INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 26, No. 2, p. 81-101, 2025
http://www.innspub.net

RESEARCH PAPER | OPEN ACCESS

Floristic diversity, stand structure and plant life traits of Mount Nlonako forest (Littoral, Cameroon)

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Article published on February 05, 2025

Key words: Floristic diversity, Stand structure, Life forms, Altitude, Mount Nlonako forest

Abstract

Cameroonian mountain forests are regarded as biodiversity concentration areas. These forests, already naturally isolated from each other within the country due to climatic or geomorphologic variations, are today extremely fragmented by anthropogenic activities. This study was aimed to assess the floristic diversity and characterizing the population structure of Mount Nlonako Forest. In total, 80 quadrats of 40 m × 40 m (12.8 ha) were established with respect to altitudes (lower altitude (A) and higher altitude (B)) in the Mount Nlonako forest. All individuals having a diameter at breast height (DBH) of 10 cm or greater were identified in each established quadrat. A total of 6,181 trees (3,720 at lower altitude (A); 2,461 at higher altitude (B)) were categorized into 278 species (177 at A; 203 at B), belonging to 177 genera (111 at A; 144 at B) and 52 families (40 at A; 46 at B). *Sterculia rhinopetala* and *Pycnanthus angolensis* were the predominant plant species at elevated and lower altitude, respectively. The predominant plant groups (FIV) in terms of families were Fabaceae and Myristicaceae at elevated altitude, whereas Malvaceae and Apocynaceae were prevalent at lower altitude. The Shannon-Wiener index value of 3.12 bits in the entire study area (3.17 bits at A; 3.14 bits at B) indicates that the Mount Nlonako forest is less diversified but has a good distribution of species within individuals (Pielou's index ≥ 0.89) as well as individuals within species (Simpson's index ≥ 0.93). Average stand density ranges from 585.5 stems/ha (A) to 384.53 stems/ha (B). The distribution of trees by diameter class reveals a majority of shrubs and a few large trees. The abundance of mesophanerophytes suggests adaptive plant strategies similar to the striving approach. The dominance of Guinean-Congolese domain species demonstrates a remarkable regeneration of species in this forest despite anthropogenic pressures. This emphasizes the vital necessity for the conservation of this area.

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Introduction

Tropical rainforests are vital ecosystems and one of the world's most species-rich biomes (Hill and Hill 2001). The Congo basin forests, the second biggest tropical forest ecosystem after the Amazon, are the richest ecosystems and play an essential role in regional and global climate systems (De Wasseige *et al.*, 2012; Kamga *et al.*, 2018; Temgoua *et al.*, 2018; Dalimer *et al.*, 2022). These forests offer a living for around 60 million nearby inhabitants while also serving social and cultural activities (De Wasseige *et al.*, 2012). Apart from those who live in the forest, many other people rely on forest products for heating, food, medicine, and other non-timber forest services (Megevand, 2013; Kamga *et al.*, 2019). However, these ecosystems are now threatened by global climate change and regional/local anthropogenic factors, of which deforestation and forest degradation are two of the most important (Kengne *et al.*, 2018). Deforestation in the Congo basin is associated with population density and related subsistence activities (agriculture and energy), which typically occur at the expense of the forest and may have a negative impact on environmental services, such as biodiversity loss and reduced carbon sequestration potential (Nguimdo, 2017; Momo *et al.*, 2018; Temgoua *et al.*, 2018).

Tropical forests, particularly those in West and Central Africa's mountains, are regarded as high biodiversity concentration zones in Africa and around the world (Bergl *et al.*, 2007). The biodiversity in these mountain zones, notably those in Cameroon, is double that of the remaining sub-Saharan African forest (Ngomin and Mvongo, 2015). Despite their ecological and social importance, a variety of behaviors, including agriculture, hunting, logging, and human habitation prompted by demographic increase, contribute to widespread deforestation in Cameroon (Sainge, 2018). Logging and non-timber exploitation have an impact on species structure in an ecosystem. Thus, large-scale timber exploitation promotes not only the destruction of adjacent plants but also soil erosion, resulting in a significant decrease in species diversity and forest regeneration capability (CIFOR, 1998). As a result, the degradation of these woody resources affects all agro- and socio-ecological aspects of life, both locally and worldwide (Mbaiyetom *et al.*, 2021). Many studies have been carried out on mountain zones along the Cameroon volcanic line, notably on Mt. Cameroon (Cable and Cheek, 1998), the Bamboutos mountains (Tiokeng *et al.*, 2019), Mount Oku (Kemeuze *et al.*, 2009; Momo, 2009; Momo *et al.*, 2018), and Mount Kupe (Tchiengue, 2004), with the aim of knowing the floristic diversity, species distribution, and different vegetation types with respect to latitude and to provide important data for forest management. Although a clear and precise description of the influence of altitudinal gradients on vegetation layering was studied nearly two centuries ago, these gradients may not be as visible today in these ecosystems, particularly as they are subjected to local and global changes caused by humans (Mbaiyetom *et al.*, 2021).

The IUCN has attempted to protect the majority of important biodiversity areas around the world, including Cameroon, in order to conserve its biodiversity, but there are still many areas of high importance that are not yet protected and are experiencing biodiversity and habitat loss, owing to high anthropogenic activities and natural factors (Mingang *et al.*, 2022).

Mount Nlonako Forest in the Littoral Region is an excellent example of such a place, as it is home to a diverse range of animal and bird species, some of which are peculiar to the region (Herrmann *et al.*, 2005). Mount Nlonako is a nature forest home to the world's largest amphibian species (*Conraua goliath*), the majority of which are critically endangered and peculiar to this region (Hermann *et al.*, 2005; Bergl *et al.*, 2007; Fonkwo *et al.*, 2011). It is one of the most endemism-rich areas, with 17 animal species (10 amphibian species out of 93 found in the area, 4 reptile species out of 89 found in the area, and 3 bird species out of 267 found in the area) (Herrmann *et al.*, 2005) and some plant species that have yet to be geoclassified, some of which may be endemic to this area. Of the 93 amphibian species identified on Mount Nlonako, 31 are endemic to Cameroon (Herrmann *et al.,* 2005). However, this mountain forest is still subjected to a variety of activities such as illegal logging, road construction, farming, mining, charcoal burning, bushfires, and overexploitation of non-timber forest products (NTFPs), resulting in the destruction of its plant biodiversity, which serves as a primary habitat for these animal species. Although floral endemism is common in this region (Letouzey, 1985), plant species are little recorded (Cheek and Onana, 2021). Despite the fact that the Mount Nlonako forest area has a rapidly growing population, which could be one of the key drivers of land degradation to fulfill the increasing need for food and urban expansion, very few studies have been conducted to estimate forest loss and propose its sustainable management. The primary goal of this study was to assess the floristic diversity, composition, and structure of the vegetation of the Mount Nlonako forest (Littoral Cameroon) under the influence of anthropogenic activities in order to aid in the conservation of the area.

