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Floristic diversity and structure of understory in semi-deciduous forests in Cameroon

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Abstract

To date, few studies on the flora's understory of the semi-deciduous forests of the Congo Basin have been carried out. The aim of this study done in the semi-deciduous forests of the Eastern Region of Cameroon was to characterize the diversity of understory trees (diameter spanning tree: 1.0-9.9cm). The sampling design was those of square plots of 20 x 20m for inventory data collection of understory trees for the diameters between [5-10cm] and those of 10 x 10m for the diameters between [1-5cm]. The parameters collected were the scientific/local/vernacular name, the diameter and height of each species of understory. Diversity indices and structure parameters of understory stratum were calculated (abundance and basal area). The results showed that species richness of study area was estimated at 186 species belonging to 93 genera and 38 families. The Shannon index (4.44) showed a rich diversity of the understory in semi-deciduous forests. In addition, this study identified 27 species as characteristic/exclusive to the understory among which *Myrianthus preussii* and *Rinorea caudata* were threatened. The number of stems and basal area of understory trees stratum were 5075 stems.ha^{-1} and 3.41m^2.ha^{-1}. Abundance decreases with increasing of diameter and height classes. This study is a contribution to the knowledge of the floristic diversity of the understory of semi-deciduous tropical forests.

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Introduction

The forests of Central Africa have an important potential in terms of floristic diversity (Maréchal *et al.,* 2013); estimated at more than 10,000 species of which 3,000 are endemic (Megevand *et al.,* 2013). Despite this important potential, this floristic diversity remained for a long time the focus of some botanists and was of little importance to the international community. The combination of increasing degradation and climate change has prompted the international community to place this diversity on the global agenda. This diversity is an integral part of national policies and planning, such as the Convention on Biological Diversity (Megevand *et al.,* 2013). According to Corlet (2016), several species are still unknown to science. Nevertheless, plant diversity has received very little conservation attention compared to animals. Better still, it has been more limited to trees, mainly those with a diameter greater than 10cm, to the detriment of understory trees. However, the understory trees would be important in forest dynamics in the sense that it represents the future forest cover, but also shelters sometimes endangered species that most often remain gregarious throughout their life cycle.

The understory corresponds to the lowest forest stratum from the soil to below the canopy tree crowns; the species found within it are growing in a microclimate with high humidity where wind is virtually absent (Addo-Fordjour *et al.,* 2009). This stratum is composed of a diversity of young trees, herbaceous plants, Pteridophytes, Fungi, animals, etc. growing under the canopy of the trees (upper stratum). The understory is the important forest stratum in forest dynamics (Hakizimana *et al.,* 2011). On the other hand, the trees species in this forest stratum (1 ≤ diameter < 10cm) contribute on average 3% to the aboveground forest biomass of semi-deciduous forests (Chimi *et al.,* 2018).

In tropical forests of Cameroon, most studies on the floristic and structural diversity of forest ecosystems have been limited to trees species of diameter ≥ 10cm (e.g. Gonmadje *et al.,* 2011; Tabue *et al.,* 2016); or to trees species of diameter ≥ 5cm (Kabelong *et al.,* 2018). Some studies such as Chimi *et al.* (2018) considered stems of diameter > 1cm in terms of diversity, structure and forest carbon stocks. However, these studies were limited to more or less summary analyses. Thus, Kabelong *et al.* (2018a,b) reported in their studies that there are species present in the understory that remain at this stage of development throughout their lives. These authors did not take this aspect into account in their study in order to highlight those that are specific to the understory compared to those that should constitute the future plant cover of the upper stratum. As a consequence, knowledge of the trees diversity of the understory species remains low. Thus, the objective of this study were to: (1) make an inventory of the understory trees, (2) characterize these understories from the floristic and structural point of view of the semi-deciduous forests in Cameroon.

