*1.* *Coula edulis* Baill.	LC
		2. *Strombosia grandifolia* Hook. f. ex Benth.	LC
		3. *Strombosia pustulata* Oliv.	LC
24.	Passifloraceae	*1.* *Barteria fistulosa Mast.*	LC
25.	Polygalaceae	*1.* *Carpolobia lutea* G. Don	LC
26.	Rhizophoraceae	*1.* *Rhizophora racemosa* G Mey.	LC
27.	Rubiaceae	*1.* *Euclinia longiflora* Salisb.	LC
		2. *Mitragyna stipulosa* Kuntze	NT
28.	Rutaceae	*1.* *Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler	LC
29.	Sapotaceae	*1.* *Donella welwitschia* (Engl.) Pierre ex Engl. SYN *Chrysophyllum welwitschia* Engl.	NE
		2. *Gambeya albida* (G. Don.)Aubrev & Pellegr. SYN *Chrysophyllum albidum* G. Don.	NT
30.	Simaroubaceae	*1.* *Odyendea gabunensis*(Pierre) Engl. SYN *Hannoa Klaineana* Pierre &Engl.	LC
31.	Violaceae	*1.* *Rinorea dentata* (P.Beauv.) Kuntze	NT

CR – Critically Endangered; LC – Least Concerned; NE – Not Evaluated; NT – Near Threatened; VU – Vulnerable (IUCN, [42]).

Table 3: LIST OF SPECIES IN DRY SEASON SAMPLING

FIELD CODE	NAME OF PLANTS	HABIT	DBH	HEIGHT	FAMILY
		SAMPLE PLOT 1			
1	*Poga oleosa*	Tree	120	25m	Anisophylleaceae
2	*Alchornea cordifolia*	Shrub	8cm	6m	Euphorbiaceae
3	*Carpolobia lutea*	Shrub	3cm	4m	Polygalaceae
4	*Ficus sur Forssk.*	Tree	10cm	7m	Moraceae
5	*Milicia excelsa*	Shrub	17cm	6m	Moraceae
6	*Irvingia gabonensis*	Tree	1.2m	17m	Irvingiaceae
7	*Terminalia ivorensis*	Tree	0.9m	14m	Combretaceae
8	*Pycnanthus angolensis*	Tree	1.0m	12m	Myristicaceae
9	*Pentaclethra macrophylla*	Tree	0.5m	8m	Fabaceae
10	*Rauvolfia vomitoria*	Shrub	3cm	4m	Apocynaceae
11	*Cola gigantea*	Tree	0.8m	15m	Malvaceae
		SAMPLE PLOT 2			
1.	*Lophira alata*	Tree	2.7m	25m	Ochnaceae
2.	*Ceiba pentandra*	Tree	4m	23m	Malvaceae
3.	*Rinorea dentata*	Tree	3m	15m	Violaceae
4.	*Rhabdophyllum calophylum*	Tree	1.0m		Ochnaceae
5.	*Ouratea calophylla*	Tree	2.7	30m	Ochnaceae
6.	*Hexalobus crispiflorus*	Tree	2.7	30m	Annonaceae
7.	*Uvariodendron fuscum* var. fuscum	Tree	0.8m	15m	Annonoceae
8.	*Antidesma laciniatum*	Tree	3m	20m	Euphorbiaceae
9.	*Berlinia bracteosa*	Tree	3m	20m	Fabaceae
10.	*Tabernaemontana pachysiphon*	Shrub	9cm	7m	Apocynaceae
		SAMPLE PLOT 3			
1.	*Pycnanthus angolensis*	Tree	0.5m	8m	Myristicaceae
2.	*Zanthoxylum zanthoxyloides*	Tree	1.5m	7m	Rutaceae
3.	*Piptadeniastrum africanum*	Tree	2m	22m	Fabaceae
4.	*Lophira alata*	Tree	1.6m	40m	Fabaceae
5.	*Musanga cecropioides*	Tree	0.4m	12m	Urticaceae
6.	*Lophira alata*	Tree	3m	30m	Ochnaceae
7.	*Baphia nitida*	Tree	0.9m	10m	Fabaceae
8.	*Staudtia kamerunensis var. gabonensis*	Tree	0.9m	8m	Myristicaceae
9.	*Uapaca guineensis*	Tree	1.2m	13m	Euphorbiaceae
10.	*Napoleonaea egertonii*	Tree	0.8m	10m	Lecythidaceae
11.	*Uapaca guineensis*	Tree	0.8m	7m	Phyllanthaceae

12.	*Lophira alata*	Tree	2.5m	25m	Ochnaceae
13.	*Piptadeniastrum africanum*	Tree	2.5m	25m	Fabaceae
14.	Irvingia gabonensis	Tree	2.5m	30m	Irvingiaceae

SAMPLE PLOT 4

1.	*Pycnanthus angolensis*	Tree	6m	50m	Myristicaceae
2.	*Piptadeniastrum africanum*	Tree	0.3m	22m	Fabaceae
3.	*Uapaca guinensis*	Tree	0.3m	15m	Euphorbiaceae
4.	*Piptadeniastrum africanum*	Tree	3m	50m	Fabeceae
5.	*Irvingia gabonensis*	Tree	0.4m	25m	Irvingiaceae
6.	*Musanga cecropioides*	Tree	0.6m	18m	Cecropioceae
7.	*Pycnanthus angolensis*	Tree	4m	45m	Myristicaceae
8.	*Lophira alata*	Tree	9m	55m	Ochnaceae