Materials and methods

Study site

The present study was conducted in the Mt. Nlonako forest, located in the Moungo division of Littoral Cameroon, between latitudes 4° 49′- 4° 56’ North and longitudes 9° 56'- 10° 01′ East (Fig. 1). It encompasses approximately 3,500 ha (Hermann *et al.*, 2005). Its slopes are covered by humid montane forest up to a 1825 m high peak (Tchoua *et al.*, 1972; Mahmoud *et al.*, 2020). Its location outside the long mountain range that goes from Mount Kupe to Mount Oku gives it the appearance of a small massif with rounded shapes. The climate is humid pseudo-tropical with a unimodal rainfall regime, with two seasons: a long rainy season that goes from March to October and a short dry season that goes from November to February.

Precipitation is abundant and varies with altitude: Nkongsamba (877 m, 2 684 mm), Nlonako (1 825 m, 3 000 mm), and Nkondjock (339 m, 2 000 mm) (Valet, 1985). The average temperature is 26°C at Nkongsamba, 20°C at the top of the mountain, and 27°C at Nkondjock. Precambrian granite, gneiss, and lateritic soils are common in the area (Kenfack, 2001). The vegetation is a dense humid semi-deciduous forest dominated by species belonging to families of Myristicaceae, Fabaceae, Olacaceae, Bombacaceae, and Anacardiaceae as the most dominant (Sainge *et al.*, 2018). Subsistence farming is the main activity of the local communities. Cultivation of cash crops such as cocoa and coffee is considerably represented (Tsewoue *et al.*, 2020).

Data collection

Base on work that has previously been conducted in tropical forests precisely those of Cameroon (Momo, 2009; Kamga *et al.*, 2019; Tchaleu *et al.*, 2024), 80 phytodiversity plots of 40 m × 40 m were established at two altitudinal zones of Mount Nlonako, 40 plots at altitude between 300m and 750 m (Zone A) and 40 plots at altitude between 800m and 1500m (Zone B) of Mount Nlonako forest. Altogether, 12.8ha of forest land were sampled where inventory of plants with a DBH (diameter at breast height) of ≥ 10 cm was conducted at 1.3 m from ground level using a diameter tape (Momo *et al.*, 2023). The diameter was then deduced using the formula C=3.14d (where C represents the circumference and d the diameter). Plant identification was done directly in the field by the assistance of a plant botanist who had knowledge in identifying plant species of the area using common identification criteria such as leaf type and arrangement, trunk and morphology, rhytidome nature and bark (Letouzey, 1982) and used by Tiokeng *et al.* (2019). Unidentified plant species were harvested and taken to be compared with those of the National herbarium in Yaounde, Cameroon for further identification. The taxonomy nomenclature which was adopted for this study was that of Phylogenic botanical classification of angiosperms (APG III, 2009). Determination and classification of life forms was done base on the location of species in the vertical stratification of the ecosystem which designate the potential of plant species to occupy space and seasons (Kassi, 2006).

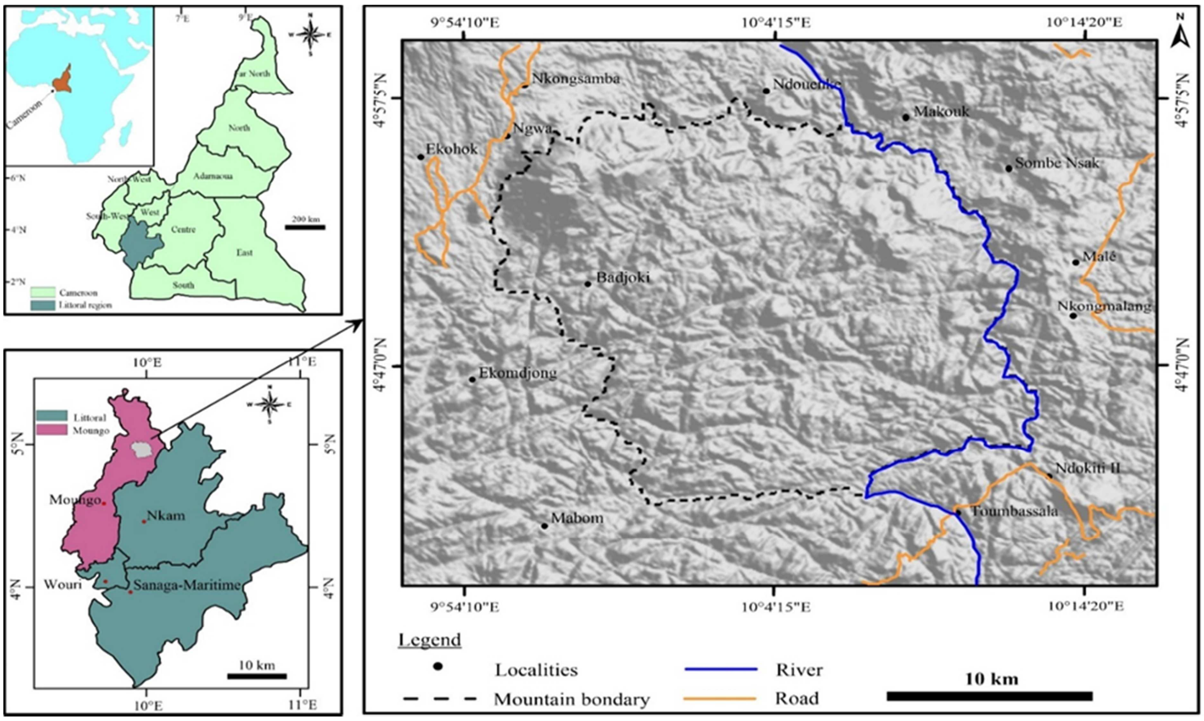

Fig. 1. Location of Mount Nlonako in Littoral region of Cameroon

Analysis of field data

Species composition was expressed using the following parameters:

Stand structure parameters

Relative frequency (RF), which is the ratio expressed as a percentage of the number of plots where the taxon is present over the total number of plots. It is obtained from the following formula.

RF=Ai/nB*100

Where Ai=Number of plots containing the species i and nB=total number of plots surveyed.

Relative density (RDen), which stands for the total number of individuals of a species all over the total number of individuals of all species sampled multiplied by a hundred (RDen = Pi*100, where Pi=ni/N, ni is the number of individuals belonging to taxon i, and N is the total number of individuals of all the plots sampled).

Relative dominance (RDom), which tells us the degree at which a taxon (species, family) is more numerous than its competitors in an ecological community, is calculated using the formula: RDom = BAi/NBA*100, where BAi is the basal area of a given species and NBA is the total basal area in the sample unit.

Relative diversity (RDiv), which is given by the formula: RDi = number of species of one family/total number of species*100.

Density, which is the number of stems per hectare, was calculated using the formula D = ni/A, where ni is the number of individuals of species i and A is the area in hectares.

Basal area (BA), which is the area of a given section of land that is occupied by the cross-section of tree trunks and stems at the base, was calculated using the formula: BA = $(\sum \pi Di)^2/4$, where D is diameter at breast height and S in m^2/ha (Mbaiyetom *et al.*, 2021).

- Important Value Index (IVI), which helps us to know the importance of each species with respect to other species in the study site, was calculated by summing the relative density, relative frequency, and relative dominance (IVI=RF+RDen+RDom) of species (Kent and Coker, 2003).

Family important value, which helps us to know the importance of each family with respect to other families in the study site, was obtained by summing the relative density, relative frequency, and relative dominance (FIV=RDen+RDiv+RDom) of families.

Indices of diversity

Specific diversity of the area was described using the following indices:

Species richness was determined by tallying all species inventoried (Yap *et al.*, 2016).

Simpson's diversity index (D), which presents the probability that if two species are taken randomly in a population studied, they belong to the same species, is computed using the formula: $D=\sum (Ni/N)^2$, where Ni is the total number of individuals of a species i and N is the total number of individuals of all species.

Shannon and Wiener diversity index, which measures the uncertainty as regards an individual taken at random belonging to a species in the sample unit. It increases with an increase in diversity and is calculated by using the formula: $H' = -\sum (ni/N) \text{Log2} (ni/N)$, where ni is the number of species i and N the total number of species (Shannon and Wiener, 1949).

Pielou's equitability index, which makes it possible to measure the distribution of individuals within species, determining specific richness (Adamou, 2010). It is calculated by using the formula: $Eq= H'/Hmax=H'/lnN$, where Eq is Pielou's index, H= Shannon diversity index, N= total of species (Pielou, 1975).

Functional spectrum of species

In order to characterize the vegetative type of the area, observations were done based on the characteristics related to diaspore type, mode of dispersal, biological type, and phytogeographical distribution. These life traits were accessed globally without taking into consideration altitudinal level.

Types of diaspores and modes of dispersal were determined by the observations of species in the field taken from Senterre (2005).

Biological types were defined based on the classification of Raunkier (1934) and used by other authors (e.g. Momo, 2009).

Phytogeographical elements were obtained by using the distribution of species found in other floras in works of many authors (e.g. Momo, 2009; Kamga, 2014; Tchuikoua and Banaga, 2016; Onana, 2019; Souza and Eisenlohr, 2020).

Results

Floristic diversity

The floristic inventories carried out in the different altitudinal zones (Altitude 300 m–750 m and Altitude 800 m–1500 m) of the Mount Nlonoko forest permitted us to identify 6181 individuals belonging to 278 plant species, 177 genera, and 52 plant families. This species richness varied with respect to altitudes. At higher altitude (Zone B, 800 m-1500 m), 2461 individuals were censused as belonging to 203 plant species, 144 genera, and 46 families, while at lower altitudes (Zone A, 300 m-750 m), 3720 individuals were inventoried as belonging to 133 plant species, 111 genera, and 40 families. Globally, the specific diversity was 21.71 species/ha, which varied with differences in altitude. At higher altitude, specific diversity was 31.71 species/ha and 20.78 species/ha at lower altitude. It emerges from analyses that relative frequency varies also with altitude. At higher altitude, four species (1.97% of the total species inventoried at this level) (*Pycnanthus angolensis* (3.03%), *Pseudospondias microcarpa* (2.94%), *Strombosia grandifolia* (2.78%), and *Oncoba glauca* (2.78%)) had a relative frequency of ≥ 2.5% each. Twenty-five species (12.31%) had a relative frequency ranging between 1% and 2.4%, some of which include *Polyanthia suaveolens* (2.13%), *Pterocarpus soyauxii* (2.04%), *Trichilia welwitschii* (1.88%), *Tabernaemontana penduliflora* (1.88%), *Klainedoxa trilesii* (1.80%), and *Uapaca guineensis* (1.64%). The remaining species (85.71%) had a relative frequency of < 1% at this level. At lower altitude this time around, *Strombosia grandifolia* (2.6 8%), *Sterculia rhinopetala* (2.61%) and *Desbordesia glaucescens* (2.54%) had a relative frequency of ≥ 2.5% each.

Thirty-nine species (29.32% of all species inventoried) had a relative frequency ranging between 1% and 2.4%, some of which include: *Rinorea* sp. (2.033%), *Baphia leptobotrys* (2.33%), *Staudtia kamerunensis* (2.26%), *Blighia welwitschii* (2.26%), and *Irvingia gabonensis* (2.26%). The remaining species (67.66% of species inventoried) had a relative frequency of < 1%. Analyses also show that relative density varied with respect to altitude. At higher altitude, 4 species (1.97% of the total species inventoried) (*Strombosia grandifolia* (7.27%), *Pycnanthus angolensis* (5.81%), *Oncoba glauca* (5.71%), and *Pseudospondias microcarpa* (5.49%)) had a relative density of ≥ 5%. Twenty-three species (11.33% of all the species inventoried) had a relative density ranging between 1% and 4.9%, some of which include *Ceolocaryon preusii* (4.51%), *Hylodendron gabunense* (3.37%), *Polyanthia suaveolens* (2.40%), *Tabernaemontana penduliflora* (2.19%), and *Elaies guinensis* (2.03%). The remaining species (86.7%) had a realtive density of less than 1%. At lower altitude, four species (*Strombosia grandifolia* (6%), *Desbordesia glaucescens* (5.95%), *Sterculia rhinopetala* (5.84%), and *Rinorea* sp. (4.85%) (3%) of the 133 species inventoried at this level had a relative density of ≥ 5%. Twenty-six species (19.54% of the species sampled) had a relative density ranging between 1% and 4.8%. Some of these species include *Baphia leptobotrys* (4.66%), *Strombosiopsis tetrandra* (4.63%), *Staudtia kamerunensis* (3.26%), *Paraberlinia bifoliolata* (2.61%), *and Funtumia elastica* (2.48%). The remaining species (77.45% of all the species sampled) had a relative density of less than 1%. Relative dominance also varied with respect to altitude, and for this, at higher altitude, 1.97% of the species sampled at this level had a relative dominance of 4.5%. They include *Pycnanthus angolensis* (12.54%), *Terminalia superba* (10.10%), *Ceolocaryon preusii* (5.52%), and *Bombax buenopozense* (4.72%). Nineteen species (9.35% of all the species inventoried at this level) had a relative dominance ranging between 1% and 4.2%, some of which include *Piptadeniastrum africanum* (4.22%), *Macaranga monandra* (4.05%), *Pseudospondias microcarpa* (2.65%), *Oncoba glauca* (2.55%), *and Duboscia macrocarpa* (2.43%). The remaining species (88.67% of all species inventoried) had a relative dominance of less than 1% at higher altitude. At lower altitude, 4 species (*Sterculia rhinopetala* (6.5%), *Alstonia boonei* (6.44%), *Desbordersia glaucescens* (5.81%), and *Pterocarpus soyauxii* (3.51%), which correspond to 3% of the 133 species inventoried, had a relative dominance of ≥ 3.5%. Twenty-two species (16.54% of all species inventoried) had a relative dominance ranging between 1.18 % and 3.2%, some of which include *Pycnanthus angolensis* (3.18%), *Paraberlinia bifoliolata* (3.17%), *Staudtia kamerunensis* (3.06%), *Rinorea* sp. (2.99%), *and Strombosia grandifolia* (2.72%). All the remaining species (80.46% of the species inventoried at this level) had a relative density of less than 1%.

At the level of altitudes, Fabaceae was still the most diverse family, with a difference in the number of species, 26 species and 18 species at higher and lower altitudes, respectively. This was followed by Rubiaceae (15 species), Meliaceae (13 species), and Annonaceae (12 species) at higher altitude, Malvaceae (9 species), Meliaceae (9 species), and Rubiaceae (9 species) at lower altitude. The most dominant species (*Pycnanthus angolensis* at Zone B and *Sterculia rhinopetala* at Zone A) occupied more space at higher and lower altitudes, respectively. Myristicaceae and Fabaceae were the most dominant families at higher and lower altitudes, respectively. The specific quotient, or the ratio of the number of species over the number of genera in Mount Nlonako forest, was 1.58, which varied at altitudes. 1.41 was obtained at higher altitude and 1.21 at lower altitude.

