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Assessment of Woody Species Biodiversity and Carbon Stock Potentials in the Arboretum of National School of Water and Forests of Mbalmayo, Center Region of Cameroon

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Abstract

Assessing forest biodiversity is crucial for supporting sustainable forest planning. We investigated the potential for biodiversity and carbon sequestration in both artificial and natural forests of the arboretum of the National School of Water and Forests (ENEF) of Mbalmayo. A floristic inventory was carried out in 72 plots measuring 25m x 25m in the artificial forest covering an area of 4.5ha, and in a quadrat measuring 250m x 180m in the natural forest of the arboretum. Carbon stocks were determined by the non-destructive method using allometric equations. The results of the woody biodiversity inventories identified 77 species belonging to 69 genera and 33 families. This species richness varied from 69 species in the natural forest to 58 species in the artificial forest. Tree density was slightly higher in the artificial forest (616 ±339 ind/ha) than in the natural forest (312 ±176 ind/ha), without being significantly different. Basal area was constant in both types of forest studied, with an average of 55.97 ±36.28 m2/ha in the artificial forest and 58.33 ±19.42 m2/ha in the natural forest. The greatest quantity of sequestered carbon was found in the natural forest with 432±146.49 tC/ha compared with 400.69±328.37 tC/ha in the artificial forest. Nevertheless, these rates were not significantly different according to the ANOVA test. Given the importance of this massif in carbon sequestration and the needs of local populations, ENEF should support these populations in agroforestry practices and in the domestication of priority tree species.

Keywords: Biodiversity, carbon stocks, natural forest, artificial forest, ENEF.

1. Introduction

Forests are among the most important ecosystems on the planet (Thies *et al*., 2011; Kok *et al*., 2017; Orsi *et al*., 2020). They are generally recognized as essential for human survival (Mori *et al.*, 2017; Brockerhof *et al.*, 2017) due to their biological, ecological, economic and socio-cultural functions (Hilmers *et al.*, 2018). In regard to their crucial role in regulating the global climate and for their multiple ecosystem services (Nasi *et al*, 2008), their protection is of paramount importance.

Indeed, according to the Food and Agriculture Organization (FAO, 2008), forests are home to about 350 million people worldwide. In developing countries, 1.2 billion people depend on agroforestry systems that promote agricultural productivity and provide income (World Bank, 2004). More than 2 billion humans derive their livelihoods, fuelwood, medicinal plants and food from forests to varying degrees (UNDP, 2000). Forests also play a major role in climate stabilization. They store about 300 billion tons of carbon (Solomon, 2007) which, if not released into the atmosphere, would contribute to climate change. The humid tropical forests of Africa regulate the precipitation regime of the region. They also act as a brake on the acceleration of climate change.

Despite the above remarkable benefits that forests grant, they are disappearing at an unprecedented rate, due to over-harvesting and the loss, degradation and fragmentation of forest landscapes and ecosystems (Bobo et al., 2006; Felipe-Lucia et al. 2020). According to FAO (2005), forests are currently disappearing at a rate of about 13 million hectares per year. Large-scale agriculture commonly practiced by companies and landowners is increasingly becoming the main direct cause of this deforestation (Rudel, 2005). In Cameroon, in addition to agriculture contributing to about 80% of forest losses (CARPE, 2005), several other factors are behind this continuous degradation of forests (Greenpeace, 2007). These factors include direct threats caused by timber and mineral resource extraction, poor management, and growing demographic pressure (Greenpeace, 2007) among the most important. In fact, recent studies show that even classified forests are facing many anthropogenic pressures that lead to their degradation and deforestation and thereby causing destruction (Zekeng et al., 2019; Djiongo et al., 2020; Fokeng et al., 2020; Temgoua et al., 2021).

In this context, sustainable forest management, i.e. management that concomitantly maintains forest biodiversity, productivity, regeneration capacity and vitality, as well as forests' potential to fulfill a wide range of functions and services has been recognized as crucial to circumvent biodiversity loss (Borghi *et al.*, 2024). Therefore, conducting substantial studies to understand the potential biomass and sequestered carbon of these forests is of particular importance. In the present study, we focus our attention on the forest massif of the ENEF of Mbalmayo, which contributes to carbon sequestration and thus to the reduction of atmospheric CO emissions through photosynthesis (Vigneron *et al*., 2021). However, little research has focused on the determination of carbon quantities in the teaching and research forest of the ENEF of Mbalmayo. Yet this site is exposed to illegal logging and agricultural exploitation contributing to the release of carbon into nature (Mingang *et al.*, 2022). Therefore, this article aims to assess the carbon sequestration potential of an artificial forest compared to a natural one in the ENEF massif of Mbalmayo.