SAMPLING POINT 5

1.	*Piptadeniastrum africanum*	Tree	4m	60m	Fabeceae
2.	*Lophira alata*	Tree	5m	60m	Ochnaceae
3.	*Staudtia kamerunensis var. gabonensis*	Tree	3m	70m	Myristicaceae
4.	*Diospyros mespiliformis*	Tree	0.2m	22m	Ebenaceae

Table 4: LIST OF SPECIES IN RAINY SEASON SAMPLING

FIELD CODE	NAME OF PLANTS	HABIT	DBH	HEIGHT	FAMILY
		Sampling Plot 1			
1.	*Terminalia superba*	Tree	2	10m	Combretaceae
2.	*Sida cordifolia*	Shrub	20cm	7m	Malvaceae
3.	*Pterocarpus osun*	Tree	15cm	10m	Fabaceae
4.	*Mitragyna stipulosa*	Tree	42cm	10m	Rubiaceae
5.	*Ceiba pentandra*	Tree	3m	30m	Malvaceae
6.	*Pentaclethra macrophylla*	Tree	10cm	5m	Fabaceae
7.	*Irvingia gabonesis*	Tree	2.5m	25m	Irvingiacea
8.	*Albizia zygia*	Tree	15cm	10m	Fabaceae
9.	*Ceiba pentandra*	Tree	10cm	20m	Apocynaceae
10.	*Pentaclethra macrophylla*	Tree	15m	10m	Streculiaceae
11.	*Funtumia elastica*	Shrub	10cm	7m	Apocynaceae
12.	*Diospyros zenkeri*	Tree	110cm	12m	Ebenaceae
13.	*Rhizophora racemose*	Tree			Rhizophoraceae
14.	*Harungana madagascariensis*	Shrub	15cm	7m	Hypericaceae
15.	*Sterculia tragacantha*	Tree	1.1m	16m	Malvaceae
16.	*Coula edulis*	Tree	10cm	7m	Olacaceae
17.	*Alstonia boonei*	Tree	19cm	8m	Apocynaceae
18.	*Hylodendron gabunense*	Tree	19cm	9m	Fabaceae
19.	*Euclinia longiflora*	Tree			Rubiaceae
20.	*Isoberlinia doka*	Tree	120cm	20m	Fabaceae
21.	*Donella welwitschia*. SYN *Chrysophyllum welwitschia*	Tree	12cm	8m	Sapotaceae
22.	*Pterygota macrocarpa*	Tree	54cm	15m	Malvaceae
		Samling Plot 2			
1.	*Pterocarpus osun*	Tree	15cm	20m	Fabaceae
2.	*Poga oleosa*	Tree	15cm	15m	Anisophylleaceae
3.	*Anthocleista vogelii*	Tree	7cm	15m	Gentianaceae
4.	*Maesobotrya barteri*	Shrub	5cm	7m	Euphorbiaceae
5.	*Rauvolfia vomitoria*	Shrub	5cm	10m	Apocynaceae
6.	*Bombax buonopozense*	Tree	100cm	20m	Malvaceae
7.	*Cola lepidota*	Tree	50cm	12m	Malvaceae
8.	*Canarium schweinfurthii*	Tree	7cm	10m	Burseraceae
9.	*Calpocalyx cauliflorus*	Tree	40cm	18m	Fabaceae
10.	*Desbordesia glaucescens*	Tree	40cm	12m	Irvingiaceae

11.	*Amphimas pterocarpoides*	Tree	45cm	13m	Fabaceae
12.	*Klainedoxa gabonensis*	Tree	120cm	20m	Irvingiaceae
13.	*Bridelia micrantha*	Shrub	14cm	5m	Euphorbiaceae
14.	*Rauvolfia mannii*	Shrub	15cm	7m	Apocynaceae

Sampling Plot 3

1.	*Garcinia kola*	Tree	1.5m	20m	Clusiaceae
2.	*Monodora crispata*	Tree	10cm	10m	Annonaceae
3.	*Ceiba pentandra*	Tree	10cm	10m	Malvaceae
4.	*Carapa procera*	Tree	5cm	7m	Meliaceae
5.	*Cola gigantea*	Tree	25cm	15m	Malvaceae
6.	*Baphia nitida*	Tree	10cm	10m	Fabaceae
7.	*Pachylobus edulis* Syn *Dacryodes edulis*	Tree	15cm	22m	Burseraceae
8.	*Tabernaemontana pachysiphon*	Tree	15cm	15m	Apocynaceae
9.	*Cola rostrata*	Tree	5cm	8m	Malvaceae
10.	*Millettia griffoniana*	Tree	10cm	5m	Fabaceae
11.	*Pachylobus edulis* Syn *Dacryodes edulis*	Tree	19cm	12m	Burseraceae
12.	*Cola hispida* Brenan	Shrub			Malvaceae

