

Original Article

# Evaluation of the Floristic Diversity and Carbon Stock of Disturbed Sites after Reforestation in the Forest Management Unit 10 025 in the East Region of Cameroon

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**Abstract** - The rate of degradation of tropical forests is at an alarming rate, requiring management measures. Reforestation is the increase in the economic volume and value of forests. However, there is little knowledge on the growth performance of species used for reforestation in Africa. This study highlights the growth and survival of exploitable species and the effect of reforestation on the carbon sequestration capacity of exploitable species in the tropical rainforest. This study was carried out in non-reforested parks and reforested parks, where sampling was carried out in 5x5m<sup>2</sup> quadrats, and all tree individuals with a diameter  $\geq 1$ cm were measured for diameter and height. The composition, structure, and carbon stock were determined for each site. The floristic inventory recorded 1,106, 820, and 220 individuals in the non-reforested parks, reforested parks, and under the forest canopy, respectively. The abundance of *Musanga cecropiodes* in non-reforested parks confirms that this tropical forest was a degraded forest, and *Triplochiton scleroxylon* in the reforested parks indicates its abundance. For the carbon stock of species exploitable between 2021 and 2025, respectively, the total carbon stock of non-planted exploitable species was higher than the carbon stock of planted exploitable species. At the early stages of growth, only the diameter is a good predictor of carbon stock; with time, the height becomes another predictor of carbon stock. The growth of exploitable species at different sites thus depends on their specific needs at the seedling stage.

**Keywords** - Biodiversity, Forest Management, Plant Biomass, Tropical forest, Sustainable management.

## 1. Introduction

Forest ecosystems are very important for the well-being of human populations [1]. They provide numerous services, nutrient recycling, soil stabilization, create natural habitats, and a wide range of outdoor recreational opportunities [2]. They also combat rural poverty by ensuring food security and the livelihood of the local population [3]. Tropical forests are thus among the most important biodiversity reservoirs and carbon sinks on the planet [4, 5]. The forests of Central Africa constitute the second largest expanse of dense tropical rainforest in the world, covering more than 250 million hectares [6]. However, recent threats indicate that Central Africa has lost more than 6 million hectares of humid primary forest since 2001 [7]. Such changes to natural forests have resulted in negative impacts on biodiversity, soil structure, and water quality [8] as well as disturbing many vital ecosystem processes [9]. These changes also result in an increased emission of greenhouse gases to the atmosphere, thereby enhancing global climate change [10]. This is thus of extreme concern as many tropical forests are considered biodiversity hotspots [11] and

host invaluable ecosystem services [12]. It is thus necessary to identify effective approaches to conserve and restore these forested landscapes for a continuous provision of their ecosystem goods and services.

Deforestation and forest degradation are extremely pervasive in tropical countries, where the total primary forest area has decreased by 62 million hectares from 1990 to 2015 [13]. Though Cameroon has the fourth-largest forest area in Central Africa with 20.2 million hectares of forest [3], deforestation is still ongoing. Deforestation and forest degradation in developing countries are caused by human activities such as agriculture, urban development, logging, and the collection of firewood and timber. Though there is evidence that if it is left alone, abandoned, disturbed sites will develop into secondary forest [14, 15], the recovery may take up to several decades to develop a closed canopy [16], and it could result in species composition that fails to meet management objectives [17, 18]. Successful establishment of later successional forest species in deforested areas has proven difficult throughout the tropical



world because of the short-lived nature of tropical forest seeds and the inability to form viable seed banks [19]. Thus, the availability of propagules is often the major factor limiting forest recovery in abandoned areas, particularly for later successional species [19, 20]. In this case, planting seeds or seedlings (active restoration) of these target species is essential to ensure their presence and to expedite the recovery process [21]. Restoration of forests with timber species is required and can be achieved through passive (natural regeneration) or active (reforestation) mechanisms. Artificial reforestation, which is a silvicultural management method, supplements natural regeneration with the planting of commercial and indigenous species, is recommended [21, 22].

Since the 1950s, most of these tropical forests have been granted to private logging companies and have been impacted by selective logging [23, 24]. Today, approximately 26% of the forested area in Central Africa is licensed to logging companies, contributing significantly to national economies [25, 26]. With mismanagement and the conversion of large tracts of West African forests to agricultural production, Central African forests are experiencing increased harvesting pressures, and this is particularly true for the few timber species targeted by selective logging [27]. Though National regulations impose minimum cutting diameters for each targeted species and 20–30-year felling cycles, these decisions are based on sound biological knowledge of the trees. Thus, after several felling cycles, timber resources of the targeted populations, i.e., the number of trees with a diameter superior to the minimum cutting diameter, have in places dramatically decreased over the long term, leading to the scarcity or vulnerability of certain ecologically exploitable species [28]. The felling and extraction of these large trunks causes substantial collateral damage to the surrounding population [29], thus affecting the soil [30], tree regeneration [31, 32], and overall carbon stocks [33]. Also, in selectively logged tropical forests, the creation of tracks and parks can disturb a considerable portion of the soil and forest cover during timber harvesting, creating distinct sites for plant establishment. Large openings are prone to invasion by shrubs, vines, and undergrowth grasses, which hinder tree regeneration by competing with seedlings of slow-growing, economically important species [34].

Planting timber species in logging gaps or restoring degraded forest areas are effective techniques that have the potential to determine the growth requirements of these species while maintaining the ecosystem diversity and resilience and protecting sensitive species of high commercial value [35]. However, firstly, logging gaps are difficult to monitor long-term, and the good performance in the early stage of tree life may be reduced by competition in later stages. Long-term monitoring provides baseline data for management decisions for sustainable forest management. Secondly, logging gaps may not be suitable for light-demanding species at the high end of the irradiance spectrum [36], and plantations may thus be considered for true pioneers, as well as for the restoration of highly

degraded areas and for reforestation. Most African timber species are widespread light-demanding species [37-39] that require high light environments at the seedling stage for survival and growth [40]. The selective logging treatments generally applied in Central Africa [23, 41] do not open the canopy sufficiently to promote their regeneration (Hall *et al.*, 2003), although tree regeneration is controlled by more than just gap size [42]. Thus, a sound knowledge of the silvicultural practices is required for the optimization of its growth. However, knowledge about the specific growth requirements of many of the commercial species that are available for planting is still very limited [43]. Little is known of the biological characteristics of these species, especially at the seedling stage [44, 45]. Also, many enrichment planting trials in Africa were based on a few or single species (e.g., *Khaya spp.*, *Tarrietia utilis*, [46]), sometimes planted on huge areas (e.g., *Aucoumea klaineana* in Gabon, [47]). The exploited forest could therefore be gradually replaced by relatively species-poor forests dominated by pioneer species, then over time by more diverse mixtures of late-succession species, ultimately leading to the re-establishment of the climax forest [48], which would affect its biodiversity. Thus, practical guidelines need to be developed, tailored to the socio-economic context and to the autecology of each timber species, and species need to be matched to the specific biophysical conditions of the site. This therefore calls for long-term monitoring of the seedlings of exploitable species to ensure species-rich forests 20-30 years after exploitation.

The world's forests also play a crucial role in carbon storage and climate regulation [49, 50]. Deforestation and forest degradation release substantial amounts of CO<sub>2</sub> into the atmosphere, contributing to global warming [51]. Forest degradation and disturbances account for 69% of total carbon losses from tropical forests [52]. With growing awareness of the importance of forests in mitigating climate change, a mechanism has been developed to reduce emissions from deforestation and forest degradation, to promote conservation, sustainable forest management, and enhancement of forest carbon stocks (REDD+) in developing countries [53]. With the rehabilitation and sustainable management of Forest Management Units (FMU), based on particular exploitable species, there is an urgent concern for the State of Cameroon to assess the management of existing Forest Management Units (FMUs), which were set up by the various structures responsible for reforestation and forest resource regeneration that have succeeded one another in the field. The potential of enrichment planting as a forest rehabilitation method, and a conservation and climate change mitigation strategy, has been evident in many studies [54]. Because enrichment planting entails the establishment of valuable species as an addition to the already existing species in a forest, this can increase the value of a forest, which may also prevent deforestation via its conversion to other land uses [55]. Despite its potential to rehabilitate degraded forestland to its original state [56], little is known of this in the tropics because most studies were biased toward the temperate regions [57]. Moreover, scientific reports on the growth rate

of the species and soil properties (Karam *et al.*, 2013) and planting seedlings [58] are dominant for rehabilitation forests and fewer on its capacity in accumulating biomass and in sequestering carbon, indicating that there are gaps in the literature in the holistic understanding of the outcome of the technique.

In this study, we analyzed the long-term survival and growth of exploitable species in enriched logging gaps and the diversity of disturbed sites after selective logging, being one of the few studies that have dwelled on enrichment planting in selectively logged sites in Cameroon. The general objective of this study was to determine the diversity, growth performance of plant species, and the accumulation of biomass and Carbon stock in the different ecosystems created by selective logging. The specific objectives of this study were therefore to: i) characterize the floral diversity of disturbed sites after selective logging; ii) determine the growth of exploitable species on disturbed sites after reforestation; and iii) estimate the change in the carbon stock of exploitable species on disturbed sites after reforestation. The data generated from this study will serve as baseline information on the growth requirements of exploitable species and their carbon stock potential at different stages of development in these sites that are under enrichment planting. Understanding its potential as a climate change mitigation strategy can help us determine how far its rehabilitation efforts have gone for its degraded forestlands. Through this, we can outline a carbon storage baseline as part of the Reducing Emissions from Deforestation and Degradation in Developing Countries (REDD) scheme [59, 60].

## 2. Materials and Methods

### 2.1. Study Sites

An enrichment planting was established in the Forest Management Units (FMU 10-025) in the East Region of Cameroon (Figure 1). This study was carried out at the Société Forestière Industrielle de Lokoundje (SFIL) Ndeng (FMU10-025), belonging to the Groupe Decolvenaere (GDC) timber company located at the Boumba and Ngoko division of the East Region, to establish baseline conditions of the forest. The East Region occupies the Southeastern portion of the Republic of Cameroon. It lies between latitude 3°08 to 3°21 North and longitude 14°31 to 14°52 East. It is bordered to the East by the Central African Republic, to the South by the Republic of Congo, to the North by the Adamawa Region, and to the West by the Centre and South Regions. It has an area of 109,011 km<sup>2</sup> with its soil predominantly ferrallitic, rich with iron and red in colour. The East Region has a wet equatorial climate with high temperatures (24°C on average) and a lack of traditional seasons with two dry and rainy seasons. Relative humidity and cloud cover are relatively high, and the annual mean precipitation is 1500-2000 mm except in the extreme eastern and northern portions, where it is slightly less [61]. The forest flora is dominated by commercially valuable *Triplochiton scleroxylon* and is heavily targeted for exploitation [62] along with other exploitable species. The presence of forest savannah transition zones makes the flora

unique, with both savannah and forest species coexisting as the forest transitions into savannah, which supports plant species unique to this habitat type [61] (Figure 1).

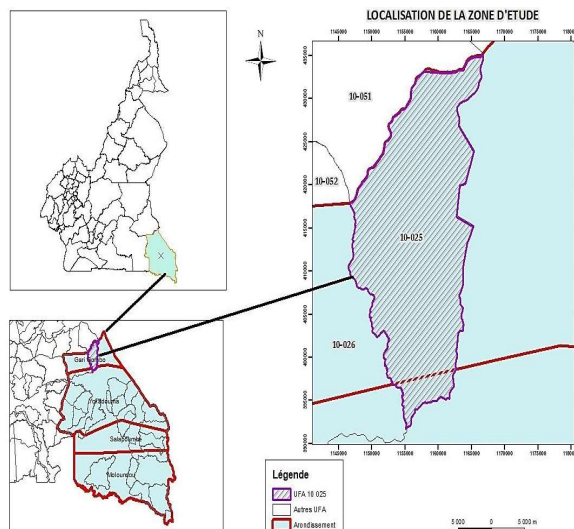


Fig. 1 Study site of enrichment planting in the East Region of Cameroon

### 2.2. Site Establishment and Demarcation

#### 2.2.1. Site Demarcation

This study was carried out in reforested parks and tracks, non-reforested parks, and under the forest canopy in Annual Allowable Cuts (AAC) (3-1, 3-2, 3-3, 3-4, 4-2) of the FMU 10 025. The parks were selected based on the distribution map of the disturbed sites being reforested and some not reforested, and the data on the growth of these species was still available from the 2021 study. To assess the natural regeneration of disturbed sites after logging, all tree species were surveyed in 20 non-reforested parks exploited in 2019. To determine the growth of exploitable species after reforestation, 20 reforested parks with their corresponding reforested tracks, enriched 19 years ago, were used to measure the growth of planted trees during reforestation (indicated as planted) and unplanted exploitable species (species that germinated from the soil seed bank) (indicated as unplanted). The reforested parks had trees that were tagged in the 2021 inventory. The 40 parks were found on a sampling area of 0.6 ha with an average length and width of 150m x 41m, respectively. In the disturbed sites, 5 x 5 m<sup>2</sup> quadrats were created across the entire length and width of the parks and tracks, using strings to mark their boundaries. The quadrat size is considered the minimum size for forest inventories and the planting space used for enrichment planting. Under the forest canopy, the total sampling area was 0.4 hectares with an average length and width of 100m x 5m. Three plots were established under the forest canopy at a distance of 0,5km apart and further divided into 5 x 5 m<sup>2</sup> quadrats. Sampling took place in each 5 x 5 m<sup>2</sup> quadrat while skipping the next to sampling the next (Figure 2). The plots under the forest canopy were considered the control plots and thus replicated. The geographical coordinates of each site were recorded using a GPS device.

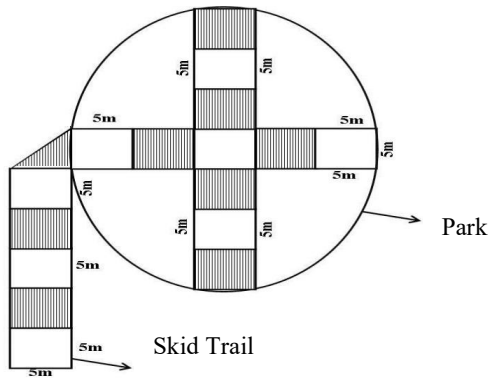


Fig. 2 Field demarcation in the East Region of Cameroon

### 2.2.2. Site Enumeration

In reforested parks and tracks, non-reforested parks, and under the forest canopy, all trees with a Diameter at Breast Height (DHB)  $\geq 1\text{cm}$  were measured, thus taking into consideration the undergrowth for their diameter and height, and identified from January to February 2025. The diameter was measured using a diameter tape for individuals  $\geq 6\text{cm}$ , a calliper for individuals  $\leq 6\text{cm}$ , and the height with a measuring tape. The collar diameter was also measured for smaller seedlings, and each stem was measured to the nearest millimetre. The diameters and heights obtained in the field during the floristic inventories were used to assess the growth and above-ground biomass of exploitable and non-exploitable species using the non-destructive method of [63]. Above-ground biomass was surveyed in 2021, and another survey was also conducted in 2025. The exploitation status of the tree species was determined from the list of forest species in Cameroon's dense forests presently exploited or potentially exploited, and the different groups obtained are the list of species subject to standing tree valuation [64]. For each tree identified, the scientific, vernacular names, and/or commercial names were noted on the basis of the distinguishing characteristics (bark, buttress, etc.) of the species by a botanist and a reforestation agent who had a good knowledge of forest species for proper identification using the Angiosperm Phylogeny Group II [65] classification.

### 2.3. Data Analyses

#### 2.3.1. Determination of the natural regeneration of disturbed sites after logging in the East Region of Cameroon

The floristic composition of an environment refers to all the plant species found in that environment, their abundance, their distribution by family, by genus, and also by biological type and morphological type. The abundance and species richness of all tree species inventoried were used to assess the floristic composition after logging. Species abundance was defined as the number of individuals of different species [66]. According to Aké-Assi [67], species richness was defined as the number of species recorded in a given area. It was measured by counting all the species recorded in each type of land use without taking into account their abundance. The importance of plant species and families was highlighted using the Importance Value Index (IVI) and Family Importance Index (FIV). The Importance Value Index (IVI) developed by Curtis and

Macintosh [68] corresponds to the sum of Relative Density (DeR), Relative Dominance (DoR), and Relative Frequency (FR). FIV was the sum of the relative diversity, relative dominance, and relative density of each family [69]. They are calculated using the following formulas:

$$IVI = SRDe + SRDo + SRF \quad (1)$$

Where SRDe = Species Relative Density, which is determined as:

$$SRDe = \frac{\text{number of individuals of that species}}{\text{total number of individuals}} \times 100$$

SRDo = Species Relative Dominance, which was determined as:

$$SRDo = \frac{\text{Basal area of that species}}{\text{total basal area}} \times 100$$

SRF = Species Relative Frequency, which was

$$RF = \frac{\text{number of quadrats with that species}}{\text{total number of quadrats}} \times 100$$

The Family Importance Value (FIV) corresponds to the most important family [69]. It was calculated by the formula:

$$FRDe + FRF + FRDo \quad (2)$$

Where FRDe = Family Relative Density, which was

$$FRDe = \frac{\text{Number of individuals in that family}}{\text{total number of families}} \times 100$$

FRDo = Family Relative Dominance, which was

$$FRDo = \frac{\text{Basal area of that family}}{\text{total basal area}} \times 100$$

FRF = Family Relative Frequency, which was

$$FRF = \frac{\text{Number of quadrats with that family}}{\text{total number of quadrats}} \times 100$$

#### 2.3.2. Estimation of the Natural Regeneration of Exploitable Species After Reforestation

Demographic performance was determined by calculating growth rates. These rates were determined as described by [70]. The absolute growth rate measures the increase in a characteristic (height, diameter, etc.) of a plant species per unit of time without relating it to the initial size of the plant species. Thus, the formula was written as:

$$\text{Absolute growth rate} = \frac{\log(H2) - \log(H1)}{t1 - t2} \quad (3)$$

In addition, the relative growth rate was calculated to enable a comparison of the growth performance of exploitable species that takes into account differences in initial sizes [70]. Its formula was written as follows:

$$\text{Relative growth rate} = \frac{\text{Log}(H2) - \text{Log}(H1)}{t1 - t2} \times 100 \quad (4)$$

Where H2 and t2 were the final diameter or height and time (2025), while H1 and time (2021) were the initial diameter or height.

### 2.3.3. Determination of carbon stock variation after reforestation

#### Estimation of Plant Biomass

The diameters obtained in the field during inventories were used to assess the above-ground biomass of individuals (planted and unplanted) recorded using the non-destructive allometric equation of [63], which was expressed mathematically as follows:

$$AGB = 0.0673 \times (\rho D^2 H)^{0.976} \quad (5)$$

Where: AGB was the above-ground biomass of the tree (kg); D was the diameter of the tree (cm); H was the total height of the tree (m);  $\rho$  was the specific density of the tree in (g.cm<sup>-3</sup>). The specific densities used for each species are those given by the Global Wood Density Database [72].

#### Estimation of Carbon Stock

To get the carbon stock, biomass estimates are converted into carbon values using the Carbon Fractions (CF) of dry matter [73]. The default fraction is 0.47 for a whole tree [73]. The formula used was therefore:

$$\text{Carbon stock} = AGB \times 0.47 \quad (6)$$

Where: AGB was the above-ground biomass of the tree (kg).

#### Estimation of Carbon Sequestration

The carbon sequestration potential of different carbon reservoirs was calculated according to [74]. The formula used was as follows:

$$CO_2-e = TCS \times 3.67 \quad (7)$$

Where, CO<sub>2</sub>-e = carbon dioxide equivalent or weight; TCS = Total Carbon Stock and 44/12 (3.67) = ratio of the molecular weight of CO<sub>2</sub> to carbon, t CO<sub>2</sub>-e t / C.

### 2.4. Statistical Analysis

To carry out this study, the data were cleaned using Microsoft Excel 2013 software. Sorting was performed using the dplyr package from the tidyverse of the R software. The data analysis itself was performed, and the tables and figures were generated using a pivot table in Excel 2013 and the R software (R Studio) version 4.2.1. using the ggplot2, ggpubr, gt summary, and labelled packages. At a 5% probability threshold, several tests were also performed using R software (R Studio, version 4.2.1), including the Shapiro-Wilk test to test the normality of the parameters, the Levene test to test the homogeneity of the variance, and the Student's t-test for paired series to assess whether there was a difference between the parameters of the same species between 2021 and 2025. Subsequently, one-way ANOVA was used to test whether a quantitative parameter varies according to a qualitative parameter and to compare diameters and heights. Finally, Tukey-Kramer's post-hoc multiple comparison test was performed for pairwise comparisons.

## 3. Results

### 3.1. Natural Regeneration of Plant Species in Disturbed Sites after Logging in the East Region of Cameroon

#### 3.1.1. Floral Composition of Disturbed Sites after Logging in the East Region of Cameroon

In the non-reforested parks after logging, there was a total of 1,106 individuals belonging to 57 species, 49 genera, and 22 families that were inventoried (Table 1 and Figure 3). Generally, there were more exploitable species (549 individuals) in the non-reforested parks than non-exploitable species (166 individuals of potentially exploitable and 392 individuals of non-exploitable species). Among the species recorded in non-reforested parks, the non-exploitable species *Musanga cecropioides* (265 individuals) was the most abundant. Specifically, the exploitable species *Terminalia superba* (120 individuals) and the potentially exploitable species *Macaranga burifolia* were abundant (72 individuals) (Table 1).

Under the forest canopy, a total of 220 individuals belonging to 43 species, 41 genera, and 21 families were inventoried, with more exploitable species. It appears that species such as the exploitable *Azelia bipindensis* (29 individuals), the potentially exploitable *Cola gigantea* (20 individuals), and the non-exploitable *Hexalobus crispiflorus* (18 individuals) were the most abundant (Table 2).



Fig. 3 View of a non-reforested park after selective logging in the East Region of Cameroon

**Table 1. Species abundance and richness in non-reforested disturbed sites after logging in the East Region of Cameroon**

<b>Exploitable</b>	<b>Abundance</b>	<b>Potentially Exploitable</b>	<b>Abundance</b>	<b>Non exploitable</b>	<b>Abundance</b>
<b>species</b>		<b>species</b>		<b>species</b>	
<b>Terminalia superba</b>	<b>120</b>	<b>Macaranga burifolia</b>	<b>72</b>	<b>Musanga cecropioides</b>	<b>265</b>
Mansonina altissima	115	Cordia sp.	17	Trema orientalis	92
Pterocarpus soyauxii	114	Tetrorchidium didymostemon	22	Discoglyprena caloneura	8
Nauclea diderrichii	41	Rothmannia lujae	15	Ficus mucoso	8
Erythropleum suaveolens	28	Rauvolfia macrophylla	8	Fagara heitzii	5
Alstonia boonei	16	Xylopia aethiopica	10	Afrostyrax lepidophyllus	4
Triplochiton scleroxylon	17	Cola gigantea	7	Hexalobus crispiflorus	3
Entandrophragma cylindricum	10	Markhamia tomentosa	5	Hymenocardia heudelotii	2
Milicia excelsa	13	Cleistopholis patens	3	Dialium bipindensis	2
Entandrophragma candollei	13	Irvingia gabonensis	3	Bosqueia angolensis	1
Klainedoxa gabonensis	12	Vernonia conferta	2	Rinorea sp.	1
Pteleopsis hylodendron	7	Enantia chorautha	1	Ficus carica	1
Detarium macrocarpum	6	Caloncoba glauca	1		
Petersianthus macrocarpus	5				
Aningeria altissima	4				
Ceiba pentandra	4				
Entandrophragma utile	3				
Piptadeniastrum africanum	3				
Gambeya perpulchra	3				
Khaya anthotheca	3				
Antiaris welwitschii	2				
Diospyros crassiflora	2				
Nesogordonia calophylloides	2				
Nesogordonia papaverifera	1				
Canarium schweinfurthii	1				
Guarea cedrata	1				
Entandrophragma angolense	1				
Pterocarpus santalinoides	1				
Amphimas ferrugineus	1				
<b>Total</b>	<b>549</b>		<b>166</b>		<b>392</b>

Figures in bold indicate the highest.

**Table 2. Abundance of species under the forest canopy in the East Region of Cameroon**

<b>Exploitable</b>	<b>Abundance</b>	<b>Potentially exploitable</b>		<b>Non exploitable</b>	
<b>Species</b>		<b>Species</b>	<b>Abundance</b>	<b>Species</b>	<b>Abundance</b>
<b>Azelia bipindensis</b>	<b>29</b>	<b>Cola gigantea</b>	<b>20</b>	<b>Hexalobus crispiflorus</b>	<b>18</b>
Petersianthus macrocarpus	27	Fagara tessmanii	3	Musanga cecropioides	5
Celtis tessmannii	25	Duboscia macrocarpa	4	Polyalthia suaveolens	9
Terminalia superba	23	Cordia sp.	1	Swartzia fistuloides	1
Pterocarpus soyauxii	21	Anthothona macrophylla	2		
Nesogordonia calophylloides	6	Drypetes sp	5		
Erythropleum suaveolens	4	Macaranga burifolia	1		

Piptadeniastrum africanum	4	Ochthocosmus calothyrsus	1		
Guarea thompsonii	2	Xylopia staudtii	1		
Entandrophragma cylindricum	4				
Alstonia boonei	3				
Klainedoxa gabonensis	1				
<b>Total</b>	<b>149</b>		<b>38</b>		<b>33</b>

Figures in bold indicate the highest.

*Most Important Species in Disturbed Sites after Logging in the East Region of Cameroon*

In non-reforested parks, the non-exploitable species *Musanga cecropioides* (83,84), the potentially exploitable species *Macaranga burifolia* (16,22), and the exploitable species *Terminalia superba* (30,43) were the most important. However, under the forest canopy, the exploitable

species *Terminalia superba* (38,84), potentially exploitable *Cola gigantea* (19,74), and non-exploitable *Hexalobus crispiflorus* (19,03) were the most important (Table III). The most important families were the Urticaceae (61,30) in non-reforested parks and the Fabaceae (30,54) under the forest canopy (Table 3).

Table 3. Most important species and families in disturbed sites after logging in the East Region of Cameroon

Sites	Esp -Exp	IVI	Esp Pexp	IVI	Esp Nexp	IVI	Familles	FIV
<b>Non-reforested parks</b>	<b><i>Terminalia superba</i></b>	<b>30,43</b>	<b><i>Macaranga burifolia</i></b>	<b>16,22</b>	<b><i>Musanga cecropioides</i></b>	<b>83,84</b>	<b>Urticaceae</b>	<b>61,30</b>
	<i>Mansonia altwassima</i>	26,18	<i>Cordia sp.</i>	6,24	<i>Trema orientalis</i>	26,81	Malvaceae	58,15
	<i>Pterocarpus soyauxii</i>	24,14	<i>Tetrorchidium didymostemon</i>	4,21	<i>Discoglyprena caloneura</i>	1,90	Fabaceae	38,64
	<i>Nauclea diderrichii</i>	8,64	<i>Rothmania lujae</i>	3,18	<i>Ficus mucoso</i>	1,88	Combretaceae	27,86
	<i>Alstonia boonei</i>	8,36	<i>Rauwolfia macrophylla</i>	2,54	<i>Fagara heitzii</i>	1,15	Ulmaceae	20,32
<b>Under Forest Canopy</b>	<b><i>Terminalia superba</i></b>	<b>38,84</b>	<b><i>Cola gigantea</i></b>	<b>19,74</b>	<b><i>Hexalobus crispiflorus</i></b>	<b>19,03</b>	<b>Fabaceae</b>	<b>60,54</b>
	<i>Celtis tessmannii</i>	30,69	<i>Fagara tessmannii</i>	7,54	<i>Musanga cecropioides</i>	10,42	Malvaceae	33,63
	<i>Petersianthus macrocarpus</i>	29,46	<i>Duboscia macrocarpa</i>	5,47	<i>Polyalthia suaveolens</i>	8,11	Combretaceae	31,66
	<i>Azzeria bipindensis</i>	24,73	<i>Cordia sp.</i>	5,32	<i>Swartzia fistuloides</i>	1,62	Meliaceae	23,41
	<i>Pterocarpus soyauxii</i>	20,10	<i>Anthonotha macrophylla</i>	5,20			Ulmaceae	22,70

Esp Exp: Exploitable species; Esp Pexp: Potentially exploitable species; Esp Nexp: Non-exploitable species

The Shannon diversity index was 4,2 bits in non-reforested parks and 4,4 bits under the forest canopy. Piélou's evenness had a value of 0,72 in non-reforested

parks and 0,81 under the forest canopy. In addition, the Simpson index had a value close to '1' (0,9 in non-reforested parks and 0,93 under the forest canopy (Table 4).

Table 4. Diversity of disturbed sites after logging in the East Region of Cameroon

Sites	Number species	Number gender	Number family	Shannon diversity (H')	Piélou's evenness (E)	Simpson index (D)
<b>Non-reforested parks</b>	57	49	22	4,2	0,72	0,9
<b>Under the forest canopy</b>	43	41	21	4,4	0,81	0,93
<b>Total sampled</b>	76	62	29	3,82	0,61	0,93

*3.1.2. Structure of Disturbed Sites after Logging in the East Region of Cameroon*

The average density of both sites (canopy and non-reforested parks) was 4,483 stems/ha, with the highest density in non-reforested parks (3,833 stems/ha). By

species, *Celtis tessmannii* has a maximum density of 67 stems/ha among the species present under the forest canopy; *Musanga cecropioides* has a maximum density of 898 stems/ha among the species present in non-forest reforested parks. Under the forest canopy, the basal area of woody

species has a high value of 2.99 m<sup>2</sup>/ha, while in non-reforested parks, this value was low at 1.58 m<sup>2</sup>/ha.

3.1.3. Growth of Tree Species in Disturbed Sites after Logging in the East Region of Cameroon

In general, plant species present under the forest canopy had a higher diameter than those present in non-reforested

parks. Specifically, in non-reforested parks, the exploitable species *Entandrophragma cylindricum* had the highest diameter (53.7 cm), while under the forest canopy, the potentially exploitable species *Cordia* sp. had the highest diameter of (414.6 cm) (Table 5).

Table 5. Diameter growth of species in disturbed sites after logging

Parameter	Diameter (mm)						
	SITE	Esp Exp	Diameter (mean±S.E)	Pexp	Diameter (mean±S.E)	EspNexp	Diameter (mean±S.E)
Non-reforested parks	<b>Entandrophragma Cylindricum</b>		<b>53,7 ± 76,3</b>	<b>Rauvolfia macrophylla</b>	<b>48,5 ± 23,3</b>	<b>Trema orientalis</b>	<b>40,5 ± 25,8</b>
	Petersianthus macrocarpus		51,28 ± 48,07	Cordia sp.	44,2 ± 44,4	Bosqueia angolensis	39,2 ± 0,0
	Alstonia boonei		47,9 ± 70,3	Cleistopholis patens	36,8 ± 32,22	Hymenocardia heudelotii	37,25 ± 6,72
	Detarium macrocarpum		35,45 ± 1,83	Enantia chorantha	32,5 ± 0	Discoglyprena caloneura	34,6 ± 3,0
	Erythropleum suaveolens		33,1 ± 28,6	Markhamia tomentosa	30,0 ± 11,8	Ficus mucuso	32,55 ± 10,81
Under the forest canopy	<b>Guarea thompsonii</b>		<b>303,2 ± 22,5</b>	<b>Cordia sp.</b>	<b>414,6 ± 0</b>	<b>Musanga cecropioides</b>	<b>199,3 ± 104,6</b>
	Eribroma oblongum		224,8 ± 0,0	Irvingia gabonensis	350,3 ± 0	Swartzia fistuloides	175,8 ± 0,0
	Khaya anthotheca		223,6 ± 0	Anthonotha macrophylla	258,6 ± 49,5	Hexalobus crispiflorus	77,5 ± 59,0
	Piptadeniastrum africanum		177,5 ± 82,1	Fagara tessmanii	229,1 ± 135,9	Polyalthia suaveolens	49,5 ± 32,18
	Terminalia superba		163,34 ± 83,64	Tetrapleura tetrapleura	140,8 ± 0		

Esp Exp: Exploitable species; Pexp: Potentially exploitable;

Generally, under the forest canopy, tree species were taller than in non-reforested parks. The non-commercial species *Hexalobus crispiflorus* recorded the highest height

(5.0 m) in non-reforested parks, while *Irvingia gabonensis* had the highest height (18.0 m) under the forest canopy (Table 6).

Table 6. Height growth of species in disturbed sites after logging in the East Region of Cameroon

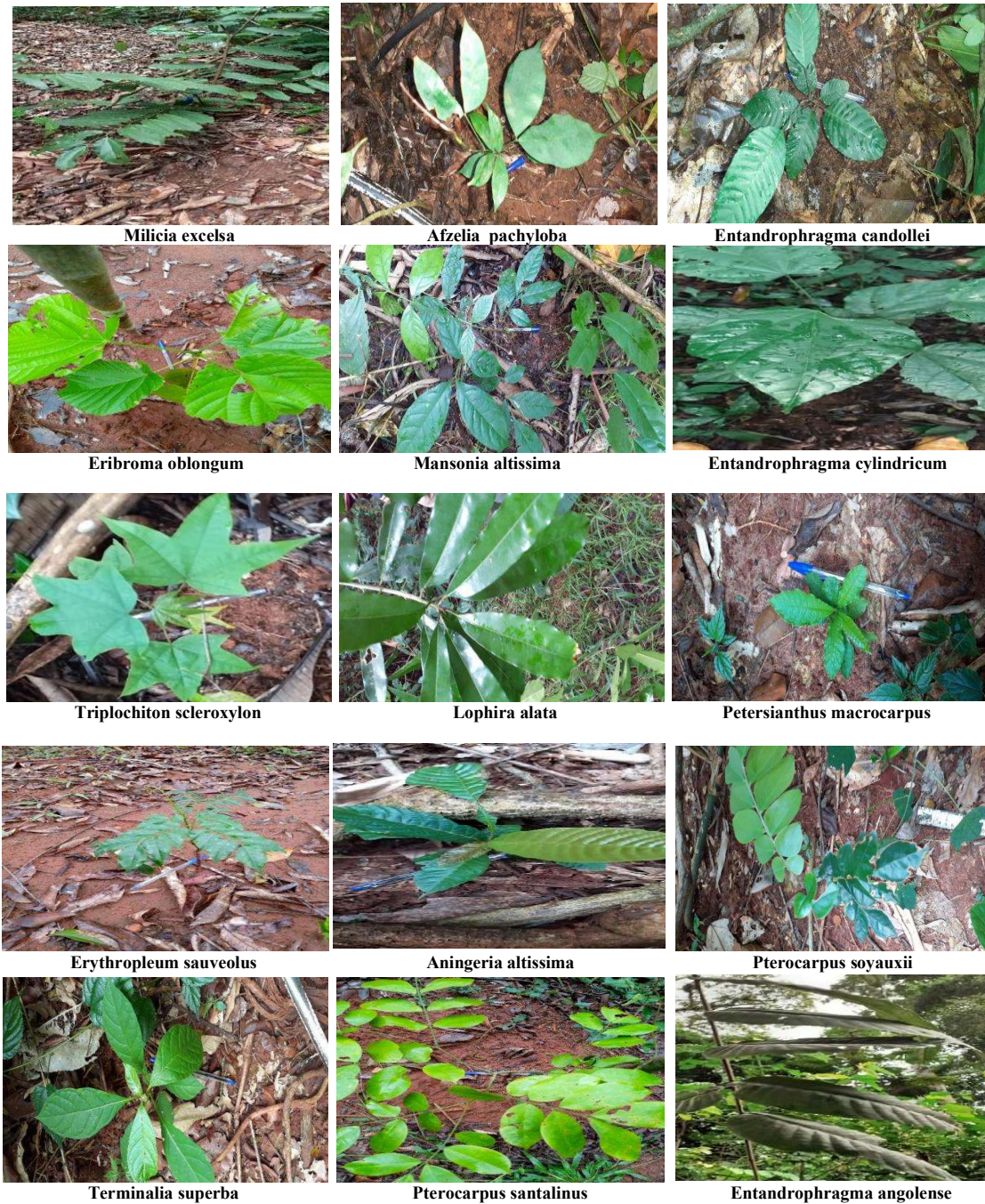
Sites	EspExp	Height (m)	Pexp	Height (m)	Esp Nexp	Height (m)
Non-reforested park	<b>Entandrophragma cylindricum</b>	<b>2,7 ± 3,6</b>	<b>Irvingia gabonensis</b>	<b>2,33 ± 1,15</b>	<b>Hexalobus crispiflorus</b>	<b>5,0 ± 3,0</b>
	Alstonia. boonei	2,5 ± 2,7	Macaranga burifolia	2,3 ± 0,9	Musanga cecropioides	2,4 ± 1,22
	Petersianthus macrocarpus	2,1 ± 1,3	Xylopia aethiopica	2,3 ± 1,4	Fagara heitzii	2,3 ± 0,8
	triplochiton scleroxylon	2,03 ± 2,63	Cleistopholis patens	2,2 ± 0,8	Trema orientalis	2,16 ± 0,95
	Diospyros crassiflora	2 ± 1,41	Cordia sp.	2,15 ± 2,5	Ficus mucuso	1,56 ± 0,62
	Under the forest canopy	<b>Khaya anthotheca</b>	<b>10 ± 0</b>	<b>Irvingia gabonensis</b>	<b>18 ± 0</b>	<b>Swartzia fistuloides</b>
Terminalia superba		8,5 ± 5,1	Picalima nitida	10,8 ± 6,3	Musanga cecropioides	7,8 ± 5,07
Eribroma oblongum		08 ± 0,0	Tetrapleura Tetrapleura	10,0 ± 0,0	Polyalthia suaveolens	5,1 ± 2,62
Piptadeniastrum africanum		6,75 ± 3,59	Anthonotha macrophylla	9,5 ± 3,5	Hexalobus crispiflorus	5,06 ± 3,7
Celtis tessmannii		5,88 ± 3,43	Fagara tessmanii	8,2 ± 8,7		

**3.2. Natural Regeneration of Exploitable Species after Reforestation**

**3.2.1. Floristic Composition of Exploitable Species after Reforestation**

The floristic composition of exploitable species after reforestation was diverse in the reforested parks, tracks, and under the forest canopy (Figure 4). A total of 820 individuals belonging to 51 species, 47 genera, and 22 families were recorded in the reforested parks. Under the forest canopy, we had a total of 212 individuals belonging

to 37 species, 37 genera, and 20 families recorded. Specifically, the reforested parks had more individuals of exploitable species (536 individuals) than the reforested tracks (40 individuals) and under the forest canopy (243 individuals). The exploitable species *Pterocarpus Soyauxii* (118 individuals) in the reforested parks, *Triplochiton Scleroxylon* (8 individuals), and *Pterocarpus Soyauxii* (8 individuals) in the reforested tracks, and *Afzelia Bipindensis* (29 individuals) under the forest canopy were the most abundant (Table 7).



**Fig. 4 Seedlings of exploited timber species in the East Region of Cameroon**

Table 7. Abundance of exploitable species in disturbed sites after reforestation in the East Region of Cameroon.

Species	Reforested parks	Reforested tracks	Under the forest canopy
<i>Azelia bipindensis</i>	50	6	<b>29</b>
<i>Alstonia boonei</i>	/	/	3
<i>Amphimas ferrugineus</i>	/	/	1
<i>Aningeria altissima</i>	1	/	/
<i>Anthothena macrophylla</i>	/	/	2
<i>Blinghia welwitschii</i>	/	/	1
<i>Canarium schweinfurthii</i>	/	/	1
<i>Celtis tessmannii</i>	/	/	25
<i>Cola gigantea</i>	/	/	20
<i>Cordia sp.</i>	/	/	1
<i>Cylicodiscus gabunensis</i>	4		/
<i>Diospyros crassiflora</i>	/	/	1
<i>Drypetes sp</i>	/	/	5
<i>Duboscia macrocarpa</i>	/	/	4
<i>Entandrophragma angolense</i>	42	/	/
<i>Entandrophragma candollei</i>	7	/	/
<i>Entandrophragma cylindricum</i>	4	/	4
<i>Entandrophragma utile</i>	1	/	3
<i>Eribroma oblongum</i>	/	/	1
<i>Erythrophleum suaveolens</i>	79	2	4
<i>Fagara tessmannii</i>	/	/	3
<i>Guarea thompsonii</i>	/	/	2
<i>Hexalobus crispiflorus</i>	/	/	18
<i>Khaya anthotheca</i>	/	/	1
<i>Klainedoxa gabonensis</i>	1	/	1
<i>Lasiodwascus fasciculiflorus</i>	/	/	1
<i>Macaranga burifolia</i>	/	/	1
<i>Mansonia altissima</i>	19	4	
<i>Milicia excelsa</i>	15	2	2
<i>Musanga cecropioides</i>	/	/	/
<i>Nauclea diderrichii</i>	14	3	/
<i>Nesogordonia calophylloides</i>	/	/	6
<i>Ochthocosmus calothyrsus</i>	/	/	1
<i>Pericopswas elata</i>	4	/	/
<i>Petersianthus macrocarpus</i>	/	/	27
<i>Picalima nitida</i>	/	/	3
<i>Piptadeniastrum africanum</i>	2	/	4
<i>Polyalthia suaveolens</i>	/	/	9
<i>Pterocarpus santalinoides</i>	2	/	/
<i>Pterocarpus santalinoides</i>	2	/	4
<i>Pterocarpus soyauxii</i>	<b>118</b>	<b>8</b>	21
<i>Rauvolfia macrophylla</i>	/	/	1
<i>Rothmannia lujae</i>	/	/	3
<i>Staudtia kamerunensis</i>	/	/	2
<i>Syzygium rowlandii</i>	15	/	/
<i>Terminalia superba</i>	53	7	23
<i>Tetrapleura tetrapleura</i>	/	/	1
<i>Tetrorchidium didymostemon</i>	/	/	2
<i>Triplochiton scleroxylon</i>	103	<b>8</b>	1
<i>Xylopi staudtii</i>	/	/	1
<b>TOTAL</b>	<b>536</b>	40	243

Figures in bold indicate the highest.

**Most Important Exploitable Species after Reforestation in the East Region of Cameroon**

The exploitable species *Triplochiton Scleroxylon* (66.21) was the most important in reforested parks.

Meanwhile, the species *Terminalia superba* was important in reforested tracks (57.17) and under the forest canopy (61.71) (Table VIII). The most important family was Fabaceae in all three sites (Table VIII).

**Table 8. The most important species in disturbed sites after reforestation in the East Region of Cameroon**

Reforested parks		Reforested tracks		Under the forest canopy	
Species	IVI	Species	IVI	Species	IVI
<i>Triplochiton scleroxylon</i>	66,21	<i>Terminalia superba</i>	57,17	<i>Terminalia superba</i>	61,71
<i>Pterocarpus soyauxii</i>	65,06	<i>triplochiton scleroxylon</i>	55,35	<i>Petersianthus macrocarpus</i>	36,06
<i>Erythrophleum suaveolens</i>	35,56	<i>Pterocarpus soyauxii</i>	47,49	<i>Celtis tessmannii</i>	28,57
<i>Terminalia superba</i>	31,61	<i>Azelia bipindensis</i>	39,03	<i>Azelia bipindensis</i>	27,57
<i>Entandrophragma angolense</i>	29,50	<i>Milicia excelsa</i>	38,71	<i>Pterocarpus soyauxii</i>	25,00

**Table 9. The most important families after reforestation in the East Region of Cameroon.**

Reforested reforested parks		Reforested reforested tracks		Under the forest canopy	
Family	FIV	Family	FIV	Family	FIV
<b>Fabaceae</b>	<b>123,2</b>	<b>Fabaceae</b>	<b>98,44</b>	<b>Fabaceae</b>	<b>66,09</b>
Malvaceae	60,98	Malvaceae	75,29	Combretaceae	53,41
Meliaceae	60,83	Combretaceae	52,17	Malvaceae	33,24
Combretaceae	26,74	Moraceae	46,21	Lecithydaceae	25,89
Moraceae	8,93	Rubiaceae	27,89	Meliaceae	25,75

The Shannon diversity index was 3.2 bits in reforested parks; 2.8 bits in reforested tracks, while it was 4.1 bits under the forest canopy. Piélou's evenness has a value of 0.76 in reforested parks, 0.94 in reforested tracks, and 0.70 under the forest canopy.

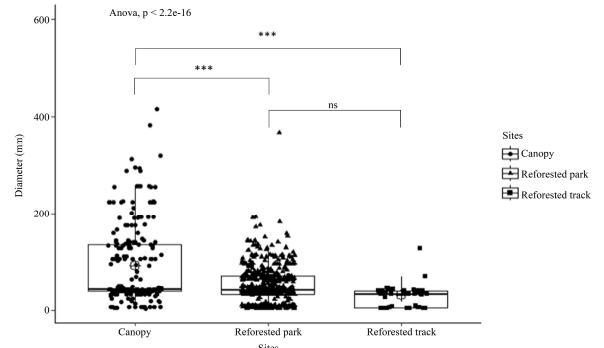
In addition, the Simpson index has a value close to '1' (0.9 in reforested parks; 0.8 in reforested tracks and 0.92 under the forest canopy). These results indicate that diversity after reforestation decreased in disturbed sites.

**3.2.2. Floral structure of Disturbed Sites after Reforestation in the East Region of Cameroon**

The basal area and density were highest under the forest canopy. Specifically, the average density of the sites was 2,314 stems/ha. By species, *Azelia bipindensis* had a maximum density of 77 stems/ha under the forest canopy, and *Pterocarpus soyauxii* had a density of 366 stems/ha in reforested parks. For basal area, the average value was 1.75 m<sup>2</sup>/ha in reforested parks, while in reforested tracks the low value was 0.06 m<sup>2</sup>/ha, and under the forest canopy the average value was 2.99 m<sup>2</sup>/ha.

**3.2.3. Growth of Exploitable Species in Exploited Areas after Reforestation in the East Region of Cameroon**

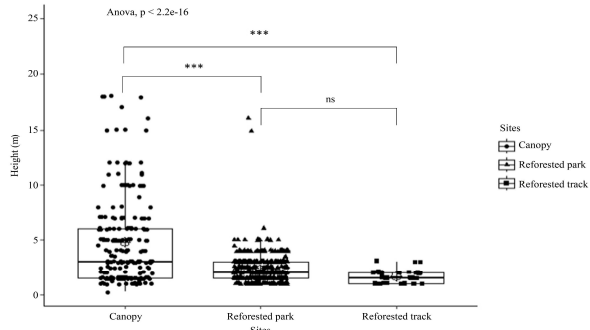
Turkey's multiple comparison test indicated that there was a significant difference (p-value < 0.05) as species under the forest canopy had a different diameter from those in reforested parks and reforested tracks. However, no significant difference was observed between the reforested parks and reforested tracks. Specifically, the reforested tracks had an average diameter of 30.22 ± 4.50 cm; the reforested parks had an average diameter of 51.16 ± 30.5 cm, and under the forest canopy an average of 92.6 ± 27.57 cm (Figure 5).



**Signif. Codes :** 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1 ; ns : non significatif

**Fig. 5 Comparison of diameter according to site in exploitable species after reforestation in the East Region of Cameroon.**

Among the species in reforested parks, *Pterocarpus santalinoides* had the maximum diameter of 90.30 ± 28.57 cm, while the minimum diameter was recorded in *Pericopsis elata* (32.2 ± 16.23 cm). In reforested tracks, *Milicia excelsa* had the maximum diameter (65.3 ± 87.82 cm), while *Pterocarpus soyauxii* had the minimum diameter of 16.78 ± 17.24 cm. Under the forest canopy, the maximum diameter of 414.6 ± 0.0 cm was observed in the species *Cordia* sp., and the minimum diameter of 29.43 ± 11.32 cm in the species *Entandrophragma utile* (Table 8). Turkey's multiple comparison test showed a significant difference in height (p ≤ 0.05) between different species and sites. Between different sites, the reforested tracks had an average of 1.69 m ± 0.25 m; the reforested parks had an average of 2.28 m ± 0.55 m, and under the canopy an average of 4.77 m ± 3.96 m. However, no significant difference was observed between the reforested tracks and the parks (Figure 6).



Signif. Codes : 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘.’ 1

Fig. 6 Comparison of growth in height of exploitable species after reforestation in the East Region of Cameroon

Among the species recorded in the reforested parks, *Entandrophragma cylindricum* had the maximum height of 5.38 m ± 7.11 m, while *Klainedoxa gabonensis* had the minimum height of 1 m ± 0.0 m (Table X).

In reforested tracks, the maximum height of 2.07 m ± 0.73 m was observed in the species *Terminalia superba*, and the minimum height of 1.63 m ± 0.35 m in the species *Pterocarpus soyauxii*.

Under the forest canopy, the maximum height of 16 m ± 0.0 m was recorded for the species *Cordia* sp, and the minimum height of 1.25 m ± 0.0 m for the exploitable species *Xylopia staudtii* (Table X).

Table 10. Growth of exploitable species after reforestation in the East Region, Cameroon.

Sites	Parameter	Species	DBH (mm)	Sites	Species	Height (m)			
Reforested park	Max	<i>P. santalinoides</i>	90,30± 28,57	Reforested park	<i>E.cylindricm</i>	5,38 ± 7,11			
		<i>E. cylindricum</i>	80,78 ± 74,43		<i>E. angolense</i>	2,76 ± 1,14			
		<i>T. superba</i>	73,76 ± 59,84		<i>T. scleroxylon</i>	2,66 ± 1,57			
		<i>E. angolense</i>	63,72 ± 31,31		<i>T.superba</i>	2,55 ± 1,05			
		<i>S. rowlandii</i>	59,74 ± 38,88		<i>P.soyauxii</i>	2,26 ± 0,84			
	Min	<i>C.gabunensis</i>	24,60 ± 18,38		<i>E.suaveolens</i>	1,93 ± 0,76			
		<i>P.africanum</i>	26,9 ± 32,67		<i>M.altissima</i>	1,71 ± 0,75			
		<i>N.diderrichii</i>	28,62 ± 19,05		<i>N.diderrichii</i>	1,69 ± 0,65			
		<i>M. excelsa</i>	29,49 ± 14,72		<i>P.africanum</i>	1,5 ± 0,71			
		<i>P. elata</i>	32,20 ± 16,23		<i>K.gabonensis</i>	1.0 ± 0,0			
Reforested Track	Max	<i>M. excelsa</i>	65,3 ± 87,82	Reforested Track	<i>T. superba</i>	2,07 ± 0,73			
		<i>T. superba</i>	41,06 ± 14,51		<i>M. excelsa</i>	2 ± 1,41			
		<i>N. diderrichii</i>	38,3 ± 4,64		<i>N.diderrichii</i>	1,83 ± 0,29			
		<i>E.suaveolens</i>	35,70 ± 4,53		<i>T.scleroxylon</i>	1,75 ± 0,27			
		<i>T.scleroxylon</i>	29,26 ± 16,37		<i>M.altissima</i>	1,5 ± 0,58			
	Min	<i>A. bipindensis</i>	25,65 ± 16,29		<i>A.bipindensis</i>	1,25 ± 0,42			
		<i>M.altissima</i>	20,55 ± 19,54		<i>E.suaveolens</i>	1,5 ± 0,71			
		<i>P.soyauxii</i>	16,78 ± 17,24		<i>P.soyauxii</i>	1,63 ± 0,35			
		Under the forest canopy	Max		<i>Cordia</i> sp	414,60±0,0	Under the forest canopy	<i>Cordia</i> sp	16,0±0,0
					<i>G.thompsonii</i>	303,2 ± 22,49		<i>P. nitida</i>	10,67 ± 6,35
<i>A.macrophylla</i>	258,6 ± 49,5			<i>T.tetrapleura</i>	10,0 ± 0,0				
<i>F. tessmanii</i>	229,07 ± 135,78			<i>A. macrophylla</i>	9,5 ± 3,54				
<i>T. superba</i>	163,34 ± 83,64			<i>T.superba</i>	8,48 ± 5,09				
<i>R. lujae</i>	40,97 ± 1,79		<i>C. gigantea</i>	2,55±1,04					
Min	<i>M.burifolia</i>	38,9±0,0	<i>M.burifolia</i>	2,0±0,0					
	<i>T.didymostemon</i>	37,25 ± 6,72	<i>S.kamerunensis</i>	1,65±1,91					
	<i>A.bipindensis</i>	29,88 ± 25,44	<i>A. ferrugineus</i>	1,5± 00					
	<i>E.utile</i>	29,43 ± 11,32	<i>X.staudtii</i>	1,5±0,0					

Max = maximum; Min = minimum

Relationship between Dendrometric Parameters of Exploitable Species after Reforestation

The relationship between the diameter and height of exploitable species is shown in Figure 7. The behaviour of

exploitable species appears to be similar between reforested tracks and parks where growth was slow, unlike under the forest canopy, where growth was more significant.

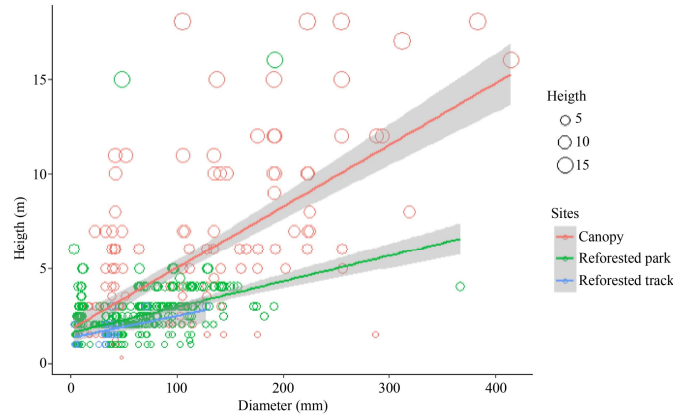


Fig. 7 Assessment of species growth of exploitable species after reforestation

3.3. The Dynamics of the Carbon Stock of Exploitable Species after Reforestation

3.3.1. Carbon Stock of Exploitable Species after Reforestation in the East Region of Cameroon

Table XI showed the amount of carbon stock in planted and unplanted exploitable species between 2021 and 2025. There was a significant difference (p-value < 0.05) in the carbon stock of exploitable species, which was higher in 2025 (21.13 kgC/ha) than in 2021 (1.25 kgC/ha) between planted and unplanted exploitable species. In 2021 and 2025, the total carbon stock of unplanted exploitable species

was 0.10 kgC/ha and 13.26 kgC/ha, respectively; while the carbon stock of planted exploitable species was 1.15 kgC/ha and 7.87 kgC/ha, respectively. Among the unplanted exploitable species, *E. angolense* stored more carbon with an average of 0.86 kgC/ha in 2021, while in 2025, *A. pachyloba* was the species that stored the most carbon with an average of 19.50 kgC/ha. Among planted exploitable species, *E. cylindricum* was the species that stored the most carbon, with an average of 1.98 kgC/ha in 2021, while in 2025, *A. pachyloba* was the species that stored the most carbon, with an average of 14.59 kgC/ha (Table XI).

Table 11. Carbon stock sequestered by planted and unplanted exploitable species after reforestation in the East Region of Cameroon

ESPÈCES	Unplanted exploitable species						Planted exploitable species							
	2021			2025			2021			2025				
	N	Biomass e Kg/ha	Stock de Carbone	CO <sub>2</sub>	Biomass e Kg/ha	Stock de Carbone	CO <sub>2</sub>	N	Biomass e Kg/ha	Stock de Carbone	CO <sub>2</sub>	Biomass e Kg/ha	Stock de Carbone	CO <sub>2</sub>
<i>Azelia pachyloba</i>	16	0,03	0,01	0,04	41,50	<b>19,50</b>	71,58	5	0,43	0,20	0,74	31,05	<b>14,59</b>	53,55
<i>Pterocarpus santalinoides</i>	20	0,45	0,21	0,78	29,88	14,04	51,53	25	3,57	1,68	6,16	20,24	9,51	34,91
<i>Mansonia altissima</i>	15	0,06	0,03	0,10	24,88	11,58	42,50	5	0,27	0,13	0,47	7,33	3,45	12,65
<i>Terminalia superba</i>	9	0,10	0,05	0,18	26,48	12,44	45,67	2	3,53	1,66	6,09	15,23	7,16	26,26
<i>Petersianthus macrocarpus</i>	12	0,03	0,02	0,06	18,92	8,89	32,63	/	/	/	/	/	/	/
<i>Entandrophragma angolense</i>	02	1,83	<b>0,86</b>	3,15	24,25	11,40	41,83	7	2,09	0,98	3,61	9,40	4,42	16,21
<i>Erythroleum sauevolens</i>	01	0,74	0,35	1,28	15,53	7,30	26,79	8	1,71	0,80	2,95	10,71	5,03	18,47
<i>Milicia excelsa</i>	01	0,45	0,21	0,77	6,91	3,25	11,92	2	0,05	0,02	0,08	14,84	6,98	25,60
<i>Entandrophragma cylindricum</i>	01	0,05	0,02	0,08	4,98	2,34	8,59	2	4,21	<b>1,98</b>	7,26	14,11	6,63	14,52
<b>Moyenne</b>	77	0,21	<b>0,10</b>	0,37	28,21	<b>13,26</b>	48,66	56	2,44	<b>1,15</b>	4,21	16,74	<b>7,87</b>	235,73

Figures in bold indicate the highest.

3.3.2. The Contribution of Dendrometric Parameters to the Carbon Stock of Exploitable Species

The correlation between diameter and carbon stock of exploitable species between 2021 and 2025 indicates a positive correlation close to 1 ( $r^2 = 0.99$  in 2021 and  $r^2 = 0.85$  in 2025). The exploitable species *P. santalinoides* and

*A. pachyloba* showed the highest correlation between diameter and carbon storage rate between 2021 and 2025, with 33.33 cm and 1.70 kg/ha for *P. santalinoides*, and 123 cm and 50.30 kg/ha for *A. pachyloba*, respectively (Figure 7).

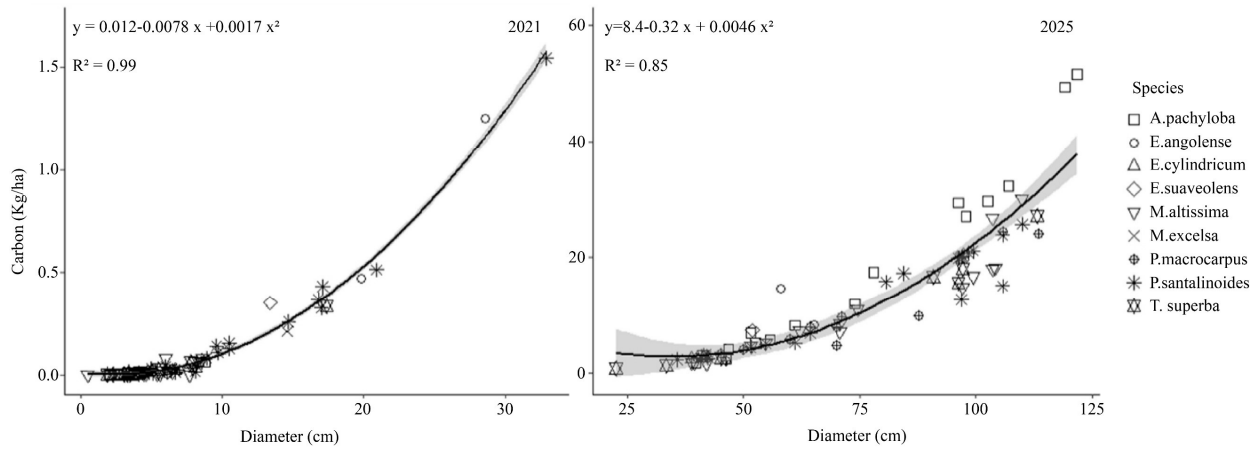


Fig. 8 Variation in stored carbon of exploitable species according to diameter

The correlation between height and carbon stock of exploitable species for 2021 and 2025 indicates a negative correlation close to 0 ( $r^2 = 0.39$  in 2021 and  $r^2 = 0.55$  in 2025). The exploitable species *P. santalinoides* and *A. pachyloba* showed the highest heights and carbon storage

correlation between 2021 and 2025. *P. santalinoides* reached a height of 250 cm and a carbon storage rate of 1.8 kg/C, while *A. Pachyloba* reached a height of 124 cm and a carbon storage rate of 55.30 kg/C (Figure 9).

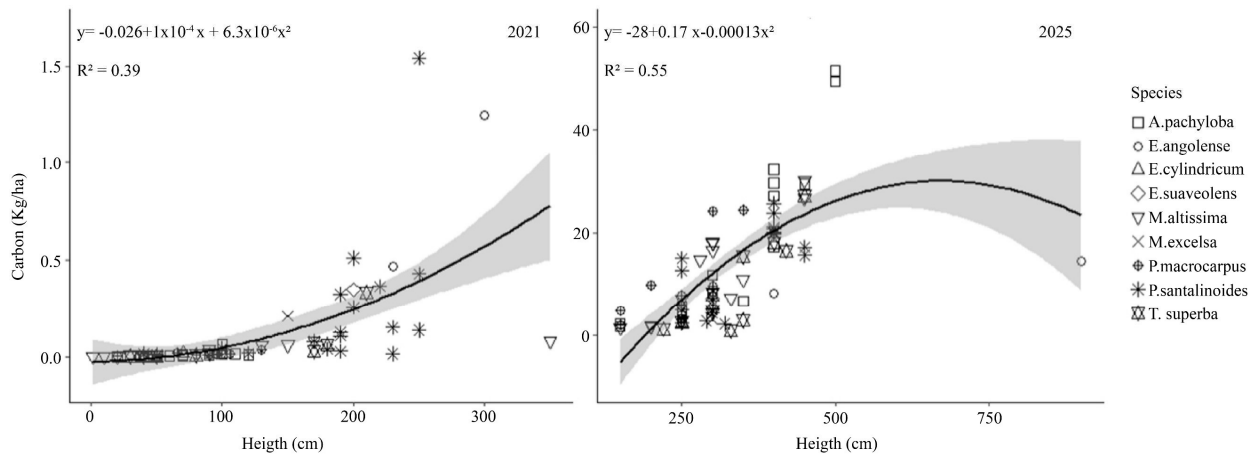


Fig. 9 Variation in stored carbon of exploitable species as a function of height

Exploitable species located under the forest canopy (natural environment) had a higher carbon storage rate in

2025 than exploitable species present in non-reforested parks (disturbed areas) in 2021 (Figure 10).

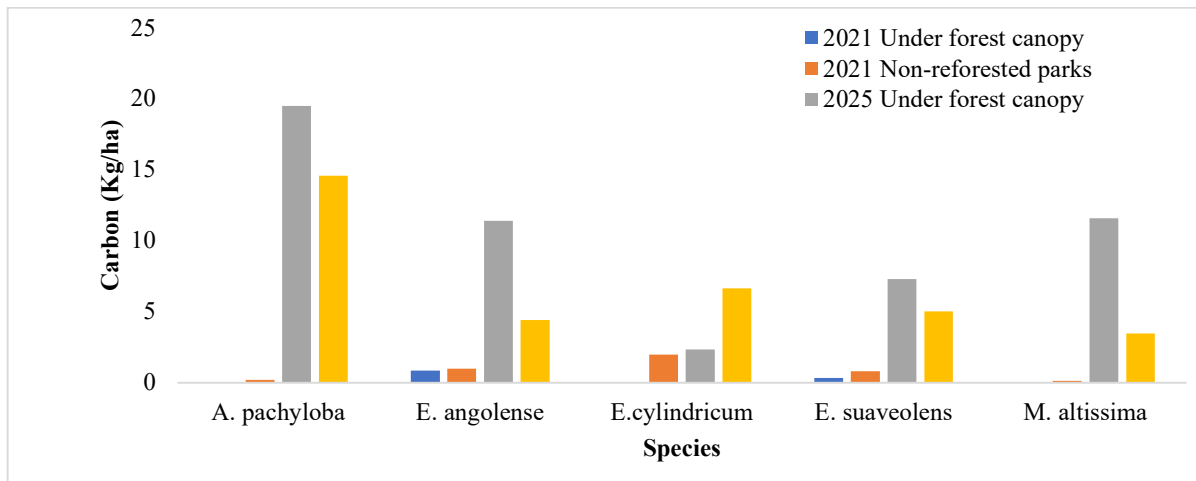


Fig. 10 Carbon stock of exploitable species in each environment.

## 4. Discussion

### 4.1. Natural Regeneration of Disturbed Sites after Logging in the East Region of Cameroon

#### 4.1.1. Floral Composition of Disturbed Sites in the East Region of Cameroon

Sustainable management of forest species requires control over their ease of regeneration, particularly in log parks. There was a total of 1,106 individuals belonging to 57 species, 49 genera, and 22 families inventoried in the non-reforested parks. The abundance was higher than that under the forest canopy, which had 220 individuals belonging to 43 species, 41 genera, and 21 families. This is to be expected as, firstly, the parks created are large for timber storage after harvesting, thus requiring much space. Secondly, the creation of parks destroys a part of the forest canopy, allowing sunlight into the forest floor, causing germination of seeds in the seed banks. This allows for the germination of the exploitable species that have just been harvested, especially those that have been in the soil seedbank. This may be the reason why the park had more species in the park as compared to that under the canopy.

The most abundant species was *Musanga cecropioides* in non-reforested parks. This is consistent with the findings of Amania [75], who studied floristic analysis in the Democratic Republic of Congo, where they stated that, generally, degraded forests are characterized by fast-growing species such as *Musanga cecropioides* (270 individuals). According to the FAO [76] and Yongo [77], soil erosion reduces fertility and can hinder natural vegetation regeneration, thereby degrading the forest and exacerbating biodiversity loss. Selective logging does not extensively change the soil entirely but acts locally in the area of logging, thus rendering the forest degraded. This therefore makes the area suitable for the establishment of the species *Musanga cecropioides*. The potentially exploitable species *Macaranga burifolia* was also abundant, with 72 individuals. Ndzai [78], in the floristic diversity of the degraded forests of the Nyanga Forest Management Unit (FMU) in the Republic of Congo, indicated the strong presence of *Macaranga* sp. among the most abundant species in these forests. This thus indicates that *Musanga cecropioides* and *Macaranga burifolia* are characteristic of degraded forests. The exploitable species *Terminalia superba* prefers well-drained soils and does not tolerate prolonged waterlogging, conditions similar to those of non-forested parks [79], which is why it thrived in the parks. The highest abundance of the species *Azelia bipidensis* under the forest canopy may be due to the wide distribution of the species [80] and is an indication that the species is a late successional species and thrives in areas with little sunlight. The Importance Value Index (IVI) is the ecological importance index, which makes it possible to identify the abundant and dominant entities in a plant community. The IVI characterizes the place occupied by each species within a vegetation community in relation to all other species within that community. In non-reforested parks, *Musanga cecropioides* (83.84) was the most important species. According to Koubouana et al. [81], *Musanga cecropioides* was classified as heliophilous and helps the forest to recover

after logging. This is thus a species that is a pioneer and light-loving species, usually present after disturbance. Similarly, under the forest canopy, the exploitable species *Terminalia superba* (30.43) was the most important. According to the International Tropical Timber Organisation (ITTO) [82], *Terminalia superba* was the most exploited species in Cameroon. These results corroborate those of Kengne et al. [83] in the community forests of Kompia/Nkolonyeng (East/South Cameroon), where the species with the highest IVI were *Petersianthus macrocarpus*, *Musanga cecropioides*, *Alstonia boonei*, *Terminalia superba*, and *Ricinedendron heudelotii*, respectively.

The most important families were the Urticaceae in the non-forested parks and the Fabaceae under the forest canopy. The Urticaceae family consists of heliophilous species that heal the forest after exploitation and also enable the restoration of tropical forests, according to Koubouana et al. [81]. The same observation was made by Moutsamboté [84] in the degraded forests of the Yombé forest, where Urticaceae (*Musanga cecropioides*, *Myrianthus arboreus*, etc.) were dominant. Under the forest canopy, the most important family was Fabaceae (30.54). Koubouana et al. [85] note that the abundance of Fabaceae was a common feature of Congo's tropical forests, playing a role in ecosystem restoration. Specifically, the Fabaceae family is the third largest family with 740 genera and 19,400 species [86]. As pioneer species, their ability to restore soil fertility was particularly relevant to sustainable forestry. This study confirmed the comparable results of Sarkar and Devi [87] in a semi-tropical forest where the Moraceae, Meliaceae, Apocynaceae, Euphorbiaceae, Ebenaceae, and Fabaceae were found to be the major family species drivers in the restoration status of a tropical semi-evergreen forest of Assam, Northeast India. This is similar to studies of Tabue et al. [88] in FMUs in the East Region and Dja Reserve in southern Cameroon. In this study, the diversity was high according to Kent and Coker [89], who indicated that communities with a Shannon index value greater than 3.5 bits are considered rich. Kengne et al. [83] and Tajeukem [90] indicated that the high value was due to the high rainfall and periodic leaf fall observed in dense semi-deciduous forests, which play an important role in regeneration. Specifically, diversity was higher under the forest canopy than in the non-reforested parks. This is to be expected as in the non-reforested parks, species have been removed through exploitation, whereas nothing has been removed from the forest canopy.

#### 4.1.2. Structure of Disturbed Sites after Logging in the East Region of Cameroon

The average stem density at both sites was 4,489 stems/ha. The density obtained under the forest canopy was 656 stems/ha and 3,884 stems/ha in non-reforested parks. The high density in non-reforested parks may be due to the destruction of the canopy, allowing the sun into the forest floor and thus germination of seeds in the soil seedbank. This is a tropical forest undergoing natural progressive dynamics, as Moutsamboté [84] indicated that differences

in density vary according to the age of the stand, particularly from the first stage to the climax stage. These results are similar to those found by certain authors in the dense forests of Central Africa; Sonké and Lejoly [91] found an average density of 461 stems/ha in the forests of the Dja Reserve in south-eastern Cameroon, while Sunderland et al. [92] in the Monts de Cristal in Gabon obtained  $562 \pm 17$  stems/ha, Balinga et al. [93] in Monte Mitra in Equatorial Guinea found  $548 \pm 108$  stems/ha, Van Gernerden [94] and Gonmadje et al. [95] reported average values of 523 and 532 trees/ha respectively in the southern forest formations, while Zekeng [96] obtained an average density of 505 stems/ha in the dense semi-deciduous forests of eastern Cameroon. The difference in densities was thought to be due to climatic variations (altitude, wind exposure) according to Gonmadje et al. [97], on the one hand, and to the sampled area of these different forests, on the other hand. The basal area under the forest canopy yielded a value of 2.99 m<sup>2</sup>/ha, while in non-reforested parks, the value was 1.58 m<sup>2</sup>/ha. These results are similar to those found by Kabelong et al. [98] in the understory of old-growth and young secondary forests in Campo Ma'an National Park, where the basal area was 1.79 m<sup>2</sup>/ha and 1.94 m<sup>2</sup>/ha, respectively, and Tsopmejo [99] in the Mindourou community forest (3.919 m<sup>2</sup>/ha). The results of the present study show a significantly larger basal area under the forest canopy and are consistent with the findings of Koubouana et al. [85], who showed that the larger the tree diameter in a stand, the greater its basal area, and larger trees were found under the forest canopy. Therefore, the basal area of disturbed sites was linked to density, as stand density plays an important role in tree growth. The higher the density, the less the increase in trunk diameter [81], which promotes vertical growth.

#### 4.1.3. Growth of Tree Species in Disturbed Sites in the East Region of Cameroon.

Tree species present under the forest canopy had a higher diameter than those present in non-reforested parks due to the removal of trees and collateral damage during exploitation. Missamba-Lola et al. [98], in a study conducted in Congo, showed that in non-reforested parks in degraded forests, individuals are mostly small in diameter. Hence, in this study, the forest species under the forest canopy had higher diameters. Specifically, in non-reforested parks, the exploitable species *Entandrophragma cylindricum* had the highest diameter of 53.7 mm. In fact, there are very few studies that specifically address the variation in light requirements during the ontogenesis of *E. cylindricum* [38]. It was therefore classified as a 'Non-Pioneer Light-Demanding Species' (NPLD) [38] or 'semi-heliophilous' [39]. Consequently, the regeneration of *E. cylindricum* was generally poor under closed canopy cover. In contrast, under the forest canopy, the potentially exploitable species *Cordia* sp. had the highest diameter of 414.6 mm. *Cordia* sp. is a 12 m shrub [101] and was therefore capable of growing under the forest canopy.

Similarly, growth in height was higher under the forest canopy than in non-reforested parks. The lack of reforestation and the degradation of vegetation led to a

reduction in the height of forest species in non-reforested parks. The results indicate that in these parks, the non-exploitable species *Hexalobus crispiflorus* had the highest height of 5.0 m. *Hexalobus crispiflorus* was a heliophilous species found in tropical forests. It can grow to a considerable height and contribute to the structure of the forest canopy thanks to its dense, green foliage [102]. Under the forest canopy in general, *Irvingia gabonensis* had the highest height of 18.0 m. Burkill et al. [103] stated that *Irvingia gabonensis* was a deciduous tree that can reach a height of 20 to 40 m. According to Gaudin [104], light was considered one of the main factors in the aggregation of tropical tree species. For species that need light to germinate and cannot grow under low light intensities (as was the case with exploitable species), the effect of patches of light can lead to the mass survival of individuals. These results are in agreement with Tilman [105], who stated that once an individual has passed the seedling stage, it needs continuous access to water and nutrients in order to survive and grow well. These may be the reasons for the growth of these species in the different sites.

## 4.2. Natural Regeneration of Exploitable Species after Reforestation in the East Region of Cameroon

### 4.2.1. Floral Composition of Exploitable Species after Reforestation in the East Region of Cameroon

In this study, the floristic composition of the exploitable species after reforestation was diverse. Indeed, a total of 820 individuals of exploitable species, distributed among 51 species, 47 genera, and 22 families, were obtained after reforestation. The species *Pterocarpus soyauxii* was recorded as the most abundant in the reforested parks (118 individuals). Doucet et al. [106] indicated that the species *P. soyauxii* had the highest growth in skid trails, indicating that the species is shade intolerant and a light demander. *Triplochiton scleroxylon* was the most abundant species (8 individuals) in the reforested tracks.

*Triplochiton scleroxylon* was a light-demanding species characteristic of dense semi-deciduous forests, according to Kobé [107]. Under the forest canopy, *Azelia bipindensis* was the most abundant (29 individuals). This was also the observation of Donkpegan et al. [108], who report that this species was very widespread. The exploitable species *Triplochiton scleroxylon* (66.21%) was the most prevalent in the reforested parks. This is a pioneer species that readily colonizes open areas and then regenerates in early successional forests.

*Terminalia superba* was the most prevalent species in the reforested tracks (51.17%) and under the forest canopy (52.38%). According to Doucet et al. [39], *Terminalia superba* was a shade-tolerant species that grows readily in the presence of average light intensity and low humidity, according to Bourland et al. [109]. This result was similar to those obtained by Kengne et al. [83] in the community forests of Kompia/Nkolenyeng (East/South Cameroon), which had obtained *Petersianthus macrocarpus*, *Triplochiton scleroxylon*, *Musanga cecropioides*, and *Terminalia superba* as the species with the highest IVI.

The Fabaceae family was the most abundant at all three sites. According to Christenhusz and Byng [86], it is a widespread family, characterized by its pod-like fruits and a large number of easily dispersed seeds. Also, according to Bienu et al. [110], the Fabaceae family was found in secondary, non-climax tropical regions of logged forest areas. Indeed, in reforested parks, Fabaceae are exposed to specific light conditions (trees in reforested parks can filter light, reducing its intensity and altering its spectrum) due to the presence of other trees, and these Fabaceae exhibit etiolated growth (stem elongation) to reach the available light [111]. In reforested tracks, Fabaceae exhibit rapid growth to take advantage of available light because reforested tracks receive more direct light due to the removal of the forest canopy [112]. Under the forest canopy, some Fabaceae species can grow in low-light conditions by modifying their morphology (leaves and stems) because light under the canopy is reduced [113]. In the Dja Reserve in southern Cameroon found similar results. For these authors, Fabaceae, Rubiaceae, Phyllanthus, Olacaceae, and Malvaceae are the most important families. The Shannon diversity index was 3.2 bits in the reforested parks, 2.8 bits in the reforested tracks, and 4.4 bits under the forest canopy. These values reflected low diversity in the reforested parks after restoration due to the removal of topsoil during the creation of the reforested parks, which reduced the seeds in the seedbank.

#### 4.2.2. Structure of Exploitable Species in Exploited Sites after Reforestation in the East Region of Cameroon

The average density obtained in this study was 2,314 stems/ha. By site, the density obtained in the reforested parks was 1,658 stems/ha, and under the forest canopy, 656 stems/ha. The species *Pterocarpus soyauxii* showed a maximum density of 366 stems/ha in the reforested parks. This result corroborates that obtained in the Ngog-Mapubi-Dibang forest massif (Cameroon) [114], which had a density of 324 stems/ha (Cameroon); Kengne et al. [83] found average densities of 406 stems/ha in the Kompia community forest and 322 stems/ha in the Nkolenyeng community forest in the East and South Regions of Cameroon, respectively. The reforested areas had a higher stem density due to the felling of trees after exploitation. This allowed the penetration of sunlight required for the growth of trees. This sunlight was otherwise prevented by a canopy created by the mature forests, which was thought to be the cause of the low representation of light by mature individuals [83]. Consequently, some light-dependent species do not grow normally in the absence of light under the forest canopy, reducing the density. The average basal area was 1.75 m<sup>2</sup>/ha in reforested parks and 0.06 m<sup>2</sup>/ha in reforested tracks. These results are similar to those found by Kabelong et al. [98] in the understory of old-growth and young secondary forests in Campo Ma'an National Park, where the basal area was 1.79 m<sup>2</sup>/ha and 1.94 m<sup>2</sup>/ha, respectively. Indeed, the higher density and basal area values observed in reforested parks appear to be related to the stability of these environments. For Adingra [115], environmental stability leads to a higher degree of organization, such that a more stable environment contains more ecological niches, and

therefore more species. According to this author, floristic evolution closely follows structural evolution. Thus, the compositional parameters (richness, density) and structural parameters (diversity) of stands generally increase along ecological successions [116]. Consequently, the structural parameters analyzed in this study, particularly density and basal area, are considered preliminary technical bases for defining management objectives [114].

#### 4.2.3. Growth of Exploitable Species after Reforestation in the East Region of Cameroon

The growth of exploitable species depends on their specific requirements at the seedling stage, in terms of light, water, temperature, and nutrients. According to Hawthorne [38], some exploitable species may be shade-tolerant, moderately shade-tolerant, or shade-intolerant, or even better, shade-tolerant, non-pioneer or pioneer species, respectively, or late- or early-successional species. Diameter and height were used as measures of growth for exploitable species. This explains why, in this study, there was a significant difference ( $p$ -value  $\leq 0.05$ ) in diameter across different sites and species. However, no significant difference was observed between the reforested parks and tracks. However, the reforested tracks had a higher diameter than the reforested parks, which may be due to the different types of species that were used for reforestation. The type of species planted in each disturbed site should depend on their growth requirements in terms of light and water. Thus, in this study, the species used in the reforested tracks were in the right place and thus had better growth.

In reforested parks, *Pterocarpus santalinoides* had a maximum diameter of 90.30 cm. According to Lemmens [117], *Pterocarpus santalinoides* was a fast-growing, sun-loving tree, thus increasing growth in reforested parks. Studies conducted in southern Cameroon showed that the *Pterocarpus santalinoides* species exhibited the fastest growth, reaching a diameter of 10.3 cm after twenty months of growth. Therefore, opening the forest canopy and disturbing the soil in reforested parks promotes tree regeneration in these parks rather than in reforested tracks [118, 119].

In this study, *Pterocarpus soyauxii* had a minimum diameter of 16.78 cm in the reforested tracks due to disturbances related to logging, while the species *Milicia excelsa* reached a maximum diameter of 65.3 cm, thus reflecting a better tolerance to environmental conditions. Indeed, *Pterocarpus soyauxii* in reforested tracks was intolerant of shade and required ample light. This finding aligns with the conclusions of Khurana and Singh [120] and Doucet et al. [106], who indicated that *Pterocarpus soyauxii* is merely a pioneer species and requires sufficient light for optimal growth and adaptation. *Pterocarpus soyauxii* prefers moist, well-drained soils with an average temperature of 23°C, conditions similar to those found in reforested parks. *Milicia excelsa* is a heliophilous species, exhibiting good growth during its juvenile stage, according to Doucet et al. [39].

Height growth was significantly different ( $p \geq 0.05$ ) between the different species and sites; however, no significant difference was observed between the reforest tracks and the reforested parks. The height growth was higher in reforested parks than in the tracks. In Bolivia, Fredericksen and Mostacedo [32] found that the highest tree regeneration growth rates were observed in areas with the greatest light transmission, particularly in reforested parks. Furthermore, tracks (with similar conditions of average light and humidity) exhibit more significant soil damage than reforested parks, which are typically restored prior to reforestation. Asner et al. [121] reported that soil damage was greater in reforested tracks (7–12%) than in reforested parks (1%) across the total harvest area in eastern Brazilian Amazonia. Consequently, soil compaction delays seed germination and seedling growth after reforestation in logging roads, which are generally not restored. Numerous studies have shown that soil compaction can delay seedling establishment [32]. However, if soils are dry during logging, commercial tree species can regenerate abundantly along reforested tracks [122]. Furthermore, competing fast-growing vegetation, such as weeds and ground-level lianas, can lead to the failure of slow-growing harvested seedlings in reforested tracks [123].

Similar results were obtained by Ne Win et al. [123]. Therefore, plant growth and development are influenced by environmental factors [124] that affect plant morphology, particularly leaf size, texture, and thickness [125]. Among the various environmental factors, light was one of the most important variables influencing photosynthesis as well as plant growth and development [126]. Plants need light not only as an energy source but also as a cue to adapt their development to environmental conditions, whether in reforested parks, tracks, or the forest canopy. The tallest species in reforested parks, *Entandrophragma cylindricum*, may be due to their growth requirements. Hawthorne [38] reported that *Entandrophragma cylindricum* is a species that tolerates low light levels in the early stages of its development and subsequently requires more light to continue growing, which explains its presence in reforested parks.

The relationship between the diameter and height of the species generally showed simultaneous evolution. The behavior of exploitable species appeared to be similar between reforested tracks and reforested parks, where slow growth was observed, unlike under the forest canopy, where growth was significant. This slow growth may be due to the fact that seedlings used for reforestation need time to acclimatize in the new environment, as compared to those under the forest canopy. However, these results show that diameter was a better predictor of growth than height.

#### 4.3. Dynamics of Carbon Stock of Exploitable Species after Reforestation in the East Region of Cameroon

The results obtained in this study showed a significant difference ( $p$ -value  $< 0.05$ ) in carbon stocks for the various exploitable tree species, both planted and unplanted, between 2021 and 2025. In 2021 and 2025, respectively, the

average carbon stock of planted exploitable species was 1.15 kg C/ha and 7.87 kg C/ha, while the average carbon stock of unplanted exploitable species was 0.10 kg C/ha in 2021 and 13.26 kg C/ha in 2025. This result was similar to those obtained by Kabelong et al. [98], who assessed carbon stocks in secondary forests on the periphery of Deng-Deng National Park (5.02 kg C/ha). Indeed, these variations in carbon stock could be due to the fact that in 2021, the tree species had a small diameter after enrichment planting, which theoretically stored less carbon compared to the large diameter species of mature forests observed in 2025, which is nine years after reforestation. Unplanted exploitable species had more carbon stock than the planted exploitable species. According to Molto et al. [127], several factors could explain variations in carbon stocks of exploitable species: forest type, age, structure, and dynamics of the studied forests. Thus, the unplanted exploitable species had already acclimatized to the environment as compared to the planted exploitable species that had just left the nursery and needed more time to acclimate to the environment. Nabuurs et al. [128] stipulated that planted exploitable species are younger than unplanted exploitable species, and have less time to accumulate biomass and store carbon. This is further confirmed by Luyssaert et al. [129], who suggested that unplanted exploitable species may be older and more mature than planted exploitable species, meaning they have had more time to accumulate biomass and store carbon. Furthermore, exploitable species that are planted are often managed to maximize timber production, which could involve pruning of the leaves, thus reducing carbon storage capacity [130]. Unplanted natural forests may support greater species diversity, have a more complex structure, with trees of varying sizes and ages, which can contribute to a higher carbon storage capacity [131].

Among the unplanted and planted exploitable species, *Entandrophragma angolense* and *Entandrophragma cylindricum*, respectively, in 2021, and *Azelia pachyloba* in 2025, were the highest in carbon stock. Glélé Kalai et al. [132] stated that *Entandrophragma angolense* was known for its dense and durable wood, reaching large sizes and living for centuries with a moderate growth rate that allows it to accumulate carbon efficiently. *Entandrophragma cylindricum*, on the other hand, is a fast-growing species, which allows it to accumulate biomass and store carbon rapidly [133]. In addition, *Azelia pachyloba* can reach large sizes and have high biomass, and its wood was known to be dense and strong, according to Phillips [134]. This is an indication that the species had large diameters and high wood densities.

##### 4.3.1. Effect of Dendrometric Parameters of Exploitable Species on the Carbon Stock in the East Region of Cameroon

The relationship between diameter and carbon stock of exploitable species between 2021 and 2025 indicates a positive correlation close to 1 ( $r^2 = 0.99$  in 2021 and  $r^2 = 0.85$  in 2025). There was a significant difference ( $p$ -value  $\leq 0.005$ ) between the species with the largest diameters between 2021 and 2025, namely *P. santalinoides* (33.33

mm) and *A. pachyloba* (124 mm). According to Chave *et al.* [63], there is an allometric relationship between a tree's diameter and its biomass, which was used to estimate carbon stock. This relationship was based on the fact that wood volume increases with diameter; trees with larger diameters accumulate more biomass over time, meaning they store more carbon, as was the case for *A. pachyloba* and *P. santalinoides*, which have the highest diameters between 2021 and 2025. This is further reflected by the  $r^2$  values, which reflect a strong positive correlation between diameter and carbon stock.  $r^2 = 0.99$  indicates a strong correlation between diameter and carbon stock in 2021. Therefore, diameter was an excellent indicator of carbon stock for *P. santalinoides*. The  $r^2$  value of 0.85 in 2025 also indicates a strong correlation between diameter and carbon stock, although slightly weaker than the  $r^2$  value observed in 2021. Consequently, this suggests that other factors (species, age, environmental conditions) also play a role in the relationship between diameter and carbon stock as the tree species gets older [127].

The correlation between tree height and carbon stock of exploitable species between 2021 and 2025 indicates a negative correlation close to 0 ( $r^2 = 0.39$  in 2021 and  $r^2 = 0.55$  in 2025). Indeed, the  $r^2$  value of 0.39 indicates a negative correlation between height and carbon stock in 2021; therefore, height was not a strong marker of tree carbon storage capacity in 2021.  $R^2 = 0.55$  in 2025 indicates a positive-negative correlation between height and carbon stock. Hence, as the tree gets older, the height becomes a predictor of carbon stock in 2025 compared to 2021. Furthermore, in disturbed sites, the rapid thickening of weeds prevents the horizontal development of exploitable species. The vertical growth is therefore encouraged, leading to an increase in height over time. This aligns with Veiera and Scariot [135], who suggested that height was not a true indicator of carbon stock.

#### 4.3.2. Comparison of the Carbon Stock of Exploitable Species by Environment in the East Region of Cameroon

The results of this study showed that exploitable species located under the forest canopy had a higher carbon storage rate in 2025 than exploitable species present in reforested parks in 2021. According to Day *et al.* [136], the high biodiversity under the forest canopy leads to an optimization

of environmental resources and therefore to increased species efficiency, which can result in an increase in biomass, thus promoting an increase in the carbon sequestration of exploitable species. Henry *et al.* [133] suggest that the low carbon sequestration rate observed in reforested parks was due to the fact that these parks have undergone silvicultural activities by humans, and the exploitable species are still growing with small diameters and average heights. Furthermore, under the forest canopy, exploitable species absorb enormous quantities of carbon stored in their wood. Consequently, tropical forests have a significant influence on the terrestrial ecosystem's capacity to accumulate carbon.

## 5. Conclusion

The main objective, which was to evaluate the effect of reforestation after logging in the tropical rainforest of the East Region of Cameroon, was achieved. In non-reforested forests, the parks were invaded by other species that were not exploitable species, leading to a decrease in growth (diameter and height) of exploitable species. In reforested forests, the composition and diversity decreased in the parks due to the removal of exploitable species during logging. Growth was highest in the reforested parks as compared to the tracks. The carbon stock was highest in 2025 than in 2021 due to the increase in diameter and height of the tree species. The diameter is a better predictor than the height of the carbon stock at the early stages of growth. However, as the tree becomes bigger, the height also becomes a good predictor of carbon stock. Thus, the growth of tree species depends on other environmental factors apart from the diameter and height for the storage of carbon.

## Conflict of interest

The authors declare no conflicts of interest regarding the publication of this paper.

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