After an introduction, this article highlights the general methodology adopted, including a map of the location of the study area. Then it presents all the results obtained and their discussion. The article ends with a conclusion presenting some avenues for slowing down the deforestation process of the ENEF of Mbalmayo arboretum and prospects for future research.

2. Methodology

2.1. Study area

The area chosen for this study is the teaching and research arboretum of the ENEF of Cameroon (Figure 1). This arboretum covers an area of approximately 700 ha. Located in the Center Region, Nyong and So'o Department, Mbalmayo Subdivision, it is bounded to the west and north by the Nyong River, to the South by the So'o River, and to the East by the Mbalmayo-Ebolowa road. This forest was selected because of its importance for research conducted at this institution and its exposure to the anthropogenic pressures of the surrounding villages.

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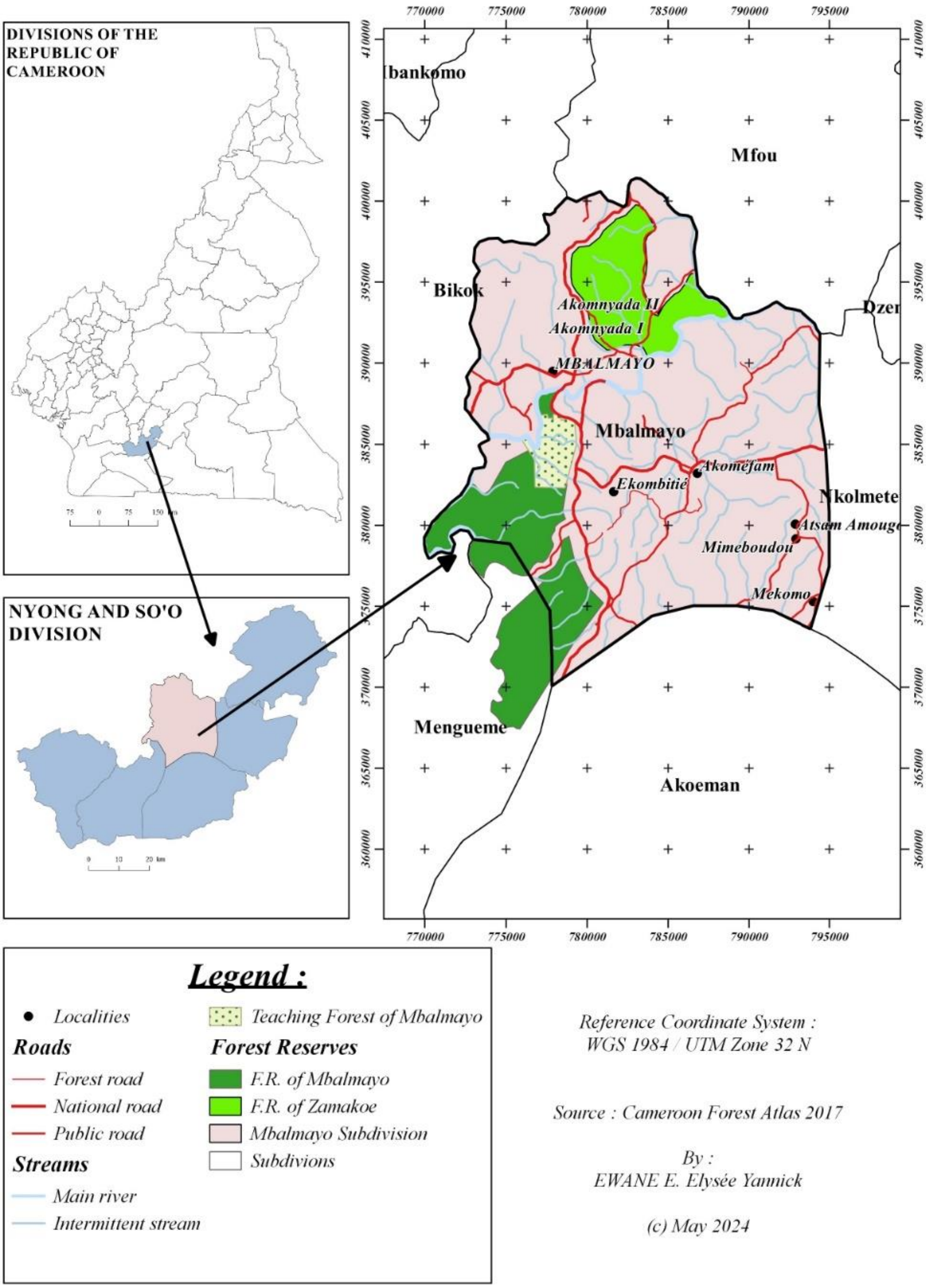

