

Diversity, Structure and Carbon Stocks from Three Pools in the Kouoghap Sacred Forest, Hedgerows and *Eucalyptus* Plantations in the Batoufam Locality (West Cameroon)

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Abstract The aim of this study was to make an inventory of the trees and estimate hedgerows and eucalyptus plantations carbon stocks in comparison with that of the Kouoghap sacred forest which is the only landscape having retained its original character. This study was conducted in the sacred forest, hedgerows and Eucalyptus plantations, which are the predominant land use type of Batoufam locality. Inventory data of trees with diameter ≥ 10 cm were made in 5 transects of 800 m x 5 m for the sacred forest and 10 transects of 300m x 5m for hedgerows and Eucalyptus plantations. The above and below ground biomass of trees was estimated using allometric equations; that of litter collected in 30 square plots of 0.5m x 0.5m, was estimated by the destructive method. A total of 70 and 11 trees species were respectively recorded in the sacred forest and hedgerows. However, Eucalyptus plantations are monospecific (only one trees species was found). The Shannon index (3.51) showed a rich floristic diversity in the sacred forest and weak diversity in hedgerows (1.94). The abundance of trees decreases with the increase in diameter classes of the sacred forest and hedgerows therefore forming and irregular appearance in the Eucalyptus plantations. No significant difference was found between these three land use according to the carbon stocks which varied from 130 to 196 tC.ha⁻¹ for aboveground and from 31 to 47 tC.ha⁻¹ for belowground carbon. As compared to, that of litter which was significantly different between the sacred forest (6.40 tC.ha⁻¹), hedgerows (9.39 tC.ha⁻¹) and Eucalyptus plantations (10.96 tC.ha⁻¹). This study confirmed the conservation of biodiversity through sacred forest and also the need to take into account other types of lands use in policies to fight against climate changes given the amount of carbon they store.

Keywords: landscapes types, species richness, carbon stocks, Batoufam, West Cameroon

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1. Introduction

For many decades, the West region of Cameroon is facing a strong demographic pressure whose use of natural resources in order to support its needs is expressed more and more in quantity and quality [1]. This situation has led to the virtual disappearance of the original natural plant formations [2]. Concerned about this finding, the authorities in the 20th century promoted the creation of forest reserves and plantations, mostly with exotic species, for the production

of timber (pine), poles and firewood (*Eucalyptus*) and for shading in coffee plantations [2,3].

Despite this pressure on natural environments, the traditional chiefdoms have contributed a lot to the preservation of some relics and forest galleries that are locally known as "sacred forests" [4]. These are natural environments where restrictions on access to and use of forest resources cannot simply be assimilated with "conservation of biodiversity" by traditional methods [4-8]. These sacred forests are recognized as biodiversity reservoirs, and sometimes the only remaining natural forest formations in some villages in the western region of

Cameroon [4]. Despite their small area, these sacred forests are the refuge for many plants and animals species [8,9]. These authors [4] identified 310 sacred forests (885 ha) ranging in size from (0.1 to 91 ha) in the Western region of Cameroon out of 1336 existing throughout Cameroon.

Batoufam is a locality in the Western region of Cameroon whose landscape presents several types of vegetal cover among which, the Kouoghap sacred forest whose earth surface decreased from 218 ha in 1964 to 144 ha in 2012 [1]. This forest remains the only environment that still reflects the original vegetation of this locality and the lack of clear boundary of this sacred forest has contributed to the encroachment on its geographical area over the years [10]. Thus, at the regional and even local scale, the current forest dynamics in Batoufam results from a combination of unequal processes of degradation / deforestation and afforestation/reforestation. It is also essentially marked by the integration of perennial trees plants and practices in order to create a significant ecological and economic interaction between wooded and non-forested components [11]. According to [12], the Kouoghap sacred forest in Batoufam is also dominated by other types of lands use mainly marked by agricultural fields, perennial tree plantations (*Eucalyptus*, *Caribbean pines*, etc.), hedgerows and infrastructures.