Sampling Plot 4

1.	*Berlinia korupensis*	Tree	15cm	15m	Fabaceae
2.	*Gambeya albida* SYN *Chrysophyllum albidum*	Tree	20cm	20m	Sapotaceae
3.	*Cleistopholis patens*	Tree	20M	22m	Annonaceae
4.	*Xylopia aethiopica*	Tree	15cm	15m	Annonaceae
5.	*Baphia nitida*	Tree	15cm	14m	Fabaceae
6.	*Uapaca acuminata*	Tree	46m	19m	Euphorbiaceae
7.	*Xylopia quintasii*	Tree	3m	35m	Annonaceae
8.	*Strombosia pustulata*	Tree	60cm	15m	Olacaceae

Sampling Plot 5

1.	*Xylopia quintasii*	Tree	120cm	30m	Annonaceae
2.	*Allanblackia floribunda*	Tree	120cm	15m	Clusiaceae
3.	*Strombosia grandifolia*	Tree	120cm	25	Olacaceae
4.	*Veronica pusilla var pusilla*	Shrub			Asteraceae
5.	*Isoberlinia doka*	Tree	120cm	25m	Fabaceae
6.	*Odyendea gabunensis* SYN *Hannoa Klaineana*	Tree	45cm	30m	Simaroubaceae
7.	*Barteria fistulosa*	Tree	55cm	21m	Passifloraceae
8.	*Antrocaryon micraster*	Tree	3.5m	40m	Anacardiaceae
9.	*Angylocalyx oligophyllus*	Shrub			Fabaceae

Table 5: Important Value index of Species found in the Study Area

S/N	Species	Rel. Frequency	Rel. Density	Rel. Dominance	IVI
1.	*Lophira alata*	3.921569	7.563025	5.644316	17.12891
2.	*Piptadeniastrum africanum*	2.941176	5.042017	3.495569	11.47876
3.	*Pycnanthus angolensis*	2.941176	5.042017	3.084325	11.06752
4.	*Irvingia gabonensis*	2.941176	5.882353	1.262517	10.08605
5.	*Ceiba pentandra*	2.941176	3.361345	2.878704	9.181225
6.	*Uapaca acuminate*	0.980392	0.420168	5.675159	7.075719
7.	*Musanga cecropioides*	1.960784	4.201681	0.616865	6.77933
8.	*Xvlopia quintasii*	1.960784	0.840336	3.701191	6.502311
9.	*Staudtia kamerunensis*	1.960784	2.10084	2.405774	6.467398
10.	*Hexalobus crispiflorus*	0.980392	2.10084	3.331071	6.412303
11.	*Antrocaryon micraster*	0.980392	0.840336	4.318056	6.138784
12.	*Antidesma laciniatum*	0.980392	1.260504	3.701191	5.942087
13.	*Rinorea dentate*	0.980392	1.260504	3.701191	5.942087
14.	*Tabernaemontana pachysiphon*	1.960784	2.10084	1.480476	5.5421
15.	*Isoberlinia doka*	1.960784	2.10084	1.480476	5.5421
16.	*Uapaca guineensis*	1.960784	2.521008	0.925298	5.40709
17.	*Zanthoxylum zanthoxyloides*	0.980392	2.521008	1.850595	5.351995
18.	*Ouratea calophylla*	0.980392	0.840336	3.331071	5.151799
19.	*Poga oleosa*	1.960784	1.260504	1.665536	4.886824
20.	*Pachylobus edulis*	1.960784	0.840336	1.850595	4.651715
21.	*Alstonia boonei*	0.980392	1.260504	2.344087	4.584983
22.	*Terminalia superba*	0.980392	0.840336	2.46746	4.288188
23.	*Rauvolfia vomitoria*	1.960784	1.680672	0.493492	4.134948
24.	*Cola gigantean*	1.960784	1.260504	0.647708	3.868996
25.	*Cleistopholis patens*	0.980392	0.420168	2.46746	3.86802
26.	*Baphia nitiida*	1.960784	1.680672	0.154216	3.795672
27.	*Donella welwitschia*	0.980392	1.260504	1.480476	3.721372
28.	*Milicia excels*	0.980392	2.521008	0.209734	3.711134
29.	*Uvariodendron fuscum*	0.980392	1.680672	0.986984	3.648048
30.	*Diospyros zenkeri*	0.980392	1.260504	1.357103	3.597999
31.	*Rhabdophyllum calophylum*	0.980392	1.260504	1.23373	3.474626
32.	*Pterocarpus osun*	1.960784	1.260504	0.18506	3.406348
33.	*Allanblackia floribunda*	0.980392	0.840336	1.480476	3.301204
34.	*Klainedoxa gabonensis*	0.980392	0.840336	1.480476	3.301204
35.	*Pentaclethra macrophylla*	0.980392	2.10084	0.18506	3.266292
36.	*Xylopia aethiopica*	0.980392	0.420168	1.850595	3.251155
37.	*Rauvolfia mannii Stapf*	0.980392	0.420168	1.850595	3.251155
38.	*Garcinia kola*	0.980392	0.420168	1.850595	3.251155