Figure 1. Map of the location of the teaching forest of Mbalmayo

2.2. Data collection

As part of this study, two types of data were collected: primary data and secondary data. The primary data consist of all the information gathered through a floristic inventory in the study area. The secondary data include information obtained from research in books, theses, scientific articles, scientific publications on the internet and in the libraries of ENSET of Douala, ICRAF, and ENEF of Mbalmayo. Additionally, data from interviews with researchers on this topic are included. The floristic inventory consisted of measuring the diameters of all woody species, including banana trees, present in the different quadrats installed on the sites considered (Figure 2). Only tree individuals with a diameter greater than or equal to 10 cm were taken into account and measured at 1.30m above ground level (DBH) for regular trunks (Figure 2a) and at 30cm above buttresses or taper deformations according to international conventions for irregular trunks (Figure 2b). For diameter and abundance data, information such as the scientific, vernacular, and commercial name of each species present, along with the habitat type, was recorded. Thus, the study was conducted in different mono-specific and poly-specific plots of 25m x 25 m for the case of the artificial forest and 250m x 180m for the case of the natural forest. In total, 72 plots of the ENEF arboretum were inventoried, covering an area of 4.5 ha. The counting units (CUs) were installed and positioned in the different vegetation formations using stakes, a compass and a measuring tape.

(a) (b)

Figure 2. Measurement of the reference diameter at 1.30 m of the regular trunk of Diospyros crassiflora (a) and 30 cm of the buttresses of the irregular trunk of Terminalia superba (b)

2.3. Data analysis

The data analysis focused on four main points, including (i) the estimation of carbon stocks in the different vegetation types, (ii) the determination of species richness and diversity index, (iii) the characterization of the vegetation structure of the vegetation types of the two forest types, and (iv) the estimation of biomass and carbon stocks. According to Segura and Kannien (2001), biomass estimation can be done in two ways: the direct or destructive method and the indirect or non-destructive method. This second method, which consists of applying regression models, volume tables or geometric formulas to measurements made in the field, is the one used in this study. The diameter data measured, and the wood density values available in the literature for each species were used to estimate the potential carbon stock. The carbon stocks were therefore estimated in aboveground biomass and belowground biomass. The characterization of the floristic diversity of the natural and artificial forest blocks was done using the inventory data from the study area. The calculated diversity indices include species richness, the Shannon diversity index, Pielou's Evenness, and the Simpson index. Species richness corresponds to the number of species identified in each forest type. As for the diversity index, it consists first of the Shannon diversity index defined by equation (1) where N_i is the number of individuals i and N the total number of individuals.

$$ISH = -\sum SH = -\sum \frac{N_i}{N} \times \log\left(\frac{N_i}{N}\right) \quad (1).$$

This index is the most recommended for the comparative study of stands. It is independent of the size of the studied population. It also gives more importance to rare species. Then comes Pielou's Evenness (Equation 2).

$$EQ = \frac{ISH}{\log(N)} \quad (2).$$

This index ranges between 0 and 1. A value close to 0 represents a great importance of the dominant species in a given ecosystem. Finally, we have the Simpson index (Equation 3) which represents a measure of dominance. It expresses the probability that two individuals drawn at random in an infinite population belong to the same species.

$$S = \frac{n_i(n_i - 1)}{N(N-1)} \quad (3).$$

In equation 3, n_i represents the number of individuals for species i and N the total population. As in the previous case, this index ranges between 0 and 1. It will have a value of 0 to indicate maximum diversity and a value of 1 to indicate minimum diversity. To characterize the vegetation structure of the two vegetation types studied, the structural parameters determined included the species importance index, the botanical family importance index, the distribution of species by diameter class and the basal area of trees per hectare. The first or Importance Value Index (IVI) was defined by Curtis and McIntosh (1950) [Equation (4)]. It corresponds to the sum of relative density, relative basal area and relative frequency. Its value ranges from 0 to 300. The species were then ranked according to their IVI, the species with the highest IVI being considered the most "important" from an ecological point of view in the survey (Curtis and Mclntosh, 1950).

$$IVI = AR + DR + FR \quad (4).$$

The second or Family Importance Value (FIV) allows to establish the relative importance of the families of the species. In this paper, the FIV index used is that of Mori et al. (1983), also used by Campbell et al. (2006) in the Gamba complex Forest in Gabon. This index defined by equation (5) corresponds to the sum of relative density, relative basal area and relative diversity. In equation (5), $Ne(X)$ is the number of species in family X, $Ni(X)$ the number of individuals in family X, $\sum Si(X)$ the sum of the basal areas of the individuals of family X and NEi the total number of species inventoried while STi is the total basal area of the inventoried individuals.

$$FIV = \frac{Ne(X)}{NEi} + \frac{Ni(X)}{NEi} + \frac{\sum Si(X)}{STi} \quad (5).$$