Hedgerows form an essential element to the enclosure agrarian landscape that characterizes the Bamiléké country in the western region of Cameroon. Hedgerows are rows of woody plants in one or more rows that form a continuous barrier [13]. According to [14], the hedge is a linear element of the landscape composed of trees or shrubs and managed by man and whose characteristics are linked to the presence of networks of linear structures of trees, which these are "traditional" hedges, recent windbreaks or spontaneous hedges resulting from the lack of maintenance of the fences. These authors [2] believe that the hedge is mainly used in the planning of rural areas. In general, in addition of being the habitat of many wildlife and plant species [9], the hedge also offers socio-economic services: Non Timber Forest Products (NTFPs), firewood, wood work, etc.; ecological services: windbreak, anti-erosion, water and soil conservation, carbon storage, etc.) and legal services: land delimitation [2,15,16].

Eucalyptus plantations are monospecific plantations of the exotic species as *Eucalyptus saligna* introduced in Cameroon in the 1920s by the colonial master [17]. Its acclimatization with the environmental conditions of the Western region of Cameroon has favored its large-scale expansion by the State authorities with the concern of reforestation mainly for their function of timber, service and firewood [3].

The carbon storage capacity of these different types of lands use differs. Studies on the quantification of carbon stocks in the ecosystems of the Western region of Cameroon remain almost non-existent despite their significant contribution in mitigating the effects of climate change. Only a recent study presents a marginal assessment of the carbon stocks carried out on the Baleng Forest Reserve from the perspective of the REDD+ program [11]. However, with the need to implement REDD+ policies in Cameroon, even though almost all the forests in this

region have disappeared, it is important to note that their contribution in mitigating climate change is taken into account. In the locality of Batoufam, the quantities of carbon stored by its different types of lands use remain unknown. In addition, we are aware that these types of lands use that characterizes it, do not always guarantee or insure the capacity of conservation of the original biodiversity and also its potentials of carbon storage. The main concern of this study then, is to evaluate their contribution in the achievement of these two ecological functions. These are actually types of lands use; in addition to the sacred forest, agricultural fields and infrastructures which dominate Batoufam's physical environment. So based exclusively on the above and below ground carbon of trees, litter biomass and trees species, this work is to compare the hedgerows and *Eucalyptus* plantations with those of the Kouoghap sacred forest. Therefore, the aim of this study is: (1) to make an inventory of trees species of these three lands use and (2) to evaluate their carbon storage capacity for their involvement in the fight against climate change.

2. Materials and Methods

2.1. Study Area

This study was conducted in Batoufam locality, a rural area in the western region of Cameroon, situated in the Koung-khi division and Bayangam subdivision (Figure 1). This locality is located at 291 km from the economic capital (Douala) and at 288 km from the political capital (Yaoundé), and covers an area of 27 km² between 5° 14' to 5° 18' North latitude and 10° 26' to 10° 31' East longitude. The hydrography is characterized by numerous tributaries of Nun basin. The climatological data recorded by the meteorological station of the Koung-khi Divisional Delegation of Agriculture and rural Development in Bandjoun, have showed that the climate of this zone belongs to the tropical type of the Cameroonian shade with altitude of two seasons; a dry season from November to February and a rainy season from March to October. The average annual precipitation and temperature are 1518 mm and 20.9°C respectively. The primary vegetation of this locality has practically disappeared to the advantage of other land use types. However, after the processing of field data and thanks to mapping tools, that of the Kouoghap sacred forest with a current area of 110 ha has retained its primitive character which is dominated by trees such as: *Syncepalum cerasiferum*, *Tricalysia Macrophylla*, *Trilepisium madagascariense*, *Markhamia tomentosa*, *Funtumia africana*, *Vitex grandifolia*, etc. [18].

On the morphostructural level, Batoufam is part of the Western Highlands of Cameroon, [19,20] belonging to the Guinean-Congolese sub-mountain area [22] and is located at the foot of the Eastern slope of the Bangou mountain [23]. There are ferruginous, ferralitic and hydromorphic soils most of which are derived from volcanic rocks [5]. It altitude can reach more than 2000 m with an average ranging from 1400 to 1800 m as compared to the heights of Yom and Tougopou hills in Bayangam [18,19].