39.	*Funtumia elastic*	0.980392	0.840336	1.23373	3.054458
40.	*Terminalia ivorensis*	0.980392	0.840336	1.110357	2.931085
41.	*Strombosia grandifolia*	0.980392	0.420168	1.480476	2.881036
42.	*Euclinia longiflora*	0.980392	0.420168	1.480476	2.881036
43.	*Rhizophora racemosa*	0.980392	1.680672	0.18506	2.846124
44.	*Berlinia bracteosa*	1.960784	0.840336	0.037012	2.838132
45.	*Napoleonaea egertonii*	0.980392	0.840336	0.986984	2.807712
46.	*Sterculia tragacantha*	0.980392	0.420168	1.357103	2.757663
47.	*Monodora crispate*	0.980392	0.420168	1.23373	2.63429
48.	*Bombax buonopozense*	0.980392	0.420168	1.23373	2.63429
49.	*Sida cordifolia*	0.980392	1.260504	0.246746	2.487642
50.	*Pterygota macrocarpa*	0.980392	0.840336	0.666214	2.486942
51.	*Cola lepidota*	0.980392	0.840336	0.616865	2.437593
52.	*Coula edulis*	0.980392	1.260504	0.123373	2.364269
53.	*Mitragyna stipulosa*	0.980392	0.840336	0.518167	2.338895
54.	*Carpolobia lutea*	0.980392	1.260504	0.037012	2.277908
55.	*Canarium schweinfurthii*	0.980392	0.420168	0.863611	2.264171
56.	*Cola hispida*	0.980392	0.420168	0.863611	2.264171
57.	*Angylocalyx oligophyllus*	0.980392	0.840336	0.394794	2.215522
58.	*Strombosia pustulata*	0.980392	0.420168	0.740238	2.140798
59.	*Barteria fistulosa*	0.980392	0.420168	0.678552	2.079112
60.	*Diospyros mespiliformis*	0.980392	0.840336	0.246746	2.067474
61.	*Vereronica pusilla var pusilla*	0.980392	0.420168	0.616865	2.017425
62.	*Albizia zygia*	0.980392	0.840336	0.18506	2.005788
63.	*Harungana madagascariensis*	0.980392	0.840336	0.18506	2.005788
64.	*Amphimas pterocarpoides*	0.980392	0.420168	0.555179	1.955739
65.	*Odyendea gabunensis*	0.980392	0.420168	0.555179	1.955739
66.	*Ficus sur*	0.980392	0.840336	0.123373	1.944101
67.	*Alchornea cordifolia*	0.980392	0.840336	0.098698	1.919426
68.	*Calpocalyx cauliflorus*	0.980392	0.420168	0.493492	1.894052
69.	*Desbordesia glaucescens*	0.980392	0.420168	0.493492	1.894052
70.	*Carapa procera*	0.980392	0.840336	0.061687	1.882415
71.	*Gambeya albida*	0.980392	0.420168	0.246746	1.647306
72.	*Hvlodendron gabunense*	0.980392	0.420168	0.234409	1.634969
73.	*Berlinia korupensis*	0.980392	0.420168	0.18506	1.58562
74.	*Bridelia micrantha*	0.980392	0.420168	0.172722	1.573282
75.	*Millettia griffoniana*	0.980392	0.420168	0.123373	1.523933
76.	*Anthocleista vogelii*	0.980392	0.420168	0.086361	1.486921
77.	*Maesobotrya barteri*	0.980392	0.420168	0.061687	1.462247
78.	*Cola rostrata*	0.980392	0.420168	0.061687	1.462247

Discussion

Conservation status based on IUCN Status

Following the IUCN redlist, the species have been classified into five (5) groups viz;

1. **CR – Critically Endangered;** *Berlinia korupensis* is classified as a critically endangered species. This classification is in line with the IUCN criteria for classification of species which is centered on population size reduction, reduction across geographical range, population decline and probability of extinction [42]. The species *Berlinia korupensis* is a newly discovered species in the Korup National Park in Cameroon which is contiguous to the study site and has been reported to have only 17 trees/stands existing [44]. The findings of this study support the assertion that there is need for a conscious conservation measure for the species owing to the fact that the species was spotted in sampling plot 4 which is characterised by rocky topography.
2. **LC – Least Concerned:** These are species that have been considered not being the focus of conservation due to the fact that they still exist in abundance. The 57 species in this study that have been classified as least concerned species form the group of major native forest Plants in west Africa used locally as food plants for their edible parts, example; (*Maesobotrya barteri, Canarium schweinfurthii, Cola lepidota, Coula edulis, Pentaclethra macrophylla,* and *Pachylobus edulis*.) [40]. Timber sources include; (*Diospyros mespiliformis, Diospyros zenkeri, Pentacethra macrophylla, Isoberlinia doka, Piptadeniastrum africanum, Pterocarpus osun* and *Pycnanthus angolensis*.) [45].
3. **NE – Not Evaluated:** In this category, seven (7) species were classified, they are *Cola hispida, Donella welwitschia, Ficus sur Ouratea calophylla, Rhabdophyllum calophylum, Sida cordifolia* and *Veronica pusilla var pusilla.* The "not evaluated" category of plant species calls for conservation concern, as several the species encountered are exploited locally within the study area and could well be under threats from over exploitation.
4. **NT – Near Threatened:** six species were classified in this category; *Gambeya albida*; *Irvingia gabonensis; Milicia excelsa*; *Mitragyna stipulosa*; *Rinorea dentata*; and *Uvariodendron fuscum* var. fuscum. These species were classified in this category because they may be vulnerable in the near future, but it does not currently qualify for the threatened status [42]. Species such as *Gambeya albidia* and *Irvingia gabonensis* are very useful fruit plants in the locality [45]. Species such as *Milicia excelsa* is a tree that is known and widely used for its timber products [46].
5. **VU – Vulnerable:** Seven species were classified as vulnerable, and include; *Antrocaryon micraster, Calpocalyx cauliflorus, Garcinia kola, Lophira alata, Napoleonaea egertonii, Pterygota macrocarpa* and *Terminalia ivorensis*. This classification indicates that in the IUCN records, these species are being threatened with extinction unless the

circumstances that are threatening their survival and reproduction improve [42]. The result of this work is important to update the records in IUCN on some of the species in this category. *Lophira alata* had 18 individual stands in the study area and was recorded to have important value index of 17.12891.

Distribution of Species

The differences in the number of tree species recorded in the sampled plots may be due to variations in ecological factors and other habitat conditions which favoured more tree growth, diversity and distribution [47]. In the dry season, a total of 29 species including 5 shrubs and 24 trees were enumerated, in the rainy season, a total of 57 species including 10 shrubs and 47 trees were enumerated. The trees were always there, the differences in numbers were actually numbers of plants that flowered during the dry and rainy seasons thus enabling easy identification. The dominance of tree species in the study area is due to the suitability of tropical rain forest habitat where the structure of the basic components of the forest is a tree with an average height of 30 m. The Osomba hills include primary tropical rain forests with annual average rainfall reaching 2000 - 3000 mm each year in line with other tropical rainforests globally [48].

The most frequently encountered family was the Fabaceae with 13 species. This is not extraordinary since trees associated to the family Fabaceae are commonly in abundance in the forest ecosystem and contribute significantly in the social and economic existence of the populace [49]. Akwaji & Edu [49] and Wakawa *et al.* [50] made similar observations when they assessed tree species in the ecosystem of their study. Trees associated to the Fabaceae family like *Afzelia africana, Pentaclethra macrophylla, Baphia nitida* and *Pterocarpus osun* are valuable to the inhabitants on account of their function in soil augmentation, livestock feed, therapeutic and economic usefulness. As a result of their relevance to the dwellers of the locality, they are mostly conserved. Also, the dominance of tree species in the Fabaceae family may be partially due to the availability of viable seeds in soil seed banks to sustain regeneration. Most members of the Fabaceae are hard-seeded, with glabarous seed coats. The dominance of the Fabaceae family supports previous research works by [51] and [47] in Cross River National Park, Oban Division and the Oban Forest Reserve which are also located in close proximity to our study area. The additional predominant families in the zone are, Malvaceae, Apocynaceae, and Euphorbiaceae, respectively. Adeyemi *et al.*, [52] have reported that dominance of these families may partly be due to their capacity to give rise to innumerable seeds which could promote their establishment at adapted habitats. The dominance of these families in the study area could be as a result of their rapid regenerating ability, connected with synergetic features, which enabled the species to effortlessly start to exist in available ecosystem categories. This observation supports that of [53] that Moraceae, Malvaceae, Annonaceae, Meliaceae and Rubiaceae were amongst the most prominent families recorded in the contiguous Takamanda forest in Cameroon. The study zone shares certain habitat attributes and geographic borderlines with Cameroon. The supremacy of

these families may in addition be an outcome of habitat adaption and commensurate beneficial eco-conditions, that boost pollination, distribution and consequent initiation of species belonging to these families [54, 55, 56, 57]. Also, Austin *et al.,* [58] reported that soil features play a significant function in species abundance and establishment at all habitat. Out of the 248 trees belonging to 50 families in the central zone, the family Fabaceae also had the greatest aggregate of species. Aigbe *et al.,* [59] and Edet *et al.,* [60] made similar observations in the contiguous Afi River Forest and Wildlife Mountain Sanctuary. Other families dominating this area include the Malvaceae, Rubiaceae and Sapotaceae, Apocynaceae, Meliaceae and Moraceae, respectively. Similar observations about the dominance of these species in the central zone have also been made by [61, 62].

Vegetation Relationship with Gradient

The relationship between the forest vegetation and elevation was very interesting. Overall species richness decreased along an elevation gradient similar to that of some previous studies [63, 64]. In disparity, tree diversity increased with elevation similar to the results of [65]. Reports have stated that the effects of elevation on plant diversity are dependent on plant life form [19] and this might account for the different patterns observed. However, the effects of elevation on tree diversity do not follow rigid patterns as uni-modal hump-shaped [66], monotonic decrease [66] as well as monotonic increase [64] that have previously been reported. Plant diversity along elevation gradient could be influenced by many factors such as climate, spatial heterogeneity, biotic processes, and evolutionary history [15]. This study observed that soil might be a major limiting factor to plant diversity along the elevation gradient as huge boulders were encountered at higher elevations. Anthropogenic factors and accessibility to the mountainous terrain and could also contribute to the patterns of the plant diversity and tree community structure in the study area [67]. Common anthropogenic activities observed were timber harvesting, firewood collections, and harvesting of plants for food and medicinal uses [68].