The distribution of species by diameter class is represented from the measurements of diameter at 1.30m above the ground for the trees. It represents the distribution of species abundances in diameter classes with a 10cm amplitude. On the other hand, the basal area of trees per hectare is expressed by equation (6) in which the quantity D represents the diameter (m) of the trees.

$$S = \frac{\pi D^2}{4} \quad (6).$$

The estimation of biomass and carbon stocks focused mainly on the estimation of aboveground biomass of trees, estimation of root biomass, estimation of carbon stocks and statistical analysis of data. The inventory data collected in the 72 plots of the artificial forest as well as those collected in the quadrat of the natural forest were used to estimate the biomass of woody plants using the non-destructive method. The allometric equation used to estimate aboveground biomass is that of Fayolle et al. (2018) [Equation (7)] which integrates two predictors including the diameter of the tree and the density specific to each species. In this equation:

$$\log(AGB) \approx a + b \times \log(WSG) + c \times \log(D) + d \times [\log(D)]^2 + e \times [\log(D)]^3 \quad (7).$$

The wood density values for each identified species were obtained from the "Global Wood Density Data Base" (Zanne et al., 2009). For species whose wood density was not available, the default value ($\rho_{défaut}$ = 0,58 g/cm^3) of the specific wood density for African tropical forests was used. The Fayolle et al. (2018) equation could not be used for oil palms and banana-plantain, so those presented in Table 1 below were used. The sum of the aboveground biomass of all individuals yielded the total aboveground biomass of the forest type studied.

Table 1. Some allometric equations used to calculate the AGB of palm and banana-plantain.

Plant species	Allometric equations	Source
Bananas (*Musaceae*)	AGB = 0,0303 x $DHP^{2,1345}$	Arifin (2001)
Palms (*Arecaceae*)	AGB = 23,487 + 41,851 x (lnH^2)	Pearson et Brown (2005)

The estimation of root biomass of standing woody plants will follow the guidelines established by the IPCC (2006). According to the IPCC, the root biomass equivalent of standing woody plants is found by multiplying the aboveground biomass value (AGB) by a coefficient R whose value is estimated at 0.235 [Equation (8)]. In equation (8), the quantities BGB and AGB represent belowground and above ground biomass respectively, while R is the root/shoot ratio. The carbon stock was obtained by multiplying the sum of the biomasses by the ratio 0.47 (Zapfack et al., 2013). Carbon stocks are calculated by equation (9). Conversion to tons (t) was done using the conversion table. The calculated parameters were extrapolated to the hectare according to equation (10). The carbon stocks of the two forest types are thus presented in t C/ha. In equation (10), FE is the extrapolation factor.

$$BGB = AGB \times R \quad (8),$$

$$Stock_{Carbone}(kg) = Biomasse_{totale}(kg) \times 0{,}47 \quad (9),$$

$$FE = \frac{10000}{Surface_{echantillonnee}} \quad (10).$$

For the statistical analysis of the data, the R software was used. The biodiversity R package of the R software was used to perform the biodiversity analyses. Analysis of variance (ANOVA) was used to test the significance between the two forest types. Principal Component Analysis (PCA) was used to assess the correlations between floristic diversity, structural parameters and carbon stocks. Finally, some graphs were produced using the Ms Excel 2016 spreadsheet of the Office 2016 package.

3. Results and Discussion

3.1. Characterization of the floristic composition of natural and artificial forests

The species accumulation curve of the study area as a function of sites is illustrated in Figure 3a. This figure presents a plateau, indicating that the sampling effort has been achieved. It also indicates almost the entirety of the species richness of the study area. Furthermore, the accumulation curve as a function of forest types is illustrated in Figure 3b. This figure shows the same pattern for both the natural forest and the artificial forest. However, the opposite seems to be observed for the natural forest, where the curve continues to rise. The biodiversity inventory carried out in the two types of forests identified 77 species belonging to 69 genera and 33 families in the study area. This result is higher than some studies carried out in African tropical forests. This is the case for the forest plantation and natural forests of Mangombé in Cameroon, where Ngueguim et al. (2010) obtained 46 and 75 species belonging to 26 and 38 families, respectively. In the community forests of Kilum-Ijim in Cameroon and the classified forests of Mekrou in Benin, Momo et al. (2017) and Bouko et al. (2016) found 38 and 58 species distributed in 28 and 27 families, respectively. However, in the Eucalyptus saligna Smith plantations in western Cameroon, Temgoua et al. (2018) recorded 55 species belonging to 23 families. Several other authors have obtained markedly different results, including Kabelong et al. (2018a), Terry et al. (2003), and Dibi et al. (2008). These observed differences may be due to the different data collection and processing methods used.