Materials and methods

Study site

This study was conducted in the forest ecosystems of the Mindourou Community Forest located in the district of Mindourou (3°10'00'' North latitude and 13°37'00'' East longitude), belonging to the Haut Nyong Division and Eastern Region of Cameroon. Geographically, this area belongs to the “South Cameroonian plateau”. It has a relatively flat, gently sloping relief consisting of plains, valleys and a few hills. The average altitude is 600 m (PNDP, 2012). The soils are essentially red and yellow and belonging to ferralitic type (Ferrasols). However, hydromorphic soils could be found in swampy areas and along watercourses. The climate in this area is sub-equatorial forest type with four unevenly distributed seasons. The average temperature varies between 23°C and 25°C and annual precipitation averages 1,800mm. A vast hydrographic network feeds this area. This forest belongs to the semi-deciduous forests domain dominated by Malvaceae and Ulmaceae (Letouzey, 1985), the flora of the study area consists mainly of forest species such as *Triplochiton scleroxylon* (ayous), *Milicia excelsa* (Iroko), *Pterocarpus sayauxii* (Padouk), *Disthemonanthus* *benthamianus* (Movingui), *Mansonia altissima* (Bété), *Baillonella toxisperma* (Moabi), *Lovoa trichiloides* (Bibolo), *Entandophrama cylindricum* (Sapelli), *Petersianthus macrocarpus* (PNDP, 2012). The vegetation presents a diversification of species with a complete stratification of trees from the upper trees to herbaceous stratum. Agriculture, which contributes to the degradation of forest ecosystems, employs nearly 95% of the active population and represents the main source of income for these riparian population estimated at about 18,000 inhabitants (4.2 inhabitants.km^{-2}) in the study area.

Data collection

Data was collected in the Mindourou Community Forest during the period from May to June 2017. The sampling design recommended by Ibrahima *et al.* (2002) and Chimi *et al.* (2018) for understory trees inventories was used in this study. This design consists of plots of 20 x 20m and 10 x 10m for the inventory data collection of understory trees with diameters between [5-10cm[and [1-5cm[respectively. These plots were installed exclusively in forest areas which was not perturbed by human activities. Thus, 30 plots were installed and sampled; i.e. 15 plots of 20m x 20m and 15 plots of 10m x 10m.

The inventory in these plots consisted in collecting information on each identified understory trees species such as: vernacular and/or commercial names, diameter, height, abundance of each identified species. The diameter was measured at 30cm above the soil as recommended by Chimi *et al.* (2018). Height was measured directly with a graduated ruler. Herbarium samples of all identified trees specimens were collected, pressed in newspapers, preserved in alcohol at 70° and then dried in an oven when returned to the field. More than 400 herbarium samples were collected and their identification was made at the Yaounde National Herbarium by comparison with available specimens and using the various available Flores basis of the discriminating characters.

The literature review was done concerning these species to determine if the species found are exclusively understory or will be later shrubs or tree (those trees which constitute the higher stratum of the forest). For that, we have consulting the herbarium specimens (looking the descriptive card of each species) and some documents available like those of Quentin *et al.* (2015), Tchouto *et al.* (2006), etc. However, the status of threatens's species of this study was done according to Onana (2011).

Data analysis

Data were analyzed using the "BiodiversityR" package of the R software version 3.4.1. These analyses focused on floristic and structural characterization. From the floristic point of view, the characterization of the flora was done using diversity index calculations such as:

(1) The Shannon Diversity Index (H'), which allows the evaluation of floristic diversity, was calculated using the opposite formula.

$H' = -\sum \frac{Ni}{N} \times \log \frac{Ni}{N}$ (Shannon and Wiener, 1949)

where ni/n indicates the probability of importance of each species in a population, with Ni = number of species i; N = number of all species. This index also takes into account the relative abundance of species. It is the most widely used and recommended index in the comparative study of stands, as it is not very sensitive to the size of the population studied. It gives more importance to rare species.

(2) The Equitability of Pielou (J'), is equal to:

$J' = \frac{H'}{\log (N)}$ (Pielou, 1966)

The Equitability of Pielou values range from 0 to 1 and corresponds to the ratio between the observed diversity and the maximum possible diversity of the number of species (N); its value could be a sign of disturbance in the environment. A low Equitability of Pielou represents a high importance of a few dominant species.

(3) The Simpson's index (D) which is defined as follows:

$D = \frac{ni\,(ni-1)}{N\,(N-1)}$.

It is used to assess dominance. It expresses the probability that two individuals, chosen at random from an infinite population, belong to the same species. It is expressed from the frequencies of the species.

For the structural characterization of the area's understory, only woody with diameter range between 1 and 10 cm were taken into account. The parameters calculated for trees with a diameter of >1cm were: the number of stems.ha^{-1} and the basal area (BA) in $m^2.ha^{-1}$. BA was calculated from the following formula:

$$BA = \frac{\pi \times D^2}{4};$$

With D: tree diameter and π = 3.14 (Kabelong *et al.,* 2018b). The distribution of trees stems per hectare according to diameter classes of amplitude 2.5 (i.e. 4 diameter classes) and with height classes of amplitude 4 m (i.e. 4 height classes) was also done. These structural parameters estimated were extrapolated at the hectare using the expansion factor (EF) defined by the following formula:

$$EF = \frac{10{,}000}{SA}$$

With SA = sampled area in m^2.

In addition to these parameters, the Importance Value Index (IVI), which shows which species are ecologically important, was calculated according to the following formula:

IVI=relative dominance + relative abundance + relative frequency (Cottam and Curtis, 1956).

With:

$$\text{Relative dominance} = \frac{\text{Basal area of species i}}{\text{Sum of basal area of all the species}} \times 100\ ;$$

$$\text{Relative abundance} = \frac{\text{Number of individuals of species i}}{\text{Total number of individuals}} \times 100\ ;$$

$$\text{Relative frequency} = \frac{\text{Number of occurence of species i}}{\text{Sum of occurences of all species}} \times 100\ ;$$

Results

Specific Richness and Diversity Index of the Study Area

The floristic inventory done have permitted to identify 186 understory trees species with diameters ranging from 1.00 to 9.99cm. These species belong to 93 genera and 38 families. 97% of these species were identified up to the taxonomic family level and 3% of the species were undetermined (which could not be classified in a taxonomic level). 13% of these species were identified only at the taxonomic family level. Thus, 16% of the species inventoried are undetermined. In general, according to biological type of understory species identified until the species level, 43% (59 species) of these trees will later become trees of the upper forest stratum; 37% (50 species) will evolve to the shrub stage and 20% (27 species) will remain in the understory stage. Thus, 27 species have been identified as trees species specific or characteristic/exclusive to the understory forest stratum.

Of the 38 families of understory species identified in the study area, the 10 most representative families in terms of abundance, representing 75%, were in decreasing order: Euphorbiaceae (15.25%), Apocynaceae (13.00%), Violaceae (9.22%), Meliaceae (7.21%), Rubiaceae (7.09%), Fabaceae (6.15%), Annonaceae (5.56%), Sapindaceae (4.14%), Ebenanceae (3.78%) and Myristicaceae (3.19%). The most abundant species (in number of stems) with more than 2% of all species richness were in decreasing order: *Tabernaemantana crassa* (8.53%), Ri*norea batesii* (8.19%), *Drypetes* sp. (5.69%), *Polyalthia suaveolens* (3.87%), *Voacanga africana* (3.41%), *Diospyros gabunensis* (3.07%), *Trichilia heudellotii* (2.16%) and *Calpocalyx dinklagei* (2.05%). The values of the calculated indices such as Shannon, Pielou and Simpson were 4.44, 0.85 and 0.98 respectively. The index of Pielou closed to 1 show that the flora, which seems to be equitably distributed, is marked by the abundance of a few species at the point of number of individuals (*Tabernaemantana crassa*, *Rinorea batesii*, *Drypetes* sp., *Polyalthia suaveolens*). The probability that 2 individuals taken at random belong to the same species is 98%.

Overall Status of Conservation

Concerning the vulnerability status of these species at the national level, on the 186 species inventoried, only the status of 85 species is available.

Thus Fig. 1 shows that 1% of the species are vulnerable (VU), 1% have insufficient data (DD), 4% will be threatened in the near future (NT) and 93% have a minor concern (LC). Species found in the understory forest stratum with a vulnerable status were: *Baillonnella toxisperma* (VU), *Myrianthus preussii* (NT), *Grossera macrantha* (NT), *Zanthoxyllum buesgenii* (NT) and *Rinorea caudata* (NT). Between these threatened species, *Myrianthus preussii* and *Rinorea caudata* are characteristics/exclusive understory.

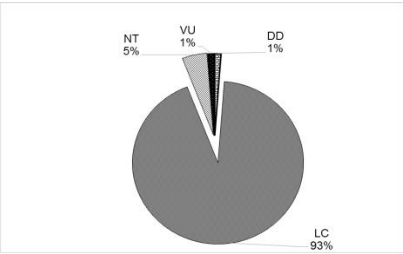

Fig. 1. Proportion of IUCN status of understory species inventoried.

Abundance and basal area of understory species

The average number of understory trees and the basal area were 5,075±1,494stems.ha^{-1} and 3.41±0.45m^2.ha^{-1} respectively. The latter was 4,673±1,146 stems.ha^{-1} and 1.95±0.65 stems.ha^{-1} for woody trees with a diameter < 5cm and 402±87 stems.ha^{-1} and 1.46±0.35 m^2.ha^{-1} for trees with a diameter between 5.00 and 9.99cm.

Distribution of stem.ha^{-1} and basal area (m^2.ha^{-1}) according to diameter and height classes

Fig. 2 shows how stems and basal area of the understory were distributed according to diameter and height classes. For both diameter and height classes, the number of stems per hectare decreased as the diameter and height classes increased, showing, as is often the case with large trees, the shape of the inverted "J" curve. In contrast, the basal area distribution followed a bell-shaped pattern earlier, with an optimum for the [2.5-5cm[and [4-8cm[classes for diameter and height respectively (Fig. 2).

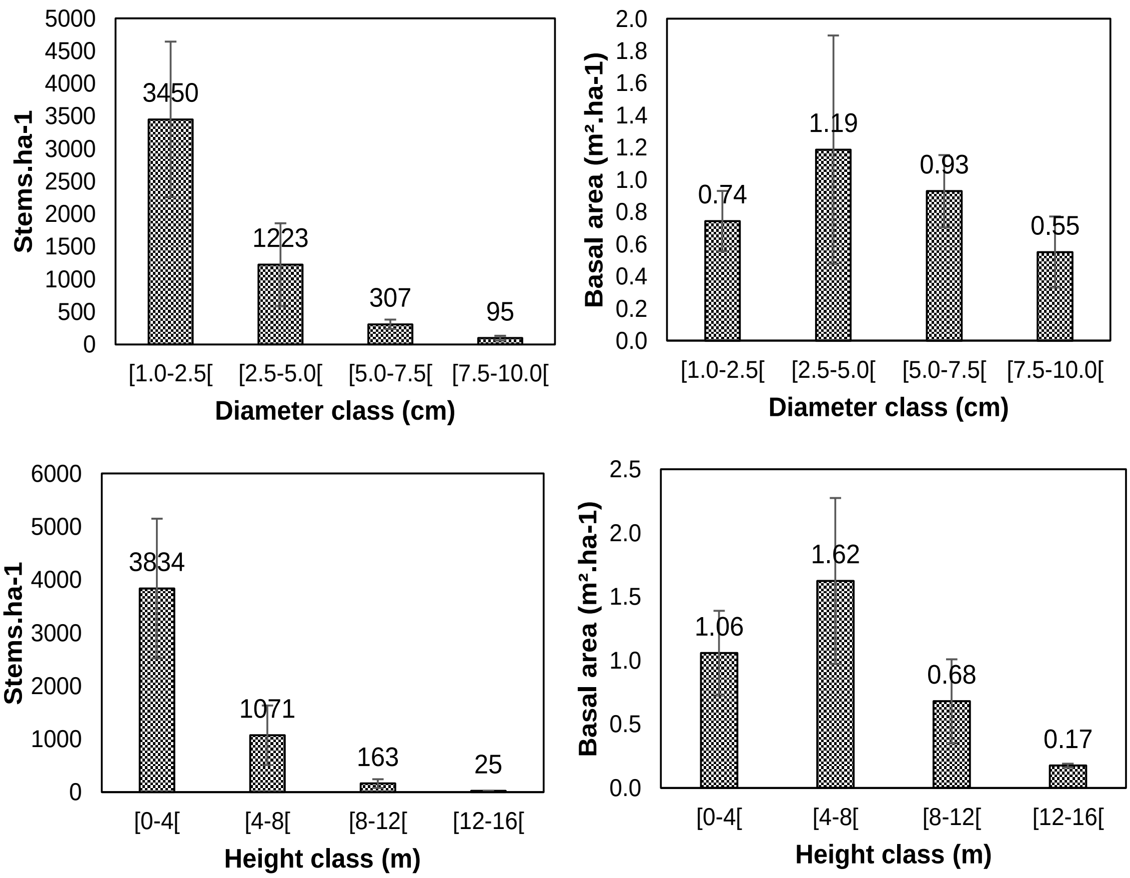

Fig. 2. Distribution of number of stems.ha^{-1} and basal area (m^2.ha^{-1}) as a function of diameter and height classes.

Importance Value Index (IVI) of understory trees species

The calculation of IVI has shown that the ecologically important species were as follows: *Tabernaemantana crassa* (80.91), *Rinorea batesii* (65.90), *Polyalthia suaveolens* (65.24), *Drypetes* sp. (54.20), *Voacanga africana* (50.06), *Coelocaryon preussii* (40.93), *Petersianthus macrocarpus* (40.32), *Diospyros gabunensis* (34.97), *Calpocalyx dinklagei* (33.04), *Trichilia rubescens* (32.16) and *Garcinia epunctata* (30.48). The IVI of the species presented above were those with an IVI greater than or equal to 30.

Discussion

Contrary to most forest trees inventory studies in forest ecosystems in Cameroon, which have been limited to trees with a diameter greater or equal than 10cm, this study focused only on understory trees with a diameter between 1.0 and 9.9cm. It identified a trees flora made up of nearly 186 species belonging to 93 genera and 38 families. This species richness is much lower than the 256 species (148 genera and 50 families) identified by Kabelong *et al.* (2018a) in the evergreen forests of Campo-Man National Park, although they were limited only to trees between 5 and 10cm in diameter. This difference could be explained by the fact that these authors worked in a forest type (evergreen) that according to the literature is more floristically rich than the semi-deciduous evergreen forests (Kabelong, 2019). However, these 186 species remain lower than the 115 species identified in semi-deciduous forest by Kabelong (2019) for the reason that these authors are limited these work only to understory with a diameter between 5 and 10cm whereas in this study we considered trees with a diameter between 1 and 10cm. Similarly, the diversity obtained in the present study is greater than that of Chimi *et al.* (2018). This difference could be explained by the low sampling rate done by these authors. In contrast to the Tchingsabe *et al.* (2017) study which have showed that the family Malvaceae is the most dominant forest family, this study showed the opposite. Indeed, these authors focused on woody trees with a diameter greater than 10cm in addition to the fact that they worked in another forest stratum.

The understory constitutes a pioneer stage in forest dynamics where the adult individuals that will make up the stand are pioneer or heliophilic species, likely to germinate only in good light conditions (Hakizimana *et al.,* 2011). Thus, although in the context of this study, we identified 5 species (5%) with a vulnerable status at the national level, our investigation based on species with a vulnerable status at the global level has shown that despite the fact that *Lannea welwitschii* and *Spathandra barteri* have LC status at the national level (Onana, 2011), they are respectively NT and VU according to the red listed at the global level. Therefore, given that they are the most accessible and disturbed vegetation stratum by humans despite the fact that they would represent the future forest cover in the future (Hakizimana *et al.,* 2011; Corlet, 2016), their preservation remains an interest for forest monitoring.

Concerning the vegetation structure of the understory, it is evident to found that the basal area compared to those of other studies which were limited to trees with a diameter greater than 10cm that it is greater than that of the understory according to their small diameter. However, the basal area and density per hectare of $3.41m^2.ha^{-1}$ and $5{,}075$ $stems.ha^{-1}$ respectively are close to the 4.85 $m^2.ha^{-1}$ and $5{,}333$ $stems.ha^{-1}$ found by Chimi *et al.* (2018) in the same forest type in the East Cameroon region. Like those of larger trees with diameter up than 10cm, the abundance of individuals per hectare decreased with diameter classes increasing for trees between 1 and 10cm in diameter (when considering 4 diameter classes with an amplitude of 2.5cm). This results reflects a natural regeneration of this forest (Addo-Fordjour *et al.,* 2009; Jiagho *et al.,* 2016; Kabelong, 2019).

Conclusion

This study showed the floristic potential of understory trees in the semi-deciduous forests of Cameroon. Thus, with its species richness of 186 species among which others have a vulnerable status, it is essential in biodiversity conservation policies that this forest stratum be taken into account in Cameroon. Moreover, given that the understory stratum is the most accessible and disturbed by human activities, this could be a danger for the conservation of these species among which others remain in the understory stage throughout their lives.

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