Globally (altitudes combined), Shannon's value obtained in the area was 3.12 bits, which varied with altitude. A value of 3.14 bits and 3.17 bits were obtained, respectively, at higher and lower altitudes. Simpson's values of 0.94 at higher altitude and 0.93 at lower altitude were obtained. For Pielou's equitability, values of 0.92 and 0.89 were obtained at higher and lower altitudes, respectively (Table 1).

Table 1. Indices of diversity at different altitudes in Mount Nlonako forest

Diversity indices	300m to 750m	800m to 1500m	General
Simpson's index	0.93±0.01	0.94±0.01	0.93±0.02
Shannon's index	3.17±0.23	3.14±0.22	3.12±0.23
Pielou's equitability	0.89±0.03	0.92±0.02	0.89±0.04

Table 2. Species with the highest values of relative frequency, relative density, relative dominance and importance value index of species in Mount Nlonako forest

Scientific names	RF	RD	RDOM	IVI
Higher altitude (800m-1500m)				
Pycnanthus angolensis	3.03	5.81	12.54	21.38
Ceolocaryon preussii	2.53	4.51	5.52	12.57
Terminalia superba	1.06	0.85	10.1	12.01
Strombosia grandifolia	2.78	7.27	1.93	11.99
Oncoba glauca	2.78	5.77	2.55	11.1
Pseudospondias microcarpa	2.94	5.49	2.65	11.08
Hylodendron gabunense	2.62	3.37	2.37	8.36
Piptadeniastrum africanum	1.47	1.14	4.22	6.83
Bombax buonopopozense	0.74	0.53	4.72	5.98
Pterocarpus soyauxii	2.04	1.75	2.14	5.93
Lower altitude (300m-750m)				
Sterculia rhinopetala	2.61	5.84	6.5	14.96
Ceiba pentandra	1.76	1.02	11.99	14.78
Desbordersia glaucescens	2.54	5.95	5.81	14.3
Strombosia grandifolia	2.68	6	2.72	11.4
Alstonia boonei	2.05	1.97	6.44	10.45
Rinorea sp	2.33	4.85	2.99	10.17
Strombosiopsis tetrandra	2.47	4.63	2.39	9.49
Baphia leptobotrys	2.33	4.66	2.16	9.14
Staudtia kamerunensis	2.26	3.26	3.06	8.58
Paraberlinia bifoliolata	1.13	2.61	3.17	6.91

RF: relative frequency, RD: relative density, RDOM: relative dominance, IVI: importance value index

Table 3. Families with highest family importance value with respect to altitudes in Mount Nlonako forest

Families	RD	RDOM	RDIV	FIV
Higher altitude (800m-1500m)				
Fabaceae	10.69	16.24	12.81	39.74
Myristicaceae	12.39	19.77	1.97	34.14
Olacaceae	10.12	5.54	3.45	19.11
Anacardiaceae	7.56	4.62	3.94	16.11
Meliaceae	5.81	3.64	6.4	15.86
Malvaceae	3.58	3.88	6.4	13.86
Annonaceae	5.08	2.08	5.91	13.07
Combretaceae	0.85	10.1	0.49	11.45
Rubiaceae	3.11	0.86	7.39	11.36
Irvingiaceae	3.49	2.93	3.45	9.88
Lower altitude (300m-750m)				
Fabaceae	16.9	17.21	17.29	51.41
Malvaceae	8.75	10.61	6.77	26.13
Apocynaceae	8.34	9.27	5.26	22.88
Irvingiaceae	9.37	8.17	3.76	21.3
Olacaceae	11.09	5.26	3.01	19.36
Bombacaceae	1.02	11.99	0.75	13.77
Myristicaceae	5.11	6.3	2.26	13.67
Meliaceae	3.82	2.29	6.77	12.88
Rubiaceae	3.01	3.04	6.77	12.82
Euphorbiaceae	4.55	2.95	5.26	12.76

Relative frequency (%), RD: Relative density (%), RDIV: Relative diversity (%), FIV: Importance value of families (%)

Indices of ecological importance of species

The ecological importance of species (IVI) disclosed that at higher altitude, *Pycnanthus angolensis* (21.38%), *Ceolocaryon preussii* (12.57%), and *Terminalia superba* (12.01%) were the most important species. One hundred and thirty-three (133) species (65.51% of all species sampled)) had an IVI of less than 1%, some of which include *Dicranolepis disticha* (0.13%), *Sclerodendron* sp. (0.13%), and *Kigelia africana* (0.12%) at higher altitudes *Sterculia rhinopetala* (14.96%), *Ceiba pentandra* (14.78%), and *Desbordersia glaucescens* (14.3%) were the most important species at lower altitude. Sixty-three (63) species (47.36% of all species sampled) had an IVI of less than 1%, some of which include *Fernandoa adolfi-friderici* (0.10%), *Cola ficifolia* (0.10%), and *Morus mesozygia* (0.10%) at lower altitude (Table 2).

Indices of ecological importance of families

Fabaceae (39.74%), Myristicaceae (34.14%). Olacaceae (19.11%), Anacardiaceae (16.19%) and Meliaceae (15.18%) were the most ecologically important families at higher altitude. Thirty families (65.21% of all the families inventoried at this level) had an FIV ranging between 1 and 14% some of which include Malvaceae (13.49%), Annonaceae (13.19%), Rubiaceae (11.51%), Combretaceae (11.46%), and Irvingiaceae (9.95%). The remaining 11 families had an FIV of < 1%, some of which include Lepidobotryaceae (0.55%), Passifloraceae (0.55%), and Thymelacaceae (0.55%). At lower altitude, Fabaceae (51.41%) was the most ecologically important family, followed by Malvaceae (26.13%), Apocynaceae (22.88%), Irvingiaceae (21.30%), and Olacaceae (19.36%). Twenty-nine families (72.5 % of the families inventoried at this level) had an FIV ranging between 1% and 14%, some of which include the following: Bombacaceae (13.77%), Myristicaceae (13.67%), Meliaceae (12.88%), Rubiaceae (12.82%), and Euphorbiaceae (12.76%). The remaining families (6 families) had an FIV of < 1%, some of which include Simaroubaceae (0.81%), Ulmaceae (0.81%), and Putrangivaceae (0.79%) (Table 3).

Stand structure of Mount Nlonako forest

Distribution of species by class diameter in Mount Nlonako forest

The distribution of class diameters of trees in the Mount Nlonako forest (higher altitude (A) and lower altitude (B)) presents a decreasing exponential curve in the form of an inverted J-shape characterizing dense humid forests (Fig. 2). The [10-20[class diameter at both altitudes had the highest number of individuals (A = 1843 individuals; B = 974 individuals).