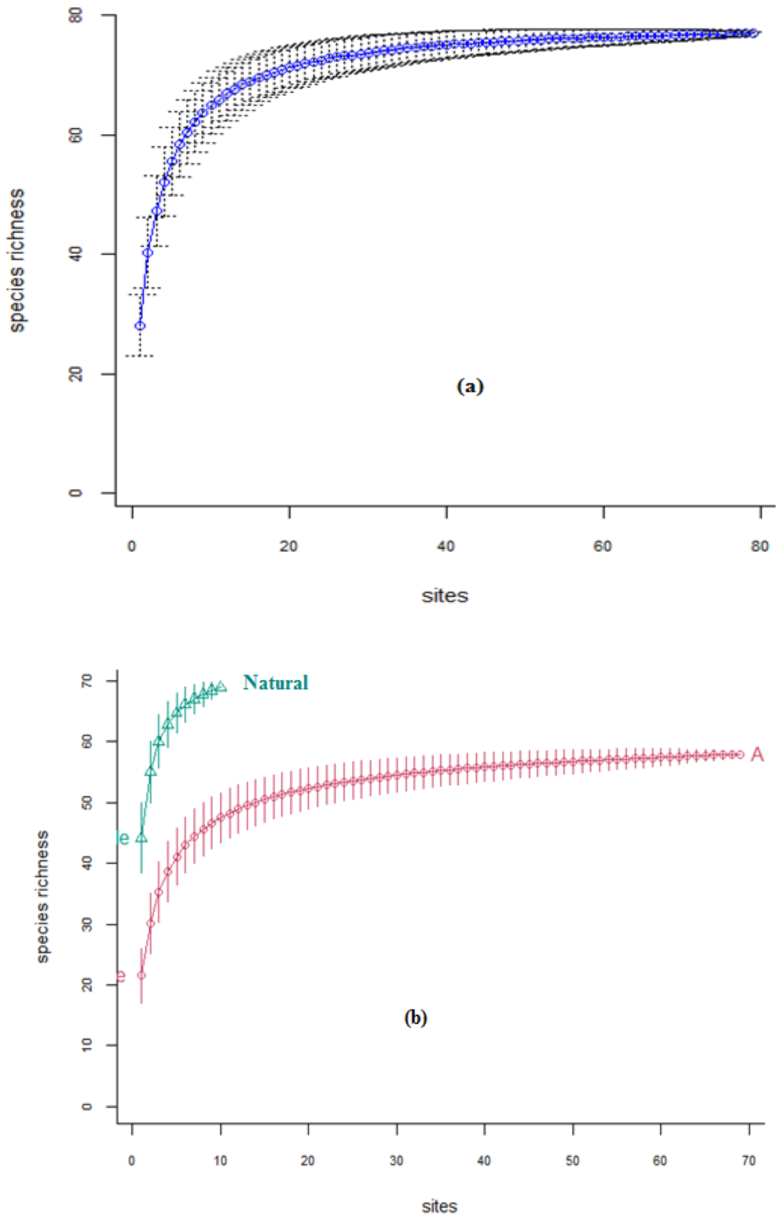

Figure 3. Accumulation curve for floristic diversity in the area using the rarefaction method.

3.2. Floristic Composition and Diversity of Natural and Artificial Forests

The numbers of species, families, and genera of the study area, and the Shannon, Piélou, and Simpson diversity indices for the two forest types studied are presented in Table 2.

Table 2. Floristic characterisation of the study area

Type of vegetation	**Floristic composition**			**Diversity index**		
	Specific richness	**Number of genres**	**Number of families**	**Shannon**	**Piélou**	**Simpson**
Natural forest	69	61	29	3,588	0,847	0,954
Artificial forest: forest plantation	58	53	28	3,461	0,852	0,956
Entire study area	77	69	33	3,737	0,860	0,965

The analysis of Table 2 shows that there is a strong affinity between the natural forest and the artificial forest concerning the taxonomic groups considered. In both vegetation types, species richness varies between 69 in the natural forest and 58 in the artificial forest. The Shannon index varies between 3.58 in the natural forest and 3.46 in the artificial forest. Piélou's evenness is close to 0.85 in both vegetation types. The same trend is observed for Simpson's diversity index, which is equivalent to 0.95 for both vegetation types. The natural forest is the most diverse, with 69 species recorded in this forest, and some species are absent in the artificial forest. The Sorensen index (74%) shows that there is a floristic affinity between the artificial forest and the natural forest. The dominant species in the natural forest include Musanga cercropoides, Distemonanthus benthamianus, Terminalia superba, and Terminalia ivorensis (Figure 4a). In contrast, in the artificial forest, the dominant species are Milletia laurentii, Diospyros crassiflora, Entandrophragma angolensis, Terminalia ivorensis, and Lovoa trichilioides (Figure 4b). These different species encountered in the natural and artificial forests justify the high values of Piélou's index close to 1. The high diversity indices show that individuals are well represented among species. These results are consistent with those of Ntonmen et al. (2020) obtained in the semi-deciduous forests of Cameroon.

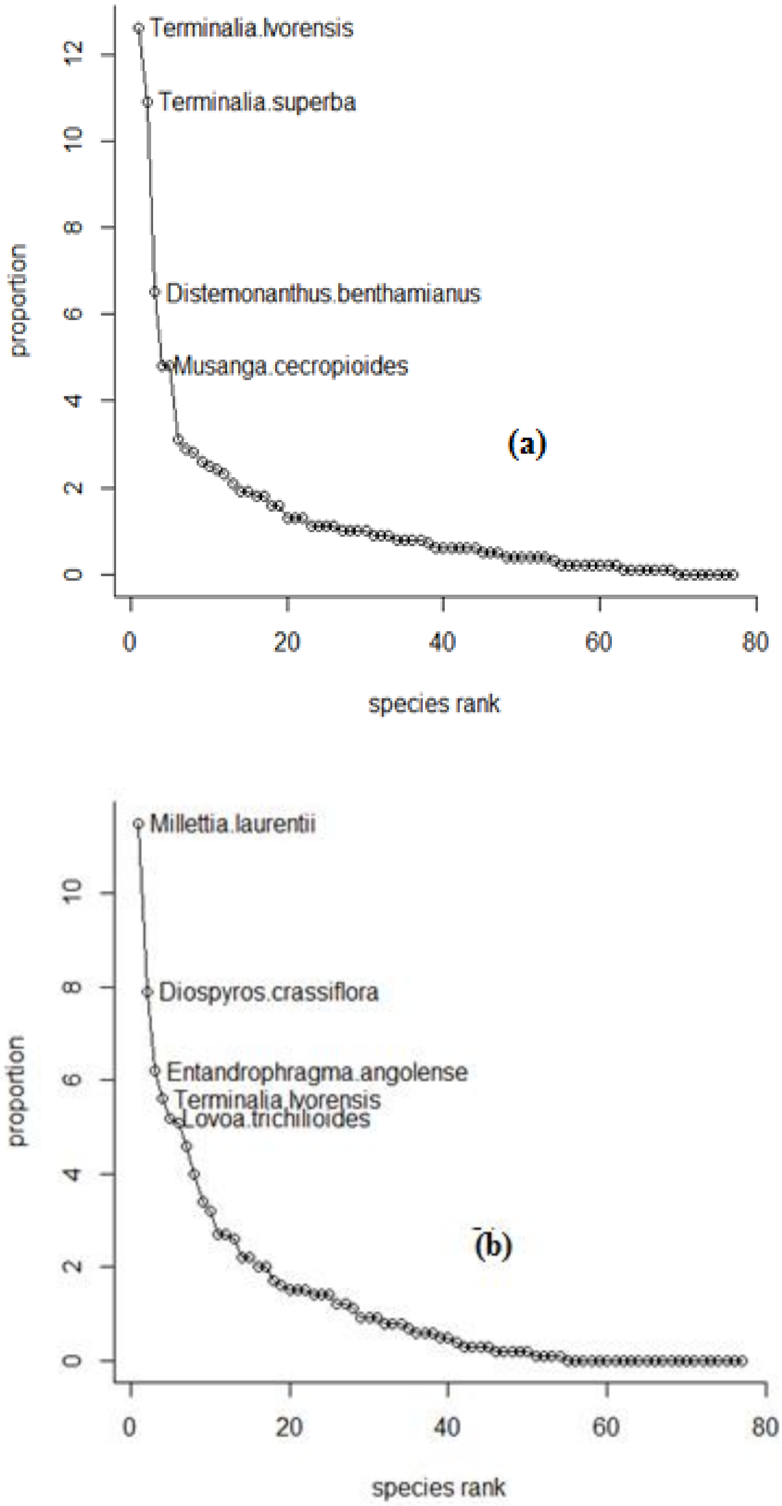

Figure 4. The ranking curve for the most common species in natural forests (Figure 4a) and artificial forests (Figure 4b).

3.3. Ecologically Important Families and Species in the Study Area

The analysis of the data collected in the field showed that ten families are the most important in terms of the number of individuals in the artificial forest and the natural forest. In the former, the Fabaceae family is the most important in terms of the number of individuals (102). It is followed by the Combretaceae (89) and the Meliaceae (77). As for the natural forest, the Combretaceae family is the most important in terms of the number of individuals (164), followed by the Fabaceae (133) and the Meliaceae (116). Only the Burseraceae family is the least important of the ten ecologically important families. Millettia laurentii is the most important species in terms of individuals (53), followed by Terminalia superba (52), Terminalia ivorensis (51), and Lovoa trichilioides (44). Acacia senegalensis (21) is the least important of the ten dominant species in the artificial forest. Furthermore, in the natural forest, Alstonia boonei is the most important species in terms of individuals (105), followed by Acacia senegalensis (102), Amphimas pteerocarpioides (100), and Terminalia ivorensis (82). Lophira alata (55) is the least important of the ten dominant species in the natural forest. These results are similar to those found by Temgoua et al. (2018) in agroforestry systems based on cocoa trees in Eastern Cameroon.

3.4. Vegetation Structure and Density of Woody Species

The diameter classes of the inventoried trees were distributed according to the forest types. The analysis of the data collected in the field showed that, for both forests studied, the density of trees is higher in the diameter class [10-20]. On the other hand, the diameter class [120 and +[is the least represented, with an average of 19 individuals/ha. The abundance of stems per hectare decreases with increasing diameter classes in the artificial forest. However, an opposite trend is observed in the natural forest. These results are consistent with those of Tsemo (2018), who found that in the teaching and research forest of IRAD in Bélabo, the diameter class [10-20[is the most densified. A reversed "J" distribution of diameter classes is observed in the natural forest, and a saw-tooth pattern is observed in the artificial forest.

3.5. Distribution of the Two Forest Types According to Their Densities and Basal Areas

Table 3 presents the average density of individuals in the two types of forests. It can be seen from this table that the average density of individuals per hectare is 616±339 N/ha in the artificial forest and 312±167 N/ha in the natural forest. These results are lower than the densities of 5075 stems/ha and 5333 stems/ha found respectively by Ntonmen et al. (2020) in the semi-deciduous forests of Cameroon. This difference may be due, firstly, to the data collection methodology and, secondly, to the fact that these authors limited themselves to trees with diameters between 1 and 10 cm. But these results are similar to those of Tsemo (2018) in the teaching and research forest of IRAD in Bélabo (619.43 stems/ha).

On the other hand, Table 4 shows the variation of the basal area according to the forest types. It is 55.97±36.28 m^2/ha in the artificial forest and 58.33±19.42 m^2/ha in the natural forest. These results corroborate those of Tsemo (2018), who showed that the highest basal area was found in mature secondary forests. In the first case, the ANOVA test showed that there is no significant difference between the density of individuals according to forest types (p=0.21), while in the second case, this test showed that there is no significant difference between the basal area of trees in the two forest types studied (p=0.93).

Table 3. Average density of individuals in the two forest types

Forest type	Density (N/ha)
Artificial forest	616±339 N/ha
Natural forest	312±167N/ha

NB : **N**= Number of individuals

Table 4. Basal area of the two forest types

Forest type	Basal area (m2/ha)
Artificial forest	55,97±36,28 m^2/ha
Natural forest	58,33±19,42m^2/ha

3.6. Carbon Stocks in Different Forest Types

Carbon stocks were estimated at two pools, including aboveground carbon (Table 5) and belowground carbon (Table 6). In the first case (Table 5), the highest amount of sequestered aboveground carbon was obtained in the natural forest (348.96±118.13 tC/ha). This carbon stock gradually decreases, without being significantly different (p=0.89), towards the artificial forest, which is (323.13±264.82 tC/ha). In the second case (Table 6), the belowground carbon stocks follow the same progression as the aboveground carbon stocks. However, the highest amount of sequestered belowground carbon was obtained in the natural forest (83.75±28.35 tC/ha). This carbon stock gradually decreases, without being significantly different (p=0.89), towards the artificial forest, which is (77.55±63.56 tC/ha). After statistical tests at the 5% probability level, it appears that there is no significant difference between the total carbon stock in the two forest types (p=0.89). The highest total carbon stock in the two forest types was obtained in the natural forest (432.71±146.49 tC/ha).

Table 5. Stock of carbon removed in the two types of forest

Types of forest	AGC (tC/ha)
Artificial forest	323,13±264,82 a
Natural forest	348,96±118,13 a
Study area	323,86±261,42

NB : Identical letters a simply mean a non-significant difference

Table 6. Hypogenous carbon stock in the two types of forest studied.

Types of forest	BGC(tC/ha)
Artificial forest	77,55±63,56 a
Natural forest	83,75±28,35 a
Study area	77,73±62,74

NB: Identical letters a simply a non-significant difference

3.7. Correlation between carbon stock, tree density, basal area and number of tree species

The PCA made it possible to show the affinities between the different parameters. It emerges from this analysis that the percentage of inertia is 87%. Carbon stocks are very positively and strongly correlated with basal area. The same is true with the density of individuals, but this correlation is weak. On the other hand, species richness does not seem to have an influence on carbon stocks and basal area. However, it remains negatively correlated with the density of individuals in the study area. This information was verified using the Pearson correlation matrix (Table 7). The analysis of Table 7 shows a positive and slightly significant correlation between the density of individuals and the basal area (r=0.46) and carbon stocks (r=0.45). This means that the basal area increases with density and carbon stocks. This link is even stronger, positive and significant between the basal area and carbon stocks (r=0.915). This also shows that an increase in basal area also leads to an increase in carbon stock. However, the correlation between these parameters and species richness is almost zero and not significant, tending towards a negative link. These results are similar to those of Tsemo (2020), who noted that there is a very strong correlation between the basal area and the carbon stock of trees (r = +0.69).

Table 7. Correlation matrix between the parameters species richness, structure and total carbon stocks

	Individual density (N/ha)	Basal area (m^2/ha)	Carbon stocks (tC/ha)	Specific richness
Individual density (N/ha)	1,000			
Basal area (m^2/ha)	0,4579***	1,000		
Carbon stocks (tC/ha)	0,4488***	0,915***	1,000	
Specific richness	-0,171	-0,015	-0,041	1,000

4. Conclusion

This study focused on the comparison of woody biodiversity and carbon stocks in the artificial and natural forests of the forest massif of ENEF in Mbalmayo. The comparison focused mainly on four elements, including (i) carbon stocks in different vegetation types, (ii) species richness

and diversity index, (iii) vegetation structure of vegetation types in the two forest types, and (iv) biomass and carbon stocks. For the estimation of biomass, the indirect or non-destructive method, consisting of applying regression models, volume tables, or geometric formulas to measurements made in the field, was used. To characterize the vegetation structure of the two vegetation types studied, the structural parameters determined focused on the importance index of species, the importance index of botanical families, the distribution of species in diameter classes, and the basal area of trees per hectare. For species richness and diversity index, the focus was on determining Shannon's and Simpson's diversity indices as well as Pielou's index. Finally, biomass and carbon stocks in different vegetation types were estimated based on Fayolle's allometric equation. The results of the study show that the flora is very rich and diverse, with 77 species belonging to 33 families. The arboretum of ENEF in Mbalmayo includes 77 species belonging to 69 genera and 33 families. The natural forest is the most diverse, with 69 species recorded, compared to 58 species for the artificial forest. For both forests studied, the density of trees is higher in the diameter class [10-20[, while the diameter class [120 and +[is the least represented, with an average of 19 individuals/ha. Unlike the natural forest, the quantity of stems per hectare decreases with increasing diameter classes in the artificial forest. The average density of individuals per hectare is 616±339 N/ha in the artificial forest and 312±167 N/ha in the natural forest. As for carbon stocks, there is no significant difference between the total carbon stock in the two forest types (p=0.89). The highest total carbon stock in the two forest types was obtained in the natural forest (432.71±146.49 tC/ha). This stock slightly decreases in the artificial forest (400.69±328.37 tC/ha). There is a weakly significant positive correlation between the density of individuals and the basal area (r=0.46) and carbon stocks (r=0.45). However, the correlation between these parameters and species richness is almost zero and not significant, tending towards a negative link. Overall, the study shows that the ecosystems of the ENEF forest massif in Mbalmayo have a strong capacity for carbon sequestration and storage, with an average of 432.71 tC/ha for the natural forest and 400.69 tC/ha in the artificial forest. Since a large part of the population in both cases consists of young trees, the ENEF forest massif has a particular status as a living carbon sink in the Congo Basin for future decisions, thus offering Cameroon a prime position in the carbon market.

Abbreviations

AGB: aboveground biomass value

BGB: Belowground biomass value

ENEF: National School of Water and Forests

FIV: Family Importance Value

IVI: Importance Value Index

PCA: Principal Component Analysis

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Not applicable.

Authors contributions

All authors made significant contributions to the conceptualization, design, data collection, data analysis, manuscript writing and editing, manuscript translation and proofread. Evariste Fongnzossie and Yannick Elysée Epée Ewane conceptualized and designed the study. Yannick Elysée Epée Ewane, Tabue Mbobda Roger Bruno, Augustin Guérin Mbamba, Ousmane Bako and Germain Mbock designed the data collection tools and conducted the study. Germain Mbock, Clautaire Mwebi Ekengoue, and Fanta Barry conducted manuscript writing and editing, and manuscript translation and proofread. Evariste Fongnzossie and Bruno Mbobda Tabue gave overall guidance for the study. All the authors gave final approval to the manuscript for journal submission and are responsible for the content of the manuscript.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Macrothink Institute.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

Open access

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