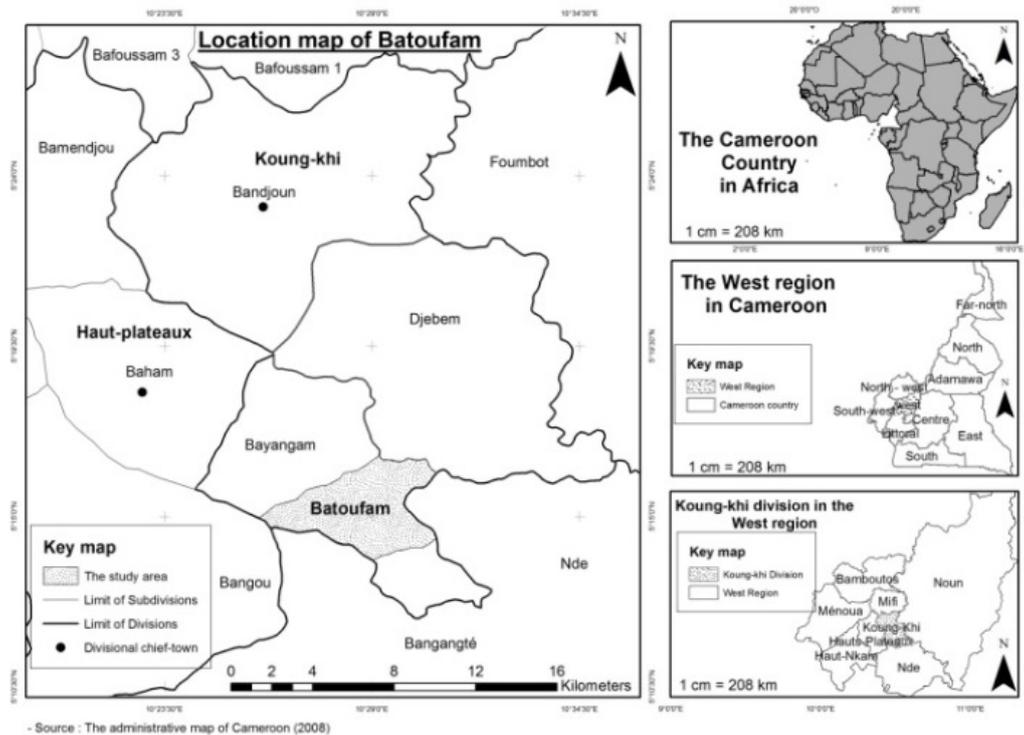


Figure 1. Location map of the study area

2.2. Data Collection

This study was carried out in the predominant types of lands use such as Kouoghap sacred forest, hedgerows and *Eucalyptus* plantations of the study area. Inventories data of all trees with diameter ≥ 10 cm was done in these lands use using the transect method. For this, 5 transects of 800 m x 5 m (2 ha) were installed in the Kouoghap sacred forest. Given the discontinuity areas occupied by hedgerows and *Eucalyptus* plantations, 5 transects of 300 x 5 m was installed in each (0.75 ha each). A total of 15 transects were installed i.e. 5 transects in each type of land use for a total area sampled of 3.5 ha. In each transect, in addition to the scientific /vernacular or common names of each tree identified, their diameter at breast height (dbh) and height were measured. The height was estimated by the trigonometric method using a clinometer.

For carbon stock estimation, data of three carbon pools (above, below ground and litter) were considered in this study. Tree biomass inventoried were estimated by the non-destructive method using allometric equations. On the other hand, the litter was estimated by the destructive method. For this, litter biomass data were collected in 0.5m x 0.5m square plots. These square plots were installed every 200 m of each transect from point 0; thus, a total of 30 quadrats sampled. In each square plot, litter present was collected and sealed in appropriate wrap. These samples were oven dried in the laboratory of Systematic and Ecology of the University of Yaoundé I at 70 °C until a constant weight was obtained. The weighing was done with the help of a sensitive laboratory scale (max: 1500g; precision: 0.05g). The dry mass thus corresponds to the difference between the fresh mass and the volume of water evaporated during the drying [24].

2.3. Data Analysis

The data was analyzed using the R software version 3.3.2 [25]. The floristic characterization of the 3 types of lands use was done based on the diversity indices such as:

1) Shannon diversity index:

$$ISH = -\sum SH = -\sum \frac{Ni}{N} \times \log \frac{Ni}{N}$$

Where Ni = number of species i ; N = number of all species. This index is the most advisable in the comparative study of stands, because it is independent of the size of the population studied, gives more importance to rare species.

2) Equitability of Piélou EQ:

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

Which is between 0 and 1. A value close to 0 represents a great importance of some dominant species in a given ecosystem.

3) Simpson's index accounts for the abundance of one or a few species. It expresses the probability that two individuals drawn at random from an infinite population belong to the same species. It is expressed as:

$$S = \frac{ni(ni-1)}{N(N-1)}$$

with ni , the number of individuals for species i and N the total population.

(4) Sorensen similarity index:

$$So = (2xC / A + B) \times 100$$

or C = number of species common to the sacred forest and hedgerows, A and B number of species identified in sacred forests and hedgerows respectively. Since *Eucalyptus*

plantations are monospecific, this land use has not been considered for the determination of floristic similarities.

From a structural point of view, the parameters taken into account were: number of trees.ha⁻¹, distribution of diameter classes (amplitude class 10cm) and height (amplitude 5m), average height and that of diameter and finally basal area which is expressed by the following formula:

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

Where *Di* is the diameter (m) of the tree, $\pi = 3.14$ was calculated for each tree; the latter was then extrapolated to the scale of the hectare. The Relative Importance Index (IVI) was calculated by the formula: IVI = Relative Abundance ($ni/N \times 100$) + Relative Dominance ($Di/D \times 100$) + Relative Frequency ($Fi/F \times 100$); where *n* is the number of individuals of species *I*; *N* the total number of individuals; *Di* = the basal area of species *i*; *D* the total basal area; *Fi* is the number of transects or species *i* was found and *F* the total number of transects. The IVI ranges from 0 (absence of dominance) to 300 (mono-dominance).

The aboveground biomass of trees was estimated by the non-destructive method from the pan-tropical allometric equation of Chave [26] based on a dataset of 4004 trees collected in the tropics (Africa, Asia and America). Moreover, this equation takes into account the dbh of the tree, the wood density of the species and an index “E” which depends on the environmental parameters of a given site; unlike that of Chave [27] which depends only on dbh and wood density or Brown [28] which takes into account only the dbh of the tree.

This equation of Chave [26] is defined as follows: $Y_e = e^{(-1.803 - 0.976 \times E + 0.976 \ln(\rho) + 2.673 \times \ln(D) - 0.0299 \times (\ln(D))^2)}$

With *Ye* = aboveground biomass (kg);

E = environmental index; ρ = wood density of the species in question;

D = diameter of the tree (cm).

The climatic index *E* defined by *E*:

$$E = (0,178 \times TS - 0,938 \times CWD - 6,61 \times PS) \times 10^{-3};$$

E is according to Chave [26] dependent on a number of climatic variables. *TS* is the seasonality of the temperature (= one-year standard deviation of the monthly mean temperature, in °C), *CWD* is the climatic water deficit (= sum over one year of the difference between monthly precipitation and evapotranspiration monthly, counting only the months when this difference is negative) and *PS* is the seasonality of precipitation (=coefficient of variation of monthly precipitation, in percentage (%)). This author [18] having mapped the values of this index worldwide to facilitate their use, those of each transect of this study were therefore extracted from the world map on the basis of their geographical coordinates (latitude and longitude) with the help of R software.

The wood density values used are those of the Global Wood Density Data Base [29] completed by those of

Reyes [30]. For species whose wood density was not available, an average of all wood densities of all species was used by default. Since carbon stocks in the study area were greater than 63 tC.ha⁻¹, the belowground biomass in this study area was estimated from these references [31]:

$$Y_h = 0,235 \times Y_e$$

With *Y_h* = belowground biomass (kg);

Ye = aboveground biomass (kg).

The Shapiro-Wilk normality test showed that the data does not follow a normal distribution, the non-parametric Krustals-Wallis test and was performed to see if there are significant differences between the types of lands use following the variables considered and the Wilcoxon test for two-by-two comparisons when a significant difference was found between these types of lands use.

3. Results

3.1. Floristic Diversity in the Study Area

A total of 78 trees species belonging to 56 genera and 29 families was inventoried in the study area. Between these species, 70 species were identified in the Kouoghap sacred forest. The Shannon diversity index (3.51), which is high for the latter, shows a rich floristic diversity in this land use (Table 1). However, the values of the Piélou and Simpson indices show that trees diversity in this land use is dominated according to the abundance by some species such as: *Trilepisium madagascariense* (10%); *Autranella congolensis* (9%); *Markhamia tomentosa* (7%) and *Polyscias fulva* (6%). In the hedgerows, the low value of the Shannon index (1.94) shows a low floristic diversity (11 species). The 3 most abundant species in this land use were *Markhamia tomentosa* (38%); *Dacryodes buttnerii* (19%) and *Markhamia lutea* (10%). In contrast, the Eucalyptus plantations in the study were monospecific with *Eucalyptus saligna* as the only trees species.

The IVI in the Kouoghap sacred forest ranges from 20.2 to 125.1, showing that all species inventoried in this land use have significant ecological value. However, trees species in this sacred forest with IVI ≥ 100 (higher ecological value) were *Autranella congolensis* (125.1), *Dacryodes buttnerii* (113.2), *Vitex grandifolia* (110.5), *Polyscias fulva* (110, 0), *Ficus exasperata* (109.9), *Markhamia tomentosa* (109.5) and *Carapa procera* (101.2). In hedgerows, IVI ranges from 2.6 for *Pycnanthus angolensis* to 67.2 for *Dacryodes buttnerii*.

Six of the 11 species identified in the hedgerows have high ecological value because IVI > 10. As *Eucalyptus* plantations are monospecific, the maximum value of IVI was found only for *Eucalyptus saligna* (300) (Table 2).

The value of the Sorensen index showed a dissimilarity between the sacred forest and hedgerows (22%). In *Eucalyptus* plantations, no similarity was found between them and the other considered types of lands use.

Table 1. Species richness, Shannon, Piélou and Simpson of the Sacred Forest, Hedgerows and Batoufam Eucalyptus Plantations

| Diversity index | Species richness | Shannon | Piélou | Simpson |
|------------------------|------------------|---------|--------|---------|
| Sacred forest | 70 | 3.51 | 0.83 | 0.96 |
| Hedgerows | 11 | 1.94 | 0.81 | 0.80 |
| Eucalyptus Plantations | 1 | 0.00 | 1.00 | 0.00 |

Table 2. Frequency, abundance, relative dominance and IVI of inventoried species in the Batoufam sacred forest, hedgerows and Eucalyptus plantation

| Species | Relative abundance | Relative dominance | Relative frequency | IVI |
|--------------------------------------|--------------------|--------------------|--------------------|-------|
| Sacred forest | | | | |
| <i>Acacia macrothyrsa</i> | 0.5 | 0.1 | 20 | 20.6 |
| <i>Alchornea cordifolia</i> | 1.2 | 0.7 | 80 | 82 |
| <i>Antiaris toxicaria</i> | 0.3 | 0.1 | 40 | 40.4 |
| <i>Artocarpus schweinfurthii</i> | 1.2 | 0.4 | 40 | 41.7 |
| <i>Aucoumea klaineana</i> | 0.5 | 2.1 | 40 | 42.5 |
| <i>Autranella congolensis</i> | 8.5 | 16.6 | 100 | 125.1 |
| <i>Bersama abyssinica</i> | 0.2 | 0.7 | 20 | 20.8 |
| <i>Bridelia ferruginea</i> | 0.5 | 0.1 | 40 | 40.6 |
| <i>Bridelia grandis</i> | 0.5 | 1.2 | 20 | 21.7 |
| <i>Bridelia micrantha</i> | 0.2 | 0.3 | 20 | 20.4 |
| <i>Bridelia</i> sp. | 0.5 | 0.2 | 40 | 40.7 |
| <i>Byttneria</i> sp. | 1.4 | 0.5 | 20 | 21.9 |
| <i>Caloncoba</i> sp. | 0.2 | 0.0 | 20 | 20.2 |
| <i>Canarium schweinfