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Stand Structure, Regeneration Status and Distribution Patterns of Six Important Tree Species along Altitudinal Gradients at the Kilum-Ijim Forest Reserve, Cameroon

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Authors' contributions

This work was carried out in collaboration among all authors. Author EEA designed the study and wrote the protocol. Author FBN collected the field data, drew the tables and wrote the first draft manuscript. Author NRN performed the statistical analysis, drew the figures and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Tropical montane forests are considered to be one of the most species diverse ecosystems. These areas pose specific edaphic and environmental characteristics which enable these areas to harbour wide varieties of organisms. Some of these organisms are threatened and others are endemic to the area. The quest for food and other resources has resulted to indiscriminate exploitation of these montane forest. This study aimed to investigate the stand structure, distribution patterns and regeneration status of six tree species (*Nuxia congesta*, *Pittosporum mannii*, *Podocarpus latifolius, Prunus africana*, *Schefflera abyssinica* and *Syzygium guineense*) along altitudinal gradients in the Kilum-Ijim Forest Reserve, Cameroon. A total of six study plots of one hectare (100 x100 m) each were laid across a 120 m elevation gradient. Two plots were

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established at each altitudinal gradient with elevations 2377 m, 2437 m and 2497 m. Measurements were taken for tree height, diameter at breast height (DBH 1.3 m) for the tree and poles. The digital Vernier callipers were used to measure collar diameters of seedlings and saplings. The highest tree density of 385 stems/ha was recorded for *N. congesta* at altitude 2497 m while the least was 20 stems/ha for *S. abyssinica* at altitude 2377m. The highest seedling density was 1563 stems/ha recorded for *P. mannii* at altitude 2377m and the least was noted for *S. abyssinica* at all the three altitudinal gradients. *Nuxia congesta* had the highest basal area of 8809.23m^2/ha at altitude 2437 m and the least of 74.82m^2/ha for *P. latifolius* at altitude 2437 m. The highest IVI occurred in *N. congesta (*131.91) was recorded at altitude 2377 m and the least (24.91) occurred in *P. latifolius* at altitude 2437 m. The spatial distributions of studied tree species were generally clumped and irregular. The regenerations of species were generally poor, though fair regenerations were noticed for *N. congesta* and *P. mannii*. The results showed that the six tree species were highly disturbed by anthropogenic activities. It is therefore imperative to develop and implement effective conservation measures to sustain the biodiversity of this reserve.

Keywords: Diameter classes (DBH); poles; sapling; seedlings; Montane forest; forest exploitation.

1. INTRODUCTION

Tropical forests are home to about half of the terrestrial plant and animal species and these biomes, are being destroyed at rates unprecedented in geological history [1]. The result is a wave of species extinctions that is making our planet both biologically impoverished and ecologically less stable. The degradation of forests and habitat loss due to anthropogenic activities are among the major causes of decline in biodiversity [2]. Cameroon's forest (22 million hectares) is of economic, cultural and socio-political importance to the countries of the Congo basin, and of ecological and scientific interest to the rest of the world [3]. Stand structure of species in a forest can partly convey its regeneration behaviour. However, natural regeneration of tree species largely depends on production and germination of seeds, establishment of seedlings and saplings, their survival and growth [4]. Inadequate number of seedlings and saplings of tree species in a forest indicates poor regeneration [5]. The species existence and recruitment process in a forest mostly depends on its regeneration potential under varied climatic factors, competition between species, predation and anthropogenic disturbances [6]. Disturbances of both natural and anthropogenic origins influence forest dynamics and tree species diversity at local and regional scales [7].

The Kilum-Ijim Forest Reserve is part of the Western Highlands of Cameroon commonly referred to as the Bamenda Highlands. The vegetation of the Bamenda Highlands, is increasingly cleared down, and has many similar species with those of East African Mountains [8]. It is estimated that about 96.5% of the original Afromontane Forest of the Bamenda Highlands has been lost due to conversion into agricultural and grazing lands and commercial logging [9]. Several forest and forest tree species in the country have showed decline in their population structure and regeneration due to the past and present disturbances [10]. This study therefore investigates population densities of six important tree species: their seedling, sapling, poles and trees, and their regeneration status along altitudinal gradients at the Klim-Ijim forest reserve, Cameroon;

2. MATERIALS AND METHODS

2.1 Study Site

The study was conducted in Kilum–Ijim Forest Reserve which is part of the Western Highlands of Cameroon and generally referred to as the Bamenda Highlands. The Kilum section of the forest (also known as Mount Oku) is situated in Bui Division in the North West Region (Fig. 2). On the Western slope is the Ijim Crater, starting from the west side of Lake Oku to Kom in Boyo Division still in the North West Region. The contiguous Kilum-Ijim Mountain Forests (now known as the Kilum-Ijim Forest Reserve) are located between latitude 6°07´ and 6°17´N and longitude 10°20´ and 10°35 E. The Kilum-Ijim Forest is 20,000 hectares, and is the most significant remnant of Afromontane forest in Central Africa [11]. It summits is 3,011 m and it is only second to mount Cameroon (4100 m) the highest peak in West and Central Africa [9] and the adjoining Ijim Crater (2000-2500m) are recognized as a globally important centre of endemism and a hotspot for biodiversity conservation [12]. This forest reserve has a large crater lake called Lake Oku that is found along the Cameroon volcanic line. This volcanic line stretches from the Bamenda highlands in Cameroon to Jos in Nigeria [13]. The climate of the Kilum-Ijim Forest Reserve is humid with the presence of fog and mist almost throughout the year [14]. The precipitation is monomodal [14]. The dry season begins from November to mid-March and the rainy season starts from mid-March to the month of October [15]. The total annual rainfall varies from 1800 to 3000 mm^3 annually, with an average temperature that varies from 22°C at 1800 m altitude to 16°C at the higher altitudes and the relative humidity is above 86% throughout the year [15]. The geological landscape found here are mainly of Basalts, trachytes, rhyolites, gneiss and granite origin [14]. The landscape is a mosaic of grassland, forest patches, lake and steep mountain forest (Fig. 1).

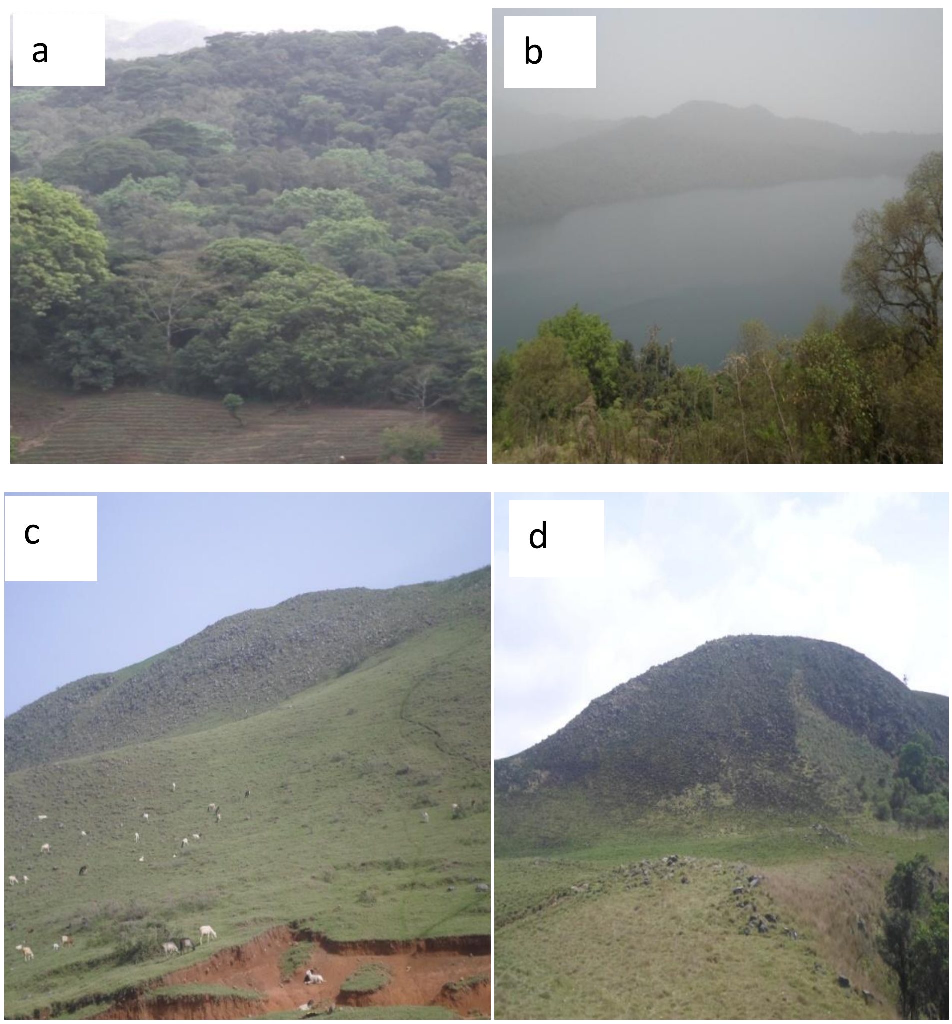

Fig. 1. Overview of the study area. (a) Forest edge of Kilum mountain forest, (b) Lake Oku at altitude 2200-2300m, (c) Landscape showing vegetation and livestock grazing in the area, (d) Kilum Mountain Forest summit

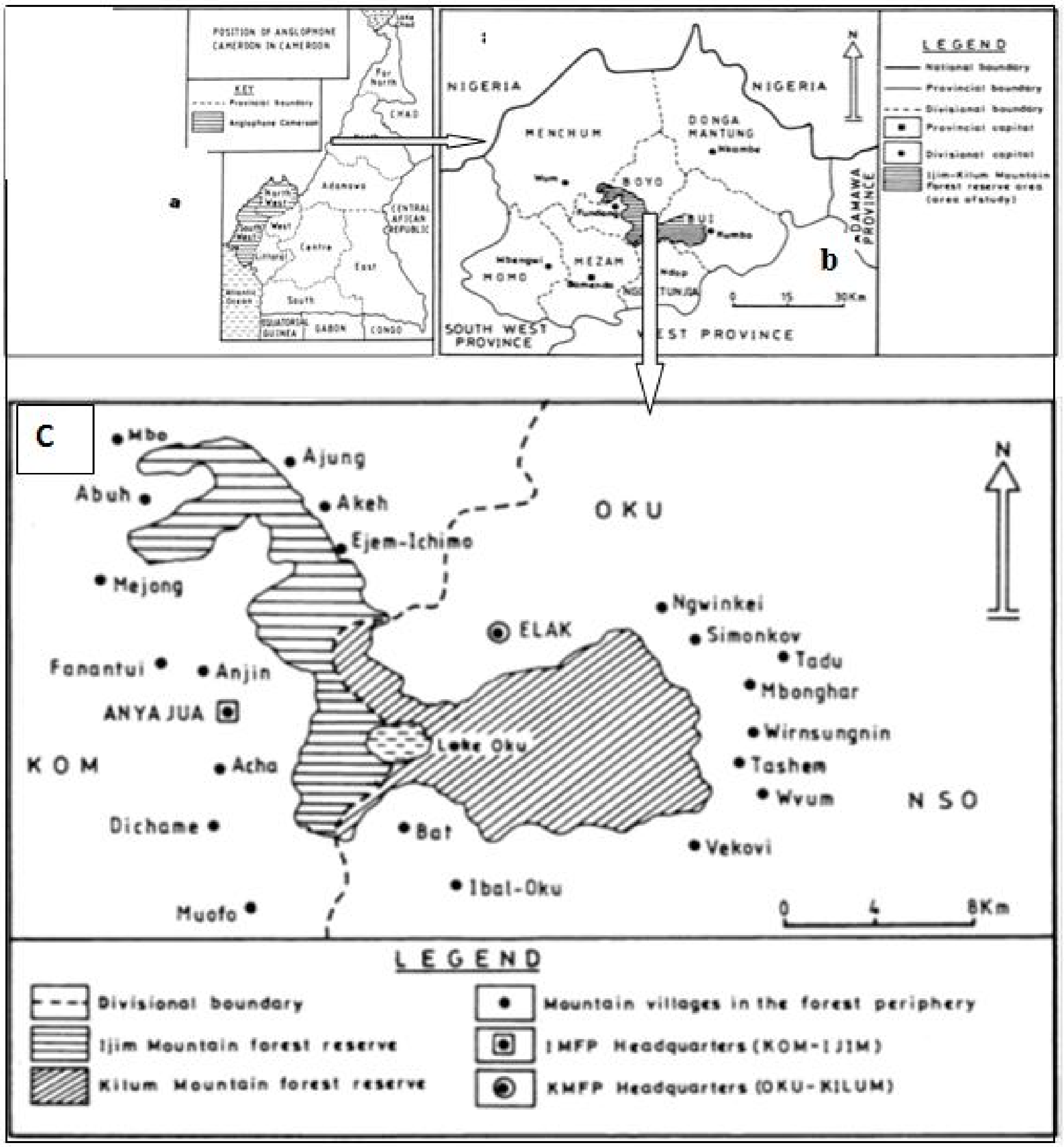

Fig. 2. a) Map of Cameroon, b) Map of North West Region showing the Bui and Boyo Divisions c) Map of Kilum-Ijim Mountain Forest. Source [14]

2.2 Study Survey

A reconnaissance survey was carried out to obtain an impression and visual description of the general vegetation physiognomy and vegetation-environment relationships such as altitude, slope, and tree stands. This study was carried out from September 2015 to September 2016. Clearance to carry out this study work was collected from the Delegation of Forestry and Wild life and the traditional authority of the Klim – Ijim Forest Reserve. In each of the communities'forest guides were identified (which could be a hunter, plant gatherer or herbalist who knows the forest and basic knowledge of the flora and fauna of the area). Focused group discussions and interviews were conducted with the local people (NTFP collectors, herbalist, hunters, timber exploiters, traders in forest products and farmers whose farms are close to the forest reserve) who are more likely to know plants and their detailed uses in their communities. During this survey, the following tree species; *Prunus africana*, (Hook. f.) Kalman, *Syzygium guineense* Willd DC, *Schefflera abyssinica* (Hochst. ex A. Rich.) Harms, *Nuxia congesta* (R.Br.Ex Fresen.), *Pittosporum manni* (Hook), and *Podocarpus latifolius* (Thunb.) R. Br. Ex Mirb, were prioritized as very useful to them based on their ecological, socio-cultural, economic and medicinal uses. Five focused groups discussions were carried across the five villages around the Kilum- Ijim Forest Reserve. A total of fifty questionnaires were administered in each of the five focused group giving a total of 250 questionnaires. The interviews were conducted alongside a forest guide of the Kilum-Ijim Forest Reserve. Apart from the hunters, herbalist and forest gatherer some notables and farmers were also included in the discussion and interviews.

2.3 Vegetation Samplings

A sampling size of 10 ha was mapped out of the study site. A total of six study plots of one hectare (100 x100 m) each were laid across a 120 m elevation gradient. The highest altitude was at the Ijim site 2497 m above sea level (ASL) and the lowest altitude was at the Kilum site 2377m ASL. The six plots of 1 hectare (ha) each was divided into three altitudinal gradients. Two plots were established at each altitudinal gradient with elevations 2377 m ASL, 2437 m ASL and 2497 m ASL. The altitude and position of each plot were measured with Garmin Colorado 400T Global Positioning System (GPS). In each of the sampling plots of 1 ha, 10 line transects of 10 m x 100 m were laid. Measurements were taken for height in meters (m) and dbh (1.3 m) for all the studied tree species. The height of trees (dbh ≥ 10 cm) and poles (dbh ≥ 5 cm to < 10 cm) was estimated using graduated measuring poles of 10 m. The initial 10 m height was first taken after which the remaining height was estimated by noting how many 10 m lengths of the poles goes to the tree top. The diameter was measured at 1.3 m (dbh) with a diameter tape. For plants that had buttresses the diameter was taken at 30 cm above the end of the buttress. For sapling (dbh ∠2.5cm to d∠4.9cm), the 10 m graduated pole was used to measure the height and a digital Vernier calliper to measure the diameter. For the seedling density, height and diameter, 10 quadrats of 4 x 4 m along each line transect were laid. The number of seedlings in each quadrat was counted for each of the species. The seedling heights were measured using a transparent 50 cm ruler. The collar diameter was measured with a digital Verniercalliper. The following precautions were taken while measuring the dbh. If the tree was branched below the breast height, the dbh was taken as individual stems, and also as separate trees. Fig. 3(a) and (b) shows measurement of tree height using a range pole, 3 (c), (d) and (e) measuring dbh using a diameter tape and 3 (f) mapping out plots using a measuring tape.

2.4 Data Analysis

The data analysis followed the procedures described in detail by [16]. Species richness was determined from the total number of tree species recorded in each site at the three altitudinal gradients. The diversity of the tree species at the three different altitudes was analyzed by using the Shannon Diversity Index [17,18]. The index takes into account the species richness and proportion of each species in all sampled quadrats of each study site. Density of the tree species was calculated by converting the total number of individuals of each tree species encountered in all the quadrats and all transects used in each of the three altitudes to equivalent number per hectare. The frequency was calculated as the proportion (%) of the number of quadrats in which each tree species was recorded from the total number of quadrats in each of the sites. Dominance of the tree species, with dbh ∠10 cm and poles with dbh ∠5 cm to < 10 cm was determined from the space occupied by a species, usually its basal area. The total basal area of each tree species was converted to equivalent basal area per hectare [18]. Importance value index (IVI), which indicates the relative ecological importance of a given woody species at a particular site [18], was determined from the summation of the relative values of density, frequency and dominance of each tree species. Relative density was calculated as the percentage of the density of each species divided by the total stem number of all species ha1. Relative frequency of a species was computed as the ratio of the frequency of the species to the sum total of the frequency of all species at each study site. Relative dominance was calculated as the percentage of the total basal area of a species out of the total basal areas of all species at each study site. The Simpson index (D) and the evenness index (E=Evenness) are considered as a measure of species dominances and a measure for evenness of spread, respectively [18].

Fig. 3. (a) Range pole (10 m) for taking the height of saplings and poles,(b) Taking the height of a tree using a 10 m range pole(c), (d)and (e) Measuring tree diameter at breast height (f) Mapping out the plots using a measuring tape

The spatial distributional patterns of the seedlings, saplings, poles and tree populations at different altitudinal gradients were analyzed using the standardized Morisita's index (Ip), since it is relatively independent of population density [17].

The standardized Morisita index of dispersion (Ip) has a range between -1 and +1, with 95% confidence limit at ± 0.5, where values of 0.0 indicate random dispersion, above 0.0 clumped dispersion, and below 0.0 uniform dispersion.

The regeneration status of key trees species in Kilum-Ijim forest was categorized as: (i) Good regeneration i.e. if number of seedlings > saplings > adults. (ii) Fair regeneration i.e. if number of seedlings> or∠ saplings ∠adults. (iii)

Poor regeneration i.e. if the species was found as sapling, but no seedlings (number of saplings maybe more, less or equal that of adults). (iv) No regeneration i.e. if individuals of species are present only as adults. (v) New regeneration i.e. if individuals of species have no adults but present as seedlings or saplings. Seedlings, saplings, poles and tree stems were counted per ha to determine regeneration status.

3. RESULTS

3.1 Tree Species Density, Basal Area and IVI at Three Altitudinal Gradients

Nuxia congesta had the highest tree species density at altitude 2377 m, with 243 individual/ha (Table 1). The lowest tree species density was 20.00 individuals/ha was noted for *S. abyssinica* (Table 1). The highest pole density at altitude 2377 m was 15.00 individuals/ha for *Pittosporum mannii* while no individual/ha was recorded for *P. africana*, *S. abyssinica* and *S. guineense* (Table 1). The highest sapling density was recorded at altitude 2377 m (2813 individuals/ha) for *P. latifolius* (Table 1) while the lowest sapling density were recorded for *P. africana*, *S. abyssinica* and *S. guineense* with no individual /ha (Table 1). The highest seedling density was obtained at altitude 2377 m (1563 individuals/ha) for *P. manni* (Table 1) while *P. latifolius*, *P. africana*, and *S. abyssinica* had no individual /ha (Table 1).

The highest basal area of these studied tree species at altitude 2377 m was observed for *N. congesta* which recorded 7141.47 m^2/ha while the lowest basal area was 164.92 m^2/ha for *P. latifolius* (Table 1).

The highest importance value index (IVI) at altitude 2377 m was noted for *N. congesta* which recorded 131.91 while the lowest was 25.57 for *S. abyssinica.* (Table 1). The highest IVI for poles at altitude 2377 m was 142.41 and this was recorded for *P. mannii* (Table 1). *P. africana*, *S. abyssinica* and *S. guineense* had no value for IVI for poles at this altitude (Table 1).

3.2 The Stand Structure of Six Important Tree Species at Altitude 2377 m

At altitude 2377 m, the stand structure showed a J- shape structure for *N. congesta* and *S. abyssinica*. We noticed a low number of and/or complete absence of individuals in the lower diameter classes and observed increase in number of individuals in the upper diameter classes (Fig. 4). *P. mannii* showed an irregular structure of individuals in the different diameter classes. We noticed high number of individuals in the lower diameter classes and a gradual decrease in number of individuals in the higher classes (Fig. 4). *P. latifolius*, *S. guineense* and *P. africana* both showed an irregular stand structure of individuals in the different diameter classes. However, individuals were observed in all diameter classes (Fig. 4).

3.3 The Stand Structure of Six Important Tree Species at Altitude 2437 m

At altitude 2437 m, the stand structure showed a J- shaped structure for *N. congesta*, *P. africana*, *S. abyssinica* and *S. guineense* (Fig. 5). We recorded a low number of and/or complete absence of individuals in the lower diameter classes and there was an increase in number of individuals in the upper diameter classes (Fig. 5). *P. mannii* and *P. latifolius* showed an irregular stand structure. Individuals were recorded in all the diameter classes (Fig. 5).

3.4 The Stand Structure of Six Important Tree Species at Altitude 2497 m

At altitude 2497 m, *N. congesta*, *S. abyssinica*, *S. guineense*, *P. latifolius* and *P. mannii* showed a J- shaped stand structure (Fig. 6). We observed low number of individuals or complete absence of individuals in the lower diameter classes. The numbers of individuals in the upper diameter classes were higher as compared with those of the lower diameter classes (Fig. 6). *P. africana* showed an irregular stand structure. It was also noted that there were individuals in all the different diameter classes (Fig. 6).

3.5 Tree, Pole, Sapling and Seedling Distribution Patterns at Three Altitudinal Gradients

At altitude 2377 m, the trees of *N. congesta* showed clump distribution pattern (Table 2) while the trees of *P. mannii*, *P. latifolius*, *P. africana*, *S. abyssinica* and *S. guineense* showed a uniform distribution pattern (Table 2). The poles of *N. congesta*had randomly distributed pattern while the poles of *P. mannii*showed uniformly distributed pattern (Table 2). Thepoles of *P. latifolius*, *P. africana*, *S. abyssinica* and *S. guineense* were not observed at this altitudinal gradient (Table 2). The saplings of *N. congesta*, *P. manni*, *P. latifolius*had uniform distribution pattern (Table 2). The saplings of *P. africana*, *S. abyssinica* and *S. guineense* were not observed at altitude 2377 m (Table 2). The seedlings of *N. congesta* and *P. mannii* showed uniform distribution pattern (Table 2). The seedlings of *S. guineense* displayed clumped distribution pattern while the seedlings of *P. latifolius*, *P. africana*, *Schefflera abyssinica* were not observed at this altitude (Table 2).

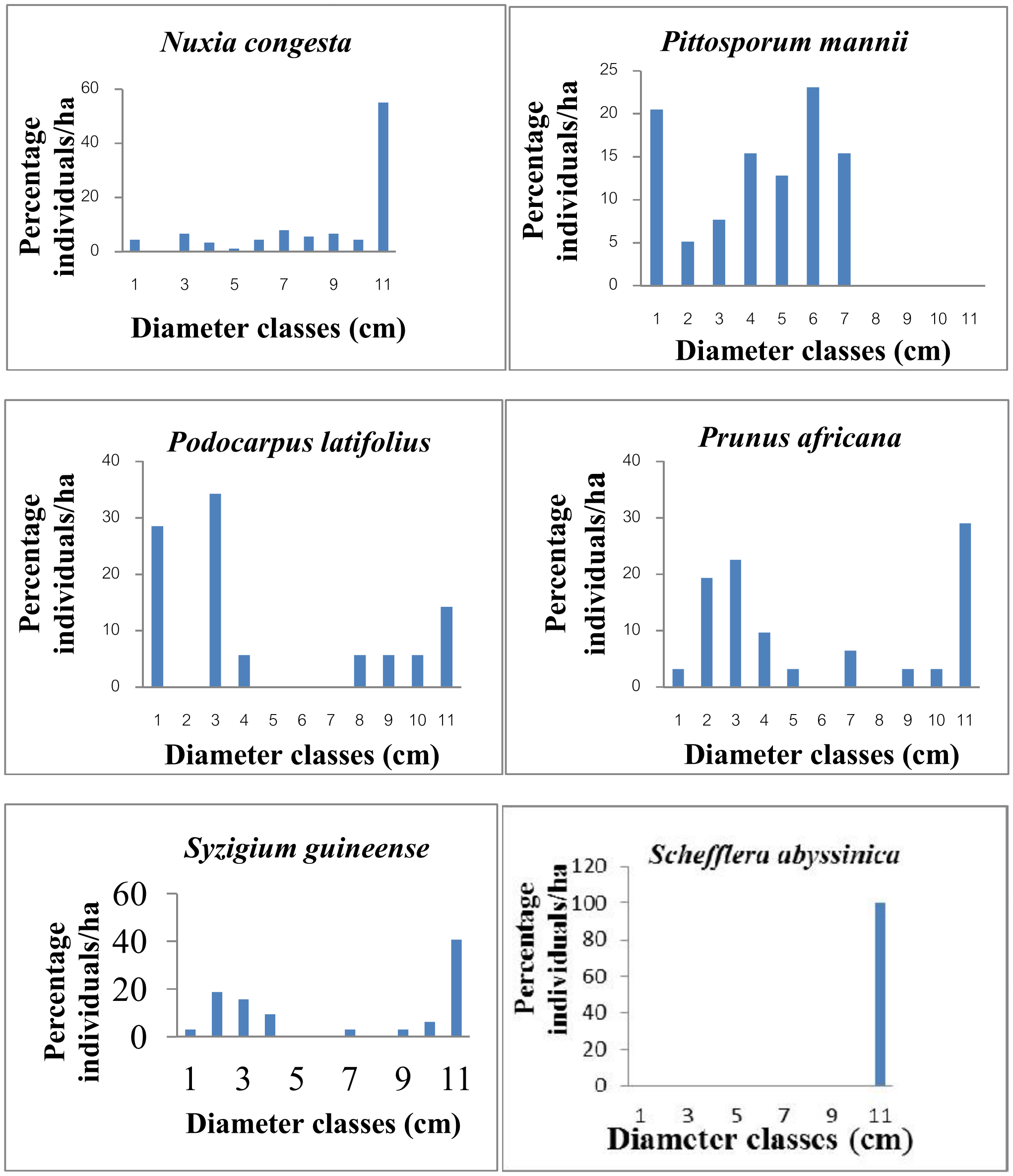

Fig. 4. The stand structure of important tree species at altitude 2377 m in the Kilum-Ijim Forest Reserve [Note DBH class distribution] where, 1) 00-10 cm, 2) 11-20 cm, 3) 21-30 cm, 4) 31-40 cm, 5) 41-50 cm, 6) 51-60 cm, 7) 61-70 cm, 8) 71-80 cm, 9) 81-90 cm, 10) 91-100 cm, 11) > 100 cm

Table 1. Density, Basal area (BA), and Importance Value Index (IVI) of six tree species at three different altitudinal gradients at the Kilum-Ijim Forest reserve, Cameroon

Tree species	Form	Altitude 2377 m			Altitude 2437 m			Altitude 2497 m		
		Density/ ha	BA(m^2/ha))	IVI	Density/ Ha	BA(m^2/ha)	IVI	Density/ ha	BA(m^2/ha)	IVI
Nuxia congesta	Tree	242.5	7141.47	131.91	220	8809.23	123.48	385	13154.7	114.02
(R.Br.Ex.Fresen.)	Pole	12.5	0.17	127.86	7.5	0.05	67.44	30	0.97	110.99
	Sapling	937.50	-	-	937.50	-	-	-	-	-
	Seedling	937.50	-	-	1250.0	-	-	2187.50	-	-
Pittosporum mannii	Tree	122.5	192.39	38.11	75	323.7	25.71	145	446.81	34.24
(Hook.f.)	pole	15	0.19	142.41	2.5	0.01	36.36	20	1.25	108.12
	Sapling	937.50	-	-	-	-	-	-	-	-
	Seedling	1562.50	-	-	-	-	-	2500.0	-	-
Podocarpus latifolius	Tree	87.5	164.92	32.28	32.5	74.82	24.91	122.5	608.81	32.49
(Thunb.) R. Br. Ex Mirb.	pole	2.5	0.01	29.73	-	-	-	2.5	-	17.97
	Sapling	2812.50	-	-	-	-	-	-	-	-
	Seedling	-	-	-	-	-	-	625.00	-	-
Prunus Africana	Tree	77.5	418.06	33.42	45	356.04	29.32	70	348.72	25.71
(Hook.f.) Kalman	pole	-	-	-	5	0.02	48.48	2.5	0.01	18.18
	Sapling	-	-	-	312.50	-	-	-	-	-
	Seedling	-	-	-	312.50	-	-	-	-	-
Schefflera abyssinica	Tree	20	533.04	25.57	25	1593.47	34.41	42.5	2475.66	31.75
(Hochst. ex A. Rich.)	pole	-	-	-	-	-	-	-	-	-
	Sapling	-	-	-	-	-	-	-	-	-
	Seedling	-	-	-	-	-	-	-	-	-
Syzygium guineense	Tree	82.5	836.85	38.72	127.5	2739.89	62.18	160	6570.65	61.8
(willd.) DC	pole	-	-	-	15	0.19	147.71	15	0.22	44.73
	Sapling	-	-	-	-	-	--	-	-	-
	Seedling	312.50	-	-	-	-		625.50	-	-

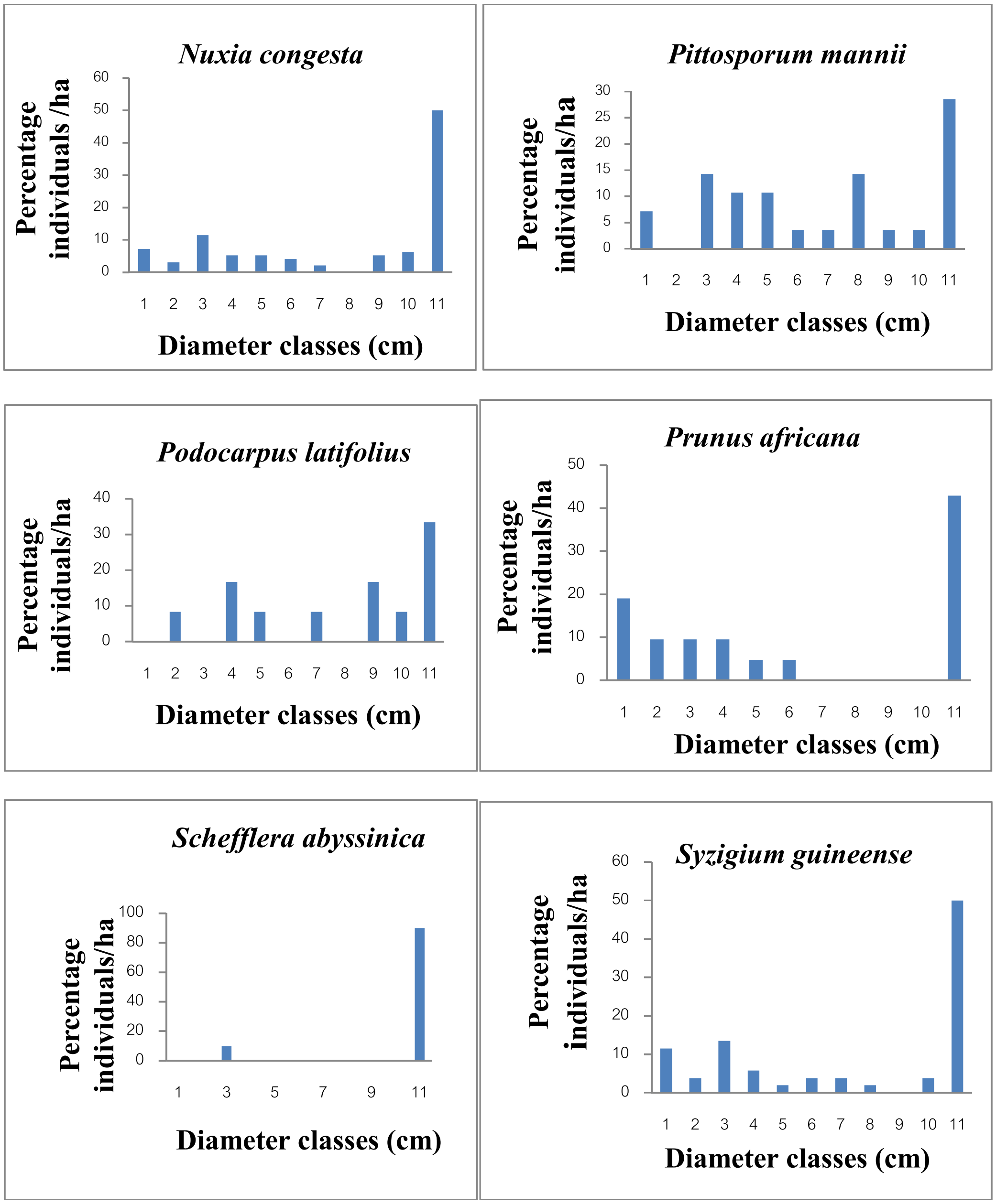

Fig. 5. The stand structure of important tree species at altitude 2437 m in the Kilum-Ijim Forest Reserve [Note DBH class distribution] where1) 00-10 cm, 2) 11-20 cm, 3) 21-30 cm, 4) 31-40 cm, 5) 41-50 cm, 6) 51-60 cm, 7) 61-70 cm, 8) 71-80 cm, 9) 81-90 cm, 10) 91-100 cm, 11) > 100 cm

At altitude 2437 m, the trees of *N. congesta*, *P. latifolius* and *P. africana* showed uniform distribution pattern (Table 2). The trees of *P. mannii*, *S. abyssinica* and *S. Guineense* showed clumped dispersion pattern (Table 2). The poles of *N. congesta*, *P. africana* and *S. guineense* showed uniform distribution pattern while the poles of *P. mannii* had clumped distribution pattern (Table 2). The poles of *P. latifolius* and *S. abyssinica* were not observed at this altitude (Table 2).

The sapling of *N. congesta* showed a uniform distribution pattern at this altitude 2437 m (Table 2). The saplings of *P. africana* had clumped distribution pattern while those of *P.mannii*, *P. latifolius*, *S. abyssinica* and *S. guineense* were absent at this altitude. At this altitude the seedling of *N. congesta* displayed uniform distribution pattern (Table 2) while the seedling of *P. africana* showed clumped distribution (Table 2). The seedlings of *P. mannii*, *P. latifolius*, *S. abyssinica* and *S. guineense* were absent (Table 2).

At altitude 2497 m the trees of *N. congesta*, *P. mannii* and *P. africana* showed a clumped distribution pattern (Table 2). The trees of *P. latifolius*, *S. abyssinica* and *S. guineense* showed uniformed distribution pattern (Table 2). The poles of *N. congesta*, *P. mannii* and *S. guineense*also showed a uniformed distribution pattern (Table 2). The poles of *P. latifolius* and *P. africana* showed clumped distribution pattern (Table 2). The poles of *S. abyssinica* were not observed at this altitude. At altitude 2497 m, the saplings of *N. congesta*, *P. africana*, and *Syzygium guineense* had a clumped distribution pattern (Table 2) while those of *P. latifolius* showed uniform distribution pattern. The saplings of *P. mannii* and *S. abyssinica* were absent (Table 2). The seedlings of *N. congesta* showed uniformed distribution pattern (Table 2) while seedlings of *P. latifolius* and *S. Guineense* had

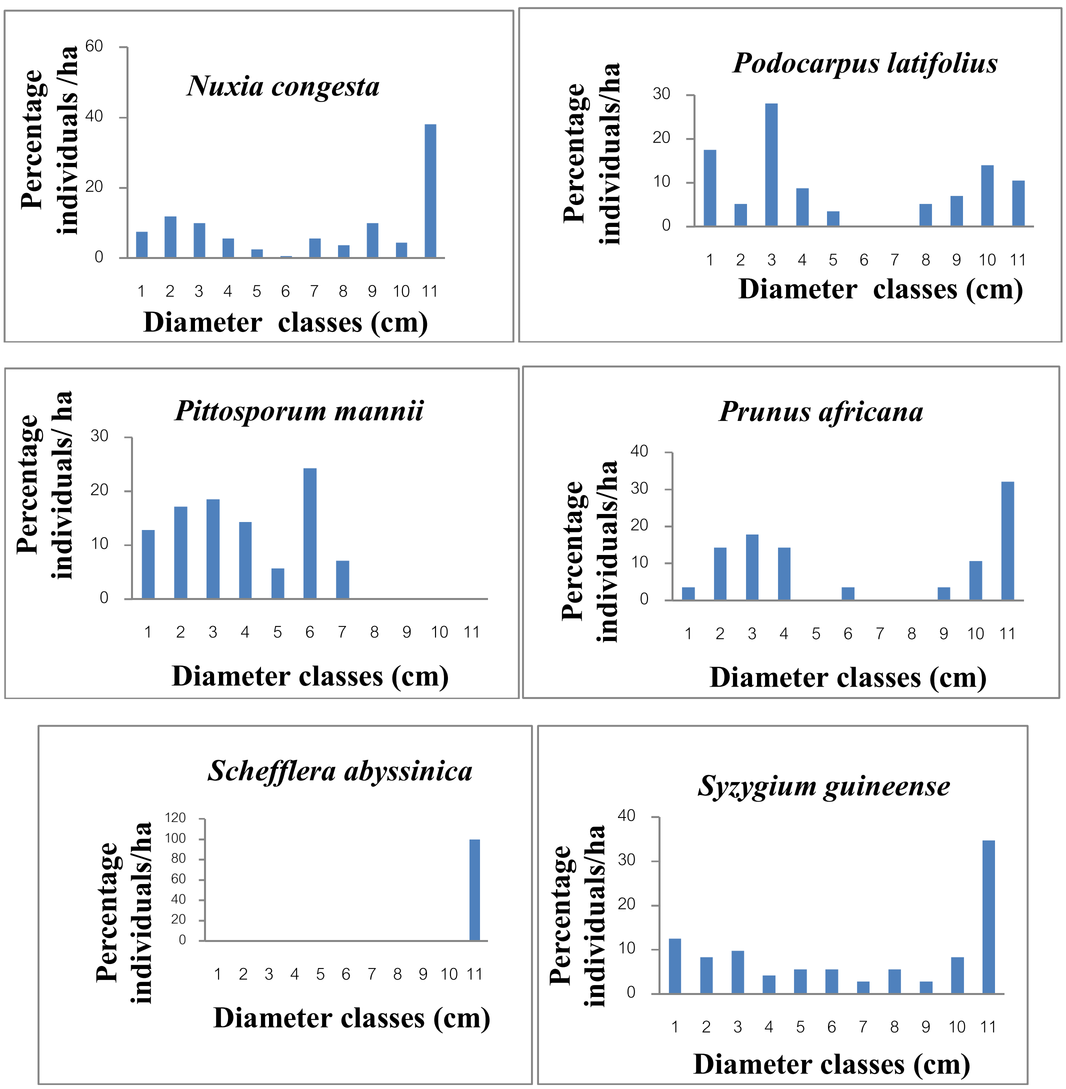

Fig. 6. The stand structure of important tree species at altitude 2497 m in the Kilum-Ijim Forest Reserve [Note DBH class distribution] where, 1) 00-10.cm, 2) 11-20cm, 3) 21-30cm, 4) 31-40cm, 5) 41-50cm, 6) 51-60cm, 7) 61-70cm, 8) 71-80cm, 9) 81-90cm, 10) 91-100cm, 11) > 100 cm

Table 2. Distribution patterns of six tree species at three different altitudinal gradients at Kilum-Ijim Forest Reserve, Cameroon

Tree species	Form	Altitude 2377 m		Altitude 2437 m		Altitude 2497 m	
		Ip	DP	Ip	DP	Ip	DP
Nuxia congesta	Tree	0.61	C	-1.87	U	0.66	C
	Pole	0	Ra	-1.05	U	-0.18	U
	Sapling	-1.58	U	-0.35	U	0.24	C
	Seedlings	-1.05	U	-2.11	U	-0.32	U
Pittosporum mannii	Tree	-0.5	U	1	C	0.5	C
	Pole	-0.18	U	1	C	-0.53	U
	Sapling	-0.35	U	-	-	-	-
	Seedlings	-2.11	U	-	-	-	-
Podocarpus latifolius	Tree	-0.5	U	-2.76	U	-0.43	U
	Pole	-	-	-	-	0.03	C
	Sapling	-0.32	U	-	-	-0.5	U
	Seedlings	-	-	-	-	0.08	C
Prunus africana	Tree	-0.85	U	-0.6	U	0.72	C
	Pole	-	-	-0.53	U	0.03	C
	Sapling	-	-	1	C	0.24	C
	Seedlings	-	-	1	C		-
Schefflera abyssinica	Tree	-1.84	U	0.73	C	-0.25	U
	Pole	-	-	-	-	-	-
	Sapling	-	-	-	-	-	-
	Seedlings		-	-	-	-	-
Syzygium guineense	Tree	-0.26	U	0.51	C	-0.66	U
	Pole	-	-	-2.63	U	-2.63	U
	Sapling	-	-	-	-	0.24	C
	Seedlings	1	C	-	-	0.08	C

- Indicate absence of species, U= Uniform dispersion, C=Clumped dispersion, Ra= Random, Ip = standardised Morisita's index

clumped distribution pattern. The seedlings of *P. mannii*, *P. africana* and *S. abyssinica* were not also observed at this altitude (Table 2).

3.6 The Regeneration Status of Six Important Tree Species along Altitudinal Gradients

At altitude of 2377 m, the regeneration status of *N. congesta* and *P. mannii* were fair (Table 3). *P. latifolius* and *S. guineense* had poor regeneration while *P. africana* and *S. abyssinica* had no regeneration (Table 3). At altitude 2437 m, *N. congesta* showed fair regeneration while the regeneration status of *P. africana* was poor (Table 3). *P. mannii*, *P. latifolius*, *S. abyssinic* recorded no regeneration (Table 3).

At altitude 2497 m, the regeneration status of *Nuxia congesta*, *Pittosporum mannii*, *Podocarpus latifolius* and *Syzygium guineense*showed fair regeneration (Table 3). *Prunus africana* showed poor regeneration at this altitude while *Schefflera abyssinica* had no regeneration (Table 3).

4. DISCUSSION

Information on species composition, stand structure and distribution patterns are fundamentals for the conservation of natural areas as these patterns have frequently been the focus on ecological studies. The knowledge on the floristic compositions of plant community is a prerequisite to understand the overall structure and functioning of an ecosystem. However, regular human interventions like overgrazing, timber exploitation, non-timber forest products collection (NTFPS) and encroachments of forest areas (settlement, agriculture) are among the key regulatory factors controlling the distribution of plant species [19]. Furthermore, altitude is also one of the most important factors which determine the distribution of tree species due to its direct effect on the microclimatic conditions of the habitat [20].

Table 3. The regeneration status of six important tee species /ha along altitudinal gradients in selected sites in the Kilum-Ijim Forest Reserve

Species	Forms	Elevation (m)		
		2377 m	2437 m	2497 m
Nuxia congesta	Tree	54	88	86
	Pole	12	8	6
	Sapling	4	1	3
	Seedling	7	4	3
	Status	F	F	F
Pittosporum mannii	Tree	58	29	35
	Pole	8	2	6
	Sapling	-	-	3
	Seedling	8	-	5
	Status	F	N	F
Podocarpus latifolius	Tree	49	13	25
	Pole	1	-	1
	Sapling	8	-	9
	Seedling	2	-	-
	Status	F	N	P
Prunus africana	Tree	29	18	31
	Pole	1	4	-
	Sapling	1	2	-
	Seedling	-	-	-
	Status	P	P	N
Schefflera abyssinica	Tree	17	10	8
	Pole	-	1	-
	Sapling	-	-	-
	Seedling	-	-	-
	Status	N	N	N
Syzygium guineense	Tree	64	51	32
	Pole	6	6	-
	Sapling	1	-	-
	Seedling	2	-	1
	status	F	N	P

-absence of species, G = good regeneration, F = fair regeneration, P = poor regeneration, N = no regeneration

In this present study the tree, poles saplings and seedlings densities of *Nuxia congesta*, *Pittosporum mannii*, *Podocarpus latifolius*, *Schefflera abyssinica* and *Syzygium guineense* increased with increase in altitude. Such trends were also reported by [21], in various forest communities in Great Himalayan National Park (GHNP) in north western Himalaya. The increase in densities for these species with altitudes may be due to little anthropogenic activities at higher altitudes as compared to the lower altitudinal gradients. However, *Prunus africana* did not show any trends in trees, poles, saplings, and seedlings densities along altitudinal gradients. It was noticed to be higher at the lower altitude and slightly higher in the higher altitudes. The densities were lowest at the mid altitudinal gradients. [22], in their work along the slopes of mount Cameroon mentioned the unsustainable harvesting of the backs of the trees could have resulted to the dead of the trees leading to low densities of the trees and seedlings. In a similar work in Adamawa region [23], also reported poor tree densities at the different altitudinal levels. The authors noted that most of the tree stands were totally debarked or felled for their barks resulting in low trees and seedling densities at the different altitudinal gradients. The basal areas of *N. congesta*, *P. mannii* and *Schefflera abyssinica* increased with increase in altitude. Similar trends were reported by [24], who worked on tree species composition and richness along altitudinal gradients. Probably, the high basal area at the high altitudes could be due to the remote nature of the area which limited access and reduced extractions of the bark. On the other hand the basal area of *Prunus africana* decreased with increase in altitudinal gradients. This results is in contrast with that of [23] who noticed a decreased in *Prunus africana* at lower altitudes than at higher altitudes in the Adamawa plateau. [22], working along the slopes of mount Cameroon observed that other factors influenced the basal area distribution along the slopes. These factors include accessibility, market demand and suitable climatic conditions for the growth of the species. The basal area of *Podocarpus latifolius* did not showed any trend with change in altitude. [6], along altitudinal gradients in different forest cover of Darhal reported similar observation. They attributed to human influence along the different altitudes. In this present study the IVI of *Nuxia congesta* and *Prunus africana* decreased with increased altitudinal gradients. On the other hand, IVI of *Syzygium guineense* increased with increase altitudinal gradients. While *Pittosporum manniiSchefflera abyssinica* and *Podocarpus latifolius* did not show any trend with change in altitudinal gradients. [25], on the effects of altitudes and climate in shaping forest composition reported that IVI represented the dominant species at the different altitudes. The IVI of the different species were higher at altitudinal gradients which suited the tree species to grow and established. This is in line with the findings of [25], on the effects of altitudes and climate in shaping forest composition.

At altitude 2377 m, the stand structure showed a J- shape structure for *Nuxia congesta* and *Schefflera abyssinica.* It was noted that there was a low number of and/or complete absence of individuals in the lower diameter classes and an increase in number of individuals in the upper diameter classes. The findings were different from that of [23] who noticed a reversed J shaped structure of individual at the different diameter classes. The J shaped structured of *Nuxia congesta* and *Schefflera abyssinica* could be attributed by anthropogenic activities occurring within and beyond the forest reserve. The high pastoral activities by the Fulani herdsmen and some natives of the area (cattle grazing, bush fire and nomadic movements) could have resulted to this structure. This finding is in line with [6], who reported distortion of population structures by anthropogenic activities. *Podocarpus latifolius*, *Syzyguim guineense* and *Prunus africana* both showed an Irregular stand structure of individuals in the different diameter classes. However, individuals were observed in all diameter classes. Probably the irregular stand structure could be as result of illegal timber exploitation and NTFPS gathering within the forest reserve. This is in line with works of [26] on population ecology and regeneration and they reported that illegal exploitation and indiscriminate collection of NTFPS could have an influence on the population structure.

At altitudinal gradients of 2437 m and 2497 m, the stand structure showed a J- shaped structure for *Nuxia congesta*, *Prunus africana*, *Schefflera abyssinica* and *Syzyguim guineense*. We recorded a low number of and /or complete absence of individuals in the lower diameter classes and observed increase in number of individuals in the upper diameter classes. Probably, the difficult terrain at the mid and higher altitudes reduced the illegal exploitation of timber and the indiscriminate harvesting of the forest products, thus most of the trees, poles and saplings could not be harvested. [27], mentioned that altitudinal changes can influences the composition and structure of the population. The complete absence of some individuals at the low diameter classes could be linked to poor seed production, low viability of the seeds and absence of suitable condition for seed germination. This finding is in line with works of [28], on ecology of regeneration of seven indigenous trees reported poor seed viability at the different altitudinal levels.

It was observed that the spatial distribution pattern of trees, poles, saplings and seedlings of these important tree species studied were generally clumped. The clumped or aggregated spatial pattern is very common among tropical tree species with minimal perturbations. Most of the saplings, poles and seedlings were adapted to grow close to the mother plant. This is in accordance with the findings of [10] who worked on the spatial distribution of non-timber forest products in the Takamanda National Park. The clumped pattern of distribution may also be attributed to gaps in the forest caused either by natural (wind and landslide) and anthropogenic (bush fire or timber harvest) activities which enabled the species to colonize most disturbed areas. This corroborates the findings [29], who worked on gaps and recruitment of species in disturbed African rainforest at Korup National Park. Poor seed dispersal and poor conditions (moisture levels, temperature, nutrients, light etc) may lead to such patterns [30]. The clumped pattern of some of these important tree species could be attributed to a resource base-niche differentiation resulting to habitat specialization, so that different species are best suited to different habitats, where they are competitively dominant and relatively more abundant [31].

However, some of the Poles, saplings and seedlings species recorded random patterns of distribution at different altitudinal gradients. This may be probably due to the topography of the terrain which provided suitable conditions for growth of species at different altitudinal gradients in the forest. This is in conformity with findings of [10] who worked on the spatial distribution of non-timber forest products in the Takamanda National Park. Perhaps these seedling populations are not dispersal- limited and /or seed to seedling establishment is not limited by both biotic and abiotic factors. This finding is in line with the work of [32] who reported on spatial patterns of trees, sapling and seedling species in tropical forest in West Polynesia. Furthermore, topography is a major physical factor that plays a vital role in seedling composition, growth and distribution in tropical forest. This is attributed to the fact that in many parts of the tropical montane forests, an extraordinary variety of wet and dry habitats exist in close proximity due to extremely broken terrain with differently exposed slopes. In this case the upper and lower part of the forest may be receiving different amounts of rainfall, sunshine and windy conditions leading to different vegetation types and contributing to high species richness in mountain forests.

The occurrence of a sufficient number of poles, saplings and seedlings in a given forest population indicates successful regeneration [6]. The above three life stages for these important tree species signify the probable forest structure in future. The present study showed that regeneration of the six tree species in the Kilum-Ijim forest reserve along the three altitudinal gradients is generally poor. Though the regeneration status of the six tree species along altitudinal gradients were generally low, it has been observed that some of the tree species were regenerating fairly (*N. congesta* and *P. mannii*) or not regenerating at all (*S. abyssinica*). This finding is in line with that of [6] who reported that the regeneration status was poor in the forests as survival from saplings to poles was found to be almost absence in all the studied sites of dominant tree species along altitudinal gradient. The poor seed germination along altitudinal gradients in this study could be attributed to anthropogenic pressures and natural disturbances along the different altitudinal gradients.

5. CONCLUSION

The present study revealed that the six tree (seedlings, saplings, poles and trees) species along altitudinal gradients generally showed a J-shaped population structure at the different altitudinal gradients. More of the tree individuals were noticed at the mature stage as compared with the seedlings and sapling stages.

The spatial distribution patterns showed clumped, irregular and regular distribution patterns. We noticed at the lower and mid elevation levels the distribution patterns were mostly irregular and clumped at the higher elevations.

The present study showed that the regeneration of the Kilum-Ijim forest was generally poor, it was observed that there were few tree species which were either regenerating fairly; *N. congesta* and *P. mannii* or no regeneration at all *S. abyssinica*. The poor regeneration of these six important tree species in the Klim-Ijim forest reserve warrants the immediate attention of forest managers and local forest dependent communities to look into reforestation and afforestation programs for these species and for sustainable management of the forest reserve.

6. RECOMMENDATION

This study recommends a regular patrol by the authorities concern to check illegal logging and harvesting of stem barks and defaulters should be heavily fine. This study also recommends that there should be enrichment planting of these six important trees in this montane forest reserve and other parts of the community. This study also recommended the establishment of forest or community nursery and a seed bank for all the targeted tree species.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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