Conclusion

The results of this study revealed a total of 78 species of woody plants in 31 families. The family Fabaceae recorded the highest number of species (13) followed by Malvaceae with 8 species, Annonaceae and Euphorbiaceae had 6 species each, Apocynaceae had 5 species. The vegetation analyses reveal the habits to be 14 shrubs and 64 tree species in the study area. In the dry season, a total of 29 species including 5 shrubs and 24 trees were enumerated, in the rainy season, a total of 57 species including 10 shrubs and 47 tree were enumerated. The conservation status of the species based on the IUCN status classified the species into 5 groups including; CR – Critically Endangered (1), LC – Least Concerned (57), NE – Not Evaluated (7) NT – Near Threatened (6) and VU – Vulnerable (7). Overall species richness decreased along an elevation gradient and tree diversity increased with elevation.

Acknowledgement

Field work was partly funded by the Institutional-based Tertiary Research Fund 2021/2022 merged grants.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

References

1. Turner, I. M. (2001). *The ecology of trees in the tropical rainforest.* Cambridge University Press, Cambridge, 298Pp.
2. Onyekwelu, J. C., Mosandl, R. and Stimm, B. (2008). Tree species diversity and soil status of primary and degraded tropical rainforest ecosystems in South-Western Nigeria. *Journal of Tropical Forest Science,* 20(3): 193-204.
3. Schmitt, C. B., Burgess, N. D., Coad, L., Belokurov, A., Besançon, C., Boisrobert, L., Campbell, A., Fish, L., Gliddon, D., Humphries, K., Kapos, V., Loucks, C., Lysenko, I., Miles, L.,. Mill, C., Minnemeyer, S., Pistorius, T., Ravilious, C., Steininger, M. and Winkel, G. (2009). Global analysis of the protection status of the world's forests. *Biological Conservation*, 142(10): 2122 - 2130.
4. FAO, (2010). *Global Forest Resources Assessment* 2010. FAO Forestry Paper No. 163. UN Food and Agriculture Organization, Rome.
5. IUCN (2010). *Plants under pressure – a global assessment.* The first report of the IUCN Sampled Red List Index for Plants. Royal Botanic Gardens, Kew, UK, Natural History Museum, London, and International Union for Conservation of Nature.
6. Gebreselassen, G. V. (2011). *Plant community's species diversity seedling bank and resprouting in Nandi Forest,* Kenya. Ph.D Thesis, Universitat Koblenz-Landau.
7. UNEP. (2007). *Global Environment Outlook 4*. United Nations Environment Programme, Nairobi. 235pp.
8. FAO. (2009). The State of the World's Forests 2009. Food and Agriculture Organization of the United Nations, Rome. 122Pp.
9. Singh, J. S. (2002). The biodiversity crises: a multifaceted review. *Current Science*, 82: 638- 647.
10. Naidu, M. T. and Kumar, O. A. (2016). Tree diversity, stand structure, and community composition of tropical forests in Eastern Ghats of Andhra Pradesh, India. *Journal of Asia Pacific Biodiversity,* 9: 328-334.
11. Buba, T. (2015). Impacts of different tree species of different sizes on spatial distribution of herbaceous plants in the Nigerian guinea savannah ecological zone. *Scientifica*, 20(15): 1-8.
12. Ogunjemite, B. G. (2015). Assessment of floristic composition of Ologbo Concession, Edo State, Nigeria, for conservation planning. *Revue Scientifique et Technique Forêt et Environnement du Bassin du Congo,* 4, 10-19.
13. Spehn, E. (2011). *Mountain biodiversity: effects of climate change and how to manage them*, vol. 60, pp.40–43.

14. Antonelli, A., Kissling, W. D., Flantua, S. G., Bermúdez, M. A., Mulch, A. and Muellner-Riehl, A. N. (2018). Geological and climatic influences on mountain biodiversity. *Natural Geoscience*, 11: 718–725.

15. McCain, C. M. and Grytnes, J. A. (2010). Elevational gradients in species richness. *Encyclopedia of Life Science (ELS),* 1–10.

16. Guo, O., Kelt, D. A., Sun, Z., Liu, H., Hu, L. and Ren, H. (2013). Global variation in elevational diversity patterns. *Scientific Report,* 3: 44 - 54.

17. Krömer, T., Acebe, A., Kluge, J., and Kessler, M. (2013). Effects of altitude and climate in determining elevational plant species richness patterns: a case study from Los Tuxtlas, Mexico. *Flora*, 208: 197–210.

18. Malizia, A., Blundo, C., Carilla, J., Osinaga Acosta, O., Cuesta, F. and Duque, A. (2020). Elevation and latitude drives structure and tree species composition in Andean forests: results from a large-scale plot network. *PLoS One*, 15:0231553.

19. Cirimwami, L., Doumenge, C., Kahindo, J. M., and Amani, C. (2019). The effect of elevation on species richness in tropical forests depends on the considered lifeform: results from an east African mountain forest. *Tropical Ecology*, 60: 473 – 484.

20. Korner, C. (2007). The use of 'altitude' in ecological research. *Trends in Ecology and Evolution,* 22: 569–574.

21. Vetaas, O. R. and Grytnes, J. A. (2002). Distribution of vascular plant species richness and endemic richness along the Himalayan elevational gradient in Nepal. *Global Ecology and Biogeography,* 11: 291–301.

22. Lee, C. B. and Chun, J. H. (2016). Environmental drivers of patterns of plant diversity along a wide environmental gradient in Korean temperate forests. *Forests*, 7:19 – 29.

23. Pandey, A., Badola, H. K., Rai, S. and Singh, S. P. (2018). Timberline structure and woody taxa regeneration towards treeline along latitudinal gradients in Khangchendzonga National Park, eastern Himalaya. *PLoS One*, 13: e0207762.

24. Whittaker, R. J., Willis, K. J. and Field, R. (2001). Scale and species richness: towards a general, hierarchical theory of species diversity. *Journal of Biogeography*, 28: 453 – 470.

25. Bhattarai, K. R., and Vetaas, O. R. (2006). Can Rapoport's rule explain tree species richness along the Himalayan elevational gradient, Nepal? Divers. *Distribution,* 12: 373–378.

26. Wani, Z. A., Negi, V. S., Bhat, J. A., Satish, K. V., Kumar, A. and Khan, S. (2023). Elevation, aspect, and habitat heterogeneity determine plant diversity and compositional patterns in the Kashmir Himalaya. *Frontier For Global Change*, 6: 11 - 19.

27. MacArthur, R. H. (1972). Geographical ecology. Princeton, NJ: Princeton University Press

28. Korner, C. (2000). Why are there global gradients in species richness? Mountains might hold the answer. *Trends in Ecology and Evolution*, 15: 513–514.

29. Rahbek, C. (2005). The role of spatial scale and the perception of large-scale species richness patterns. *Ecological Letters*, 8: 224 – 239.

30. Kessler, M., Kluge, J., Hemp, A., and Ohlemuller, R. (2011). A global comparative analysis of elevational species richness patterns of ferns. *Global Ecology and Biogeography*, 20: 868 – 880.

31. Cardelus, C. L., Colwell, R. K., and Watkins, J. E. (2006). Vascular epiphyte distribution patterns: explaining the mid elevation richness peak. *Journal of Ecology*, 94: 144–156.

32. Körner, C., Jetz, W., Paulsen, J., Payne, D., Rudmann-Maurer, K. M., and Spehn, E. (2017). A global inventory of mountains for bio-geographical applications. *Alp. Bot*., 127: 1–15.

33. United States Agency for International Development (USAID) (2006). *Nigeria biodiversity and tropical forestry assessment* http://pdf.usaid.gov/pdf_docs/Pnadn536.pdf retrieved 12-05-2023.

34. Ogunjobi, J. A., Meduna, A. J., Oni, S. O., Inah, E. I. and Enya, D. A. (2010). Protection Staff's job perception in Cross River National Park, Southern Nigeria, Middle-East *Journal of Scientific Research*, 5 (1): 22-27.

35. Jimoh, S. O., Adesoye, P. O., Adeyemi, A. A. and Ikyaagba, E. T. (2012). Forest Structure Analysis in the Oban Division of Cross River National Park, Nigeria. *Journal of Agricultural Science and Technology B*, 2: 510-518.

36. Holland, M. D., Allen, R. K. G., Barton, D. and Murphy, S. T. (1989). *Cross River National Park (Oban Division); Land Evaluation and Agricultural Recommendations.* World Wide Fund for Nature, Godalming, United Kingdom. p.140.

37. Schmitt, K. (1996). *Zoological survey of the Oban division of Cross River National Park Oban Hill programme*, Calabar. p. 21.

38. Mbong, E. O., Anwana, E. D. and Ezekiel, A. G. (2020). Correlating the Response of Woody Species to environmental gradient within University of Uyo Arboretum-Uyo. *Journal of Earth Science and Climate Change*, 10: 1-10.

39. Umoh, O. T. (2020). Preliminary Inventory of Plants Diversity in University of Uyo Main Campus. *Asian Journal of Research in Botany,* 3(1), 62–84.

40. Bassey, M. E., Anwana, E. D., Umoh, O. T. and Mbong, E. O. (2024). Pteridophytes and lycophytes from Osomba Hills, Cross River National Park, Nigeria. *Ceylon Journal of Science*, 53(2): 219 – 229.

41. IUCN (2022). The IUCN Red List of Threatened Species. Version 2022-2. Retrieved on 8th June, 2024 from https://www.iucnredlist.org.

42. Cochran, N. W. (1963). *Sampling technique.* 2nd ed., New delhi: Wiley Eastern Limited, p.413

43. Mackinder, B. A. and van der Burgt, X. M. (2009). *Berlinia korupensis* (Leguminosae – Caesalpinioideae), a new tree species from Cameroon. *Kew Bulletin*, 64: 129 – 134.

44. Etukudo, I. (2003). *Ethnobotany conventional and Traditional uses of plants*. The Verdict Press, Uyo. 136pp.

45. Nyananyo, B. L. (2006). *Plants from the Niger Delta,* Onyoma Research Publications Port Harcourt, Nigeria. 403pp.

46. Aigbe, H. I. and Omokhua, G. E. (2015). Tree species composition and diversity in Oban Forest Reserve, Nigeria. *Journal of Agricultural Studies*, 3(1): 10 - 24.

47. WWF (2010). *The Amazon rainforest*. WWF, U. S. Geological Survey, ICTA, TNC, University of Kassel. 23pp.

48. Akwaji, P. I. and Edu, E. A. (2017). Population frequency, density, abundance and diversity of tree species in ten communal forests of Northern Cross River State, Nigeria. *International Journal of Current Research,* 9(10): 59581 - 59596.

49. Wakawa, L., Suleiman, A., Ibrahim, Y. and Adam, L. (2017). Tree species biodiversity of a Sahelian ecosystem in Noertheast Nigeria. *Journal of Bartin Faculty of Forestry,* 19(2): 166 - 173.

50. Adeyemi, A. A., Jimoh, S. O. and Adesoye, P. O. (2013). Assessment of tree diversities in Oban Division of the Cross River National Park (CRNP), Nigeria. *Journal of Agriculture, Forestry and the Social Sciences,* 11(1): 216 - 230.

51. Adeyemi, A. A., Ibe, A. E. and Okedimma, F. C. (2015). Tree structural and species diversities in Okwangwo Forest, Cross River State, Nigeria. *Journal of Research in Forestry, Wildlife and Environment,* 7: 36 - 53.

52. Deka, J., Tripathi, P. O. and Khan, L. M. (2012). High dominance of Shorea robusta Gaertn. in Alluvial Plain Kamrup Sai Forest of Assam, Northeast India. *International Journal of Ecosystems,* 2(4): 67 - 73.

53. Pausas, J. G. and Austin, M. P. (2001). Patterns of plant species richness relation to different environments: An appraisal. *Journal of Vegetation Science*, 12: 153 - 166.

54. Adekunle, V. A. J., Akindele, S. O. and Fuwape, J. A. (2004). Structure and yield models of tropical lowland rainforest ecosystem of Southwest Nigeria. *Food, Agriculture and Environment*, 2(2): 395 - 399.

55. Ojo, L. O. (2004). The fate of a tropical rainforest in Nigeria; Abeku sector of Omo Forest Reserve. Global Nest: *The International Journal,* 6(2): 116 - 130.

56. Adekunle, V. A. J. and Olagoke, A. O. (2008). Diversity and bio-volume of tree species in natural forest ecosystem in the bitumen-producing area of Ondo State: A baseline study. *Biodiversity and Conservation,* 17: 2735 - 2755.

57. Austin, M. P., Pausas, J. G. and Nicholls, A. O. (1996). Patterns of tree species richness in relation to environment in South Eastern New South Wales. *Australian Journal of Ecology,* 21: 154 - 164.

58. Aigbe, H. I. Akindele, S. O. and Onyekwelu, J. C. (2014). Tree species diversity and density pattern in Afi River Forest Reserve, Nigeria. *International Journal of Scientific and Technology Research*, 3(10): 178 - 185.

59. Edet, D. I., Ijeoma, H. M. and Ogogo, A. U. (2012). Preliminary assessment of tree species diversity in Afi Mountain Wildlife Sanctuary, Southern Nigeria. *Agriculture and Biology Journal of North America*, 3(12): 486 - 492.

60. Adekunle, V. A. J. (2006). Conservation of trees species diversity in tropical rainforest ecosystem of South West Nigeria. *Journal of Tropical Forest Sciences,* 3(1): 91 - 101.

61. Adekunle, V. A. J., Olagoke, O. A. and Ogundare, L. F. (2010). Rate of timber production in a tropical rainforest ecosystem of southwest Nigeria and its implications on sustainable forest management. *Journal of Forestry Research*, 21: 225 - 230.

62. Yang, K. C., Lin, J. K., Hsieh, C. F., Huang, C. L., Chang, Y. M., Kuan, L. H. Su, J. F. and Chiu, S. T. (2008). Vegetation pattern and woody species composition of a broad-

leaved forest at the upstream basin of Nantzuhsienhsi in mid-southern Taiwan. *Taiwania*, 53: 325 - 337.

63. Zhang, C. S., Li, X. Y., Chen, L., Xie, G. D., Liu, C. L. and Pei, S. (2016). Effects of topographical and edaphic factors on tree community structure and diversity of subtropical mountain forests in the Lower Lancang River Basin. *Forests*, 7: 222 - 228.

64. Baruch, Z., (1984). Ordination and classification of vegetation along an altitudinal gradient in the Venezuelan Paramos. *Vegetation*, 55: 115 - 126.

65. Ren, X., Yang, G., Zhu, F., Qin, X., Wang, D., Liu, Z. and Feng, Y. (2012). Plant communities, species richness and lifeforms along elevational gradients in Taibai Mountain , China. *African Journal of Agricultural Research*, 7: 1834 - 1848.

66. Trigas, P., Panitsa, M. and Tsiftsis, S. (2013). Elevational gradient of vascular plant species richness and endemism in crete - the effect of post-isolation mountain uplift on a continental Island system. *PLoS One*, 8: e59425.

67. Gebrenhiwot, K., Demissew, S., Woldu, Z., Fekadu., M., Desalegn and Teferi., E. (2019). Elevational changes in vascular plants richness, diversity, and distribution pattern in Abune Yosef mountain range, Northern Ethiopia. *Plant Diversity*, 41: 220 - 228.

68. Adeniyi, A., Asase A., Ekpe, P. K., Asitoakor K. B., Adu-Gyamfi, A., and Avekor Y. P. (2018). Ethnobotanical study of medicinal plants from Ghana; confirmation of ethnobotanical uses, and review of biological and toxicological studies on medicinal plants used in Apra Hills Sacred Grove. *Journal of Herbal Medicine*, 14: 76 - 87.