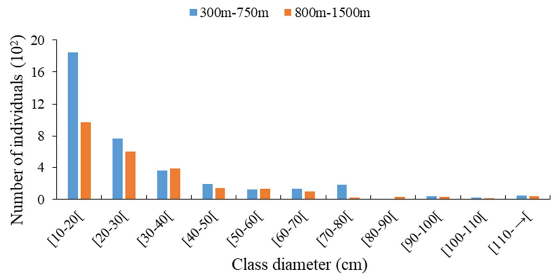

Fig. 2. Diameter distribution of individuals in Mount Nlonako forest

This was followed by [20-30[class diameter (A = 764 individuals; B = 596 individuals). It was noticed that as the diameter increases, the number of individuals decreases progressively. At higher altitude, the ten largest species had a diameter ranging between 200 cm and 290 cm, while at lower altitude, the range was between 136 cm and 143 cm. The mean diameter obtained at lower altitude and higher altitude were 28.63±21.99 cm and 31.47±27.44 cm, respectively.

Tree density and Basal area of species

Globally, a basal area of 112.09 m2/ha and a population density of 482 trees/ha were obtained in the Mount Nlonako forest. This value varied with altitudes. They were greater at lower altitudes (59.48 m^2/ha; 585 trees/ha) compared to higher altitudes (52.61 m^2/ha; 384 trees/ha). *Strombosia grandifolia* (27.97 trees/ha) and *Pycnanthus angolensis* (22.34 trees/ha) had the highest tree density, while *Trichoscypha giletii* (0.16 trees/ha) and *Xylopia villosa* (0.16 trees/ha) had the lowest tree density at higher altitude. At lower altitude, *Strombosia* *grandifolia* (34.34 trees/ha) and *Desbordersia glaucescens* (34.53 trees/ha) had the highest tree density, while *Ricinodendron heudelotii* (0.15 trees/ha) and *Sterculia tragacantha* (0.15 trees/ha) had the lowest tree density. *Ceiba pentandra* (7.54 m^2/ha), *Pycnanthus angolensis* (6.6 m^2/ha) and *Terminalia superba* (5.31 m^2/ha) had the highest basal area, while *Pausinystalia macroceras* (< 0.00 m^2/ha) and Macaranga paxii (< 0.00 m^2/ha) had the lowest basal area at higher altitude. *Sterculia rhinopetala* (4.09 m^2/ha) had the highest basal area, while *Sclerodendron* sp. (< 0.00 m^2/ha) and *Kigelia africana* (< 0.00 m&^{2}/ha) had the lowest basal area at lower altitude.

Table 4. Species with highest basal area and tree density in Mount Nlonako forest

Basal area and tree density of species			
Basal area			
Lower altitude (300m-750m)		Higher altitude (800m-1500m)	
Species	BA (m^2/ha)	Species	BA (m^2/ha)
Ceiba pentandra	7.54	*Pycnanthus angolensis*	6.60
Sterculia rhinopetala	4.09	*Terminalia superba*	5.31
Alstonia boonei	4.05	*Ceolocaryon preussii*	2.91
Desbordersia glaucescens	3.66	*Bombax buonopopozense*	2.48
Pterocarpus soyauxii	2.21	*Piptadeniastrum africanum*	2.22
Pycnanthus angolensis	2.00	*Macaranga monandra*	2.13
Paraberlinia bifoliolata	1.99	*Pseudospondias microcarpa*	1.40
Staudtia kamerunensis	1.92	*Oncoba glauca*	1.34
Strombosia grandifolia	1.71	*Duboscia macrocarpa*	1.28
Strombosiopsis tetrandra	1.50	*Hylodendron gabunense*	1.25
Tree density			
Lower altitude (300m-750m)		Higher altitude (800m-1500m)	
Species	Den (trees/ha)	Species	Den (trees/ha)
Strombosia grandifolia	34.8	*Strombosia grandifolia*	28.0
Desbordersia glaucescens	34.5	*Pycnanthus angolensis*	22.3
Sterculia rhinopetala	33.9	*Oncoba glauca*	22.2
Rinorea sp	28.1	*Pseudospondias microcarpa*	21.1
Baphia leptobotrys	27.0	*Ceolocaryon preussii*	17.3
Strombosiopsis tetrandra	26.9	*Hylodendron gabunense*	13.0
Staudtia kamerunensis	18.9	*Polyanthia suaveolens*	9.2
Paraberlinia bifoliolata	15.2	*Tabernaemontana penduliflora*	8.4
Funtumia elastica	14.4	*Elaies guineensis*	7.8
Tapura africana	14.4	*Staudtia kamerunensis*	7.3

BA: Basal area, Den: Density

Life forms and phytogeographic distribution of species

Based on the type of diaspores, the group of species most represented corresponds to the Sarcochores, which have important proportions of 62.33%, followed by Pterochores (13.21%). Pogonochores, Ballochores, Sclerochores, and Barochores are the least represented (Table 4). The mode of dissemination of grains in the studied population of Mount Nlonako Forest is illustrated in Table 5. It shows that the principal mode of dissemination of grains is zoochory with 65.98% of the species, followed by nemochory with 21.8%, while autochory (12.24%) and barochory (6.7%) were the least represented. The analyses of the biological spectrum indicate that mesophanerophytes are the most dominant biological types in the area with 44.83%, followed by megaphanerophytes and microphanerophytes with 38.43% and 11.5%, respectively. Nanophanerophytes were the least represented, with 1.2% (Table 4).

In general, Omni-guineo-Congolese are the most represented phythogeographic type with 26.38%, followed by Central Guinean-Congolese (20.83%), Guinean inferior (15.36%), and species of linkage 12.88%.

Afro-malagasy, Guinean superior, Sub-guino-congolese, Pantropical, and Afro-tropical species were the least represented in the area with 2.77 %, 4.15 %, 11.5%, 1.38 %, and 4.59%, respectively (Table 5).

Table 5. Functional spectrum of species in Mount Nlonako forest

Functional spectrum	Ecological parameters	Percentage (%)	Cummulative percentage
Types of diaspore	Pterochores	13.21	13.21
	Sarcochores	62.33	75.54
	Ballochores	12.23	87.77
	Sclerochores	4.36	92.13
	Barochores	4.33	96.46
	Pogonochores	3.54	100
Mode of dispersion	Anemochory	11.29	11.29
	Zoochory	63.93	75.22
	Autochory	18.08	93.3
	Barochory	6.7	100
Biological types	Megaphanerophytes	39.43	39.43
	Mesophanerophytes	45.83	85.26
	Microphanerophytes	12.5	97.76
	Nanophanerophytes	2.6	100
Phytogeophical distribution	Central-guino-Congolese	20.83	20.83
	Guinean inferior	15.36	36.19
	Omni-guino-Congolese	26.38	62.57
	Sub-guinean-Congolese	11.5	74.07
	Linkage species	12.34	86.41
	Afro-American	0.69	87.1
	Afro-Malagasy	2.77	89.87
	Pantropical	1.39	91.26
	Guinean superior	4.15	95.41
	Afro-Tropical	4.59	100

Discussion

Floristic composition, richness and diversity

Floristic inventory remains the principal item for understanding floristic diversity, floristic composition, and the state of forests nowadays (Melom *et al.*, 2015). The floristic inventory carried out in the Mount Nlonako forest allowed us to identify 278 forest species grouped into 177 genera and belonging to 52 plant families. At higher altitude (800–1500 m), 203 species belonging to 46 families and 144 genera were inventoried, while at lower altitude (300–750 m), 133 species belonging to 40 families and 111 genera were inventoried. This high specific diversity is due to environmental conditions that favor the growth of these species. Also, the intensity of anthropogenic activities, which turns out to be higher at lower altitude and lower at higher altitude, could also influence the development of species. The reduced human activities at higher altitude could primarily be due to the distance and topography of the area, which make it little or less accessible. Hence, anthropogenic activities reduce with an increase in altitude, as observed by other authors (Sainge, 2018). Also, the number of species in a less disturbed forest is superior to that of a disturbed forest (Konan *et al.*, 2015). Morestill, the elevated values of species richness and diversity in the studied zones could be attributed to diverse ecological niches that accompany changes in relief and altitudinal gradient. Comparing the obtained results with results of other studies, this diversity in terms of number of species, genera and families is higher than values obtained by Tiokeng *et al.* (2019), who observed 168 species grouped into 131 genera and belonging to 61 families in the Fossimondi submontane forest of Mount Bambouto (1000 m – 1900 m). However, these values were lower compared to those obtained by Momo (2009) in Mount Oku Forest (2100 m – 2900 m), who observed 400 species grouped into 260 genera belonging to 90 families, and Sainge (2018) in the Rumpi Hills Forest Reserve (1000 m – 1800 m), who observed 617 species grouped into 279 genera belonging to 71 families. The large difference in the number of species could be because in the study of Momo (2009), herbaceous and tree plants were considered, while in that of Sainge (2018), trees with a DBH ≥ 1 cm were also taken into consideration, which is different from our study where only woody plants with a DBH ≥ 10 cm were considered. Also, the sampling method used by these authors was a nested quadrat system, while in our study, we used a simple quadrat system of sampling.

Even though a relatively high number of species was observed, this method (square plot) does not take into account a better knowledge of the flora (Sonké and Couvreur, 2014) but has an advantage in that it takes into consideration many individuals in different portions of the forest since they are established randomly . In the study of Sonké and Couvreur (2014) in the Dja faunal reserve, a line continue transect method was used, which permitted them to obtain 312 species belonging to 54 families and 213 genera. Comparing the obtained values of species richness with other studies, they are lower to those observed by Gonmadje *et al.* (2011) in the Ngovayang forest (1000 m), Cameroon (293 species), and by Fongnzossie *et al.* (2008) in the Mengamé gorilla forest reserve (800 m), South Cameroon (304 species), and Manfothang *et al.* (2022) in the Ngambe-Ndom-Nyanon Communal Forest (550 m), Littoral Region of Cameroon (395 species). The study of these authors was conducted in protected areas where human activities are low compared to that of our study, especially at lower altitude. Human activities turn out to be less control since they are manage by the government (Temgoua *et al.*, 2021). These differences could also be due to the sample size. It has been demonstrated that there exists a high correlation between sample size and the diversity of a population studied (Sonké and Couvreur, 2014). More globally, little-scale climate variation in relation to relief and altitude determines factors such as temperature and sun exposure, which may explain the spatial and temporal distribution of the taxa along the altitudinal gradient of Mt Nlonako. Indeed, the hilly terrain leads to variations in precipitations and temperatures as well as certain climatic circumstances in submontane areas (presence of fog and clouds) that can contribute remarkably to the high diversity and structure of these ecosystems.

The Shannon diversity index obtained for this study is 3.12 bits. This implies that the forest community of Mount Nlonako is not diversified (rich). According to Kent and Coker (1992), a forest community is considered to be rich when it is characterized by a Shannon diversity index equal to or greater than 3.5 bits. At the altitudinal level, the values of the Shannon diversity index were slightly different: 3.14 bits at higher altitudes and 3.17 bits at lower altitudes. This low diversity recorded in the area could be a result of the high level of anthropization, especially at lower altitudes. This value (3.12 bits) is higher compared to 2.02 bits observed by Tiokeng *et al.* (2020) in the Western Highlands of Cameroon and 3.0 bits by Tiokeng *et al.* (2019) in the Fossimondi community forest of Mount Bamboutos. It was lower compared to 4.46 bits by Tiokeng *et al.* (2015) in the Highlands of Lebialem (2500 m), 3.63 bits, and 3.92 bits by Sunderland *et al.* (2004) in Mount Cristal Forest of Gabon (300 m – 650 m). These differences in the values of the specific quotient and Shannon diversity index could be due to the method of sampling, edaphic and or climatic factors, which could favor the growth of some plants compared to others, thereby increasing their species richness. The values of Pielou's equitability index (0.89 in Mount Nlonako forest, 0.89 at 300 m-750 m, and 0.92 at 800 m-1500 m) obtained for this study enter the range (0.6-0.8) considered by Odum (1976) as being optimal. These results indicate a more or less regular distribution of individuals within species, but also the stability of the forest. At higher altitudes, Pielou's value is higher than at lower altitudes, which therefore means that there is a better distribution of individuals within species at higher altitudes than at lower altitudes. Even though the Mount Nlonako forest has suffered from anthropic pressures, the values of Shannon and equitability indices show that the vegetation is still diversifying to a certain extent. The value of the Simpson index is very sensible to the partition of species within individuals in a population. It is an index that represents directly the heterogeneity of a studied population. The value of Simpson noted for this study is 0.93 and ranges between 0.93 and 0.94 with altitudes. High values of this index imply a weak organization of the ecological system and correspond, according to Dajoz (1982), to environmental conditions favoring the establishment of many species represented by a small number of individuals, while low values are characteristic of a population where the species are dominant. This value of equitability (0.93) is greater than that obtained by Tiokeng *et al.* (2019) in the Bangang mid-altitude forest of the Bambouto Mountain (0.83). Hence, the high values of Simpson imply a good repartition of species within individuals in the Mount Nlonako forest.

The specific richness per hectare gave us a value of 21.71 species/ha. This low average value of species richness per hectare could be due to the high anthropic activities, especially at lower altitude, which eventually lead to biodiversity loss, thereby reducing the species diversity of the area. The values of specific richness obtained are lower compared to those of Tiokeng *et al.* (2019) in the Fossimondi submontane forest (42 species/ha) and Bangang mid-altitude forest (32.2 species/ha) of Mount Bambouto in Western Cameroon and Momo (2009) in Mount Oku forest (24.5 species/ha) in North West Cameroon. The difference in the number of species could be due to the sample size in each study. The sample size used by Tiokeng *et al.* (2019) (9 hectares) was low compared to the sample size used in our study (12.8 hectares), while that of Momo (2009) (16.32 ha) was greater than the sample size used for this study. Many studies carried out in other forest ecosystems of Cameroon and in Central Africa show values that are higher than those in our study. The value obtained is far lower to those observed by Gonmadje *et al.* (2011) in the Ngovayang forest in South Cameroon (105.5 species/ha), Sunderland *et al.* (2004) in the Takamanda forest reserve in the south-west of Cameroon (100 species/ha), and Balinga (2006) (106 species/ha) in the Waka national park of Gabon. The high specific richness in plant formations also reflects a high variability of niches and therefore biotic and abiotic factors favorable in the development of a large number of species (Tiokeng *et al.*, 2015). These differences in the number of species observed per hectare could be due to the surface area sampled and also due to the type of habitat or, moreover, due to the difference in temperature, which could favor the growth of plant species in these forests.

Characteristic families of this area (Mount Nlonako Forest) were Fabaceae, Olacaceae, Myristicaceae, Irvingiaceae, Malvaceae, Apocynaceae, Cecropiaceae, Phyllantacaee, and Combretaceae, which characterize the floristic background of typically dense humid forests with high anthropic pressures (Beina, 2011; Melingui *et al.*, 2017; Sainge *et al.*, 2018).

Regarding the diversity of plant families, Fabaceae was the most diversified plant family with 43 species, followed by Malvaceae (18 species), Meliaceae (18 species), Rubiaceae (18 species), and Annonaceae (15 species) in Mount Nlonako forest. Fabaceae was also the most represented, dominant, and most diversified plant family at both altitudes (26 species and 23 species at higher and lower altitude, respectively). This diversity is however very low compared to that of Cheek *et al.* (2004) in the Kupe-Mwanenguba-Bakossi mountains of Cameroon (137 species) but higher to that of Momo (2009) in Mount Oku (16 species). The difference in the number of species could be due to the sample size. Hence, an increase in surface area leads to an increase in the number of species inventoried (Melom *et al.*, 2015).

Another reason that can explain the high diversity of Fabaceae is that species in the family Fabaceae adapt to a broad range of climate and soil conditions, which could explain the diversity of species in this plant family (Zhigila *et al.*, 2016). Such abundance of Fabaceae has been observed in other dense humid forests in tropical Africa (Sonké, 2005; Gonmadje *et al.*, 2011; Tchatou *et al.*, 2015). Plant species belonging to this family produce fleshy and succulent fruit organs, which are easily eaten and transported to other parts of the forest by animals, thus facilitating the dissemination of seeds. This high diversity of Fabaceae in our study is in accordance with the findings observed by other authors in Cameroon who had the Fabaceae as the most diverse family (Tiokeng *et al.*, 2015; Momo *et al.*, 2018). This diversity is an indication of an environment belonging to the Guineo-Congolese phythogeographic domain (Gonmandje *et al.*, 2012; Amba *et al.*, 2021). The high abundance of Fabaceae (895 individuals) in Mount Nlonako implies the presence of endemic species in the area, which is in accordance with the study of Doucet (2003) in the moist forest of Gabon, where a high level of endemism is due to the abundance of Fabaceae, Olacaceae, and Burseraceae. Also, based on the findings of Leal (2001), the abundance of Fabaceae and Olacaceae characterizes old forests.

Importance value of species and families

According to Siraj and Zhang (2018), IVI indicates the ecological importance of a species in a community. IVIs also indicate dominance of species in mixed populations and give an idea about important species and their composition in a forest. *Sterculia rhinopetala* (14.96%), *Ceiba pentandra* (14.78%), *Desbordesia glaucescens* (14.30%), *Strombosia grandifolia* (11.40%), and *Alstonia boonei* (10.45%) were the most important species at lower altitude, while *Pycnanthus angolensis* (21.38%), *Ceolocaryon preusii* (12.57%), *Terminalia superba* (12.01%), *Strombosia grandifolia* (11.99%), and *Oncoba glauca* (11.01%) were the most important species at higher altitude based on their Important Value Index values. The high IVIs of these species could be a result of edaphic factors such as soil quality of the area, which may favor the growth conditions of these species. These were also the most abundant, most frequent, and most dominant species in the area of study. A good number of these species are used for timber and for the production of charcoal in the Mt. Nlonako area. This corroborates with the findings of Zapfack (2005) in the Central region of Cameroon, where the same species were identified and used as timber for the construction of houses, bridges, and fences. Some of these species (*Pycnanthus angolensis, Strombosia grandifolia*) are considered pioneer species and characteristics of disturbed forest. The importance of *Ceiba pentandra*, *Pyncnanthus angolensis,* and *Terminalia superba* is related to their relative dominance, which could be due to individuals of these species having large diameters. At lower altitudes, *Strombosia grandifolia* was the most frequent and abundant species, while *Ceiba pentandra* was the most dominant species. At higher altitude, *Pycnanthus angolensis* was the most frequent and dominant species, while *Strombosia grandifolia* was the most abundant species. *Pycnanthus angolensis* and *Strombosia grandifolia* are species that develop in an open canopy, which implies that they are species that highly depend on light for their growth. According to Nabe-Nielsen *et al.* (2007), the density of trees increases in areas that have an open canopy with a rapid proliferation rate due to the high demand for light. Fredericksen and Mostacedo (2000) concluded in their study that areas with an open canopy favor the development of lianas and non-commercial species, thereby creating a high level of competition in the area. This therefore implies that at higher altitude, the forest is an old secondary disturbed forest with patches of primary forest and secondary disturbed forest at lower altitudes.

Families that were ecologically important were Fabaceae (51.41%), Malvaceae (26.13%), Apocynaceae (22.88%), Irvingiaceae (21.30%), Olacaceae (19.36%), Bombacaceae (13.77%) and Myristicaceae (13.67%) at lower altitudes, and Fabaceae (39.74%), Myristicaceae (34.14%), Olacaceae (19.11%), Anacardiaceae (16.11%), Meliaceae (15.86%), Malvaceae (13.86%), and Annonaceae (13.87%) at higher altitudes based on their FIV values. At higher altitudes, Myristicaceae were the most abundant family but less diversify, while Fabaceae were the most dominant and diversify family. This therefore explains the reason why Fabaceae is the most important family instead of Myristicaceae at higher altitudes. At lower altitudes, Fabaceae were the most dominant, most frequent, most abundant, and most diversified plant family. According to Kengne *et al.* (2018), these families are known to contribute remarkably to restoring the plant biodiversity of degraded areas. These families inventoried in the MNFP are similar to those mentioned by authors in other Cameroonian forests, such as Fongnzossie *et al.* (2011) in the Mengamé gorilla reserve in South Cameroon, Sonké and Couvreur (2014) in the Dja faunal reserve, South Cameroon, and Kengne *et al.* (2018) in Kompia and Nkolenyeng community forests of Cameroon. These plant families are known for their richness as pioneer species and contribute to the restoration of plant biodiversity in degraded areas (Zapfack *et al.*, 2002). In general, one of the important characteristics of African dense forests is their richness in Fabaceae, Olacaceae, Myristicaceae, and Euphorbiaceae (Xiao-Tao and Jian-Wei, 2010).

Stand structure of species

The distribution of individuals inventoried by diameter class shows a high presence of individuals with small diameters (10-20) compared to trees with large diameters (above 40). This implies that the forest has a good regeneration capacity. Although, the reverse J structure observed in the distribution of individual per classes of diameter is common in tropical forest, the reduced number of trees with large diameters could be exacerbated by illegal and industrial exploitation. The presence of individuals with small diameters is characteristic of tropical forests, where the structure of the population studied presents an inverted “J"-shaped pattern (Atoupka, 2016; Ngueguim *et al.*, 2018). This phenomenon of illegal and industrial exploitation are mostly common at lower altitudes and natural disturbances caused by the presence of death trees mostly at higher altitude. The high presence of death individuals at higher altitude could be a result of high pluviometry, which leads to soil erosion and landslides, thereby leading to the fall of trees, which eventually die. The distribution of species is characterized by the presence of a small number of large individuals who have few surviving members when they approach the seed class. According to Agbodjogbe (2011), decreasing exponential structure is typical of tropical rain forests. Such a distribution indicates good forest reconstitution in the environment (Doucet, 2003). Ouédraogo *et al.* (2005) and Bouko *et al.* (2007) reported in their findings that the large number of individuals in the diameter classes [10-20 cm[and [20-30 cm[constitutes a regenerative potential for woody vegetation.

The wood density in Mount Nlonako showed *Strombosia grandifolia* (27.97 trees/ha) and *Pycnanthus angolensis* (22.34 trees/ha) had the highest tree density at higher altitudes, while *Strombosia grandifolia* (34.34 trees/ha) and *Desbordersia glaucescens* (34.53 trees/ha) had the highest tree density at lower altitudes. Globally, 482 trees/ha were recorded in the Mount Nlonako forest, which was lower than those observed by Tiokeng *et al.* (2009) in Mekoup forest (894 trees/ha) and Tiokeng *et al.* (2019) in the Fossomondi (1182.5 trees/ha) and Bangang (855.3 trees/ha) forests of Mount Bamboutos in western Cameroon. However, it was higher compared to that of Sainge (2018) in the Rumpi Hills Forest Reserve (RHFR) in South West Cameroon (481 trees/ha). Tree diversity values varied with altitude and showed 585 trees/ha and 384 trees/ha at lower and higher altitudes, respectively. The difference in altitude could be due to the high level of anthropization at lower altitude, which permits the high density of trees, and was confirmed during inventory by the presence of a high number of individuals belonging to species like *Musanga cecropioides*, *Myrianthus arboreus*, *Pycnanthus angolensis, Alstonia boonei, Tabernaemontana crassa, and Macaranga monandra,* known as pioneer species (Tajeukem *et al.*, 2014). At higher altitudes, the low amount of trees per hectare could be due to natural factors. The mountain has at that level a very steep and sloppy landscape, which easily causes the falling of large trees, especially during the rainy season (Kenfack, 2001). Some factors, such as relief, soil, and altitude, could influence the diameter growth of individuals. Indeed, some authors, such as Aiba and Kitayama (1999), have shown a decrease in the average tree size with increasing altitude. Similarly, in hilly areas with steep slopes, the soils are less stable and could not support very large trees. The basal area was in relation to the individual diameter and the species density.

Plant life traits and phytogeographic distribution of species

The dispersal of plants in space strongly depends on the way in which their diaspores are dispersed, and for this study, the most important mode of seed dispersal studied in the Mount Nlonako forest is zoochory, followed by autochory (18.08%) and anemochory (11.29%), while barochory was the less common (6.7%). This result can testify to the presence of numerous plant-dispersing animals in the environment, which are important for the zoochorous species. Mount Nlonako forest thus contributes to the conservation of animal biodiversity since it provides food eaten by these animals, thereby preventing them from starvation. At inventory, rodents, monkeys, squirrels, and birds were met in the forest. The high proportion of zoochorous species can indicate the high importance of animal species in the dispersal and therefore the regeneration of forest species. This therefore makes animals indirectly important in the proper functioning of the forest. Momo *et al.* (2018) observed the same tendency in the Koupa-Matapit forest in the Western region. According to Kimpouni *et al.* (2013) and Melingui *et al.* (2017), dispersal by zoochory is more important in tropical rainforests than in non-tropical forests. This type of dispersal accelerates the evolution of an ecosystem floristically and structurally, thus allowing a level of high stability and resilience after disturbance (Caldeira *et al.*, 2005; Wallington *et al.*, 2005). Indeed, Puig (2001) noted that the mutualistic relationship between plants and animals makes it possible to break seed dormancy in tropical forests, thus providing favorable conditions for germination as well as the propagation of diaspores in a settlement. The most represented diaspore type in the MNFP are sarcochores diaspores. Sarcochores diaspores are fleshy fruit organs produced by plants that are mostly disseminated by animals and are advantageous to the plants in the dispersal of their seeds to far distances away from the parent plants. This therefore implies that animals, which mostly feed on fleshy seeds, are indirectly important for the survival of these plant species, and a constant reduction in their number slows the floristical and structural evolution of an ecosystem (Caldeira *et al.*, 2005). This result is similar to that of Momo (2009) in Mount Oku and Momo *et al.* (2018) in Koupa-Matapit gallery forest. Other studies carried out in many forests show the same results. Some of them include: Fongnzossie (2011) in the Kom National Park-Mengame Gorilla Sanctuary in South Cameroon; Doucet (2003) in the central forests of Gabon; and Kimpouni *et al.* (2013) in the Haute Sangha in the DRC, who reported in their findings the presence of sarcochores as the most produced diaspore type by plant species. According to Lebrun (1977), biological types reflect the capacity of plants to occupy space. The dominance of mesophanerophytes (45.83%), followed by megaphanerophytes (39.53%), microphanerophytes (12.5%), and nanophanerophytes (2.6%), confirms that the biological types reflect the varied environmental conditions and structural parameters. The strong predominance of these biological types shows the formation of a forest with tall trees, hence a dense forest. This result also reflects the fact that the study area belongs to the Guinea-Congolese domain. The result is not in accordance with those of Soro *et al.* (2021) in the relic forest of the Poro region in Ivory Coast, who obtained a 70% predominance of microphanerophytes. This predominance of microphanerophytes could be due to the fact that the relic forest is under regeneration due to the intense exploitation of tall trees. The phytogeographical distribution of plant species depends on the adaptation of plants in the area, the living conditions in the area, and also the reflection of climatic conditions (Ngnignindiwou *et al.*, 2021). The dominance of Guinean-Congolese species (Central and omni guinean congolese) in the forest can reflect the maturity of species in this area, as observed by Tiokeng *et al.* (2019) in the western highland forest. This therefore implies that the Mount Nlonako forest belongs to the Guinean-Congolese region.

Conclusion

The knowledge of floristic composition, stand structure, and plant life traits of the vegetation of Mount Nlonako forest was conducted in this study. A comparative study on the floristic differentiation of sites studied (higher and lower altitude) showed that higher altitude are more diverse (203 species) in terms of species compared to lower altitude (133 species).

Pycnanthus angolensis and *Sterculia rhinopetala* were the ecologically important species at higher and lower altitudes, respectively. All over the Mount Nlonako area that is at both altitudes, the Fabaceae and Myristicaceae were the most important plant families. The diversity indices of Shannon, Simpson, and Pielou affirm that the area is less diversified even though there exists a good distribution of species with individuals and individuals within species. With respect to tree density and basal area, they were elevated at lower altitude compared to higher altitude. The diametric distribution of individuals presents an inverted J-shaped structure with the presence of large class diameters at higher altitude than at lower altitude. Analyses of the traits of life of species show that the Mount Nlonako forest and periphery are more dominated by sarchocorous species, with zoochory as the most important mode of spore dissemination. Guineo-Congolese species were the most dominant phytogeographic type in the area. This study therefore provides information on the floristic composition, stand structure variation, and plant life traits to provide factual information for the ratioal management of the Mount Nlonako forest. This work emphasizes a pressing need to put into effect efficient management practices in order to conserve this forest area.

Acknowledgments

This work was conducted at the University of Dschang, Cameroon, as part of the author's Ph.D study. The authors wish to thank all those who were involved directly or indirectly in the realization of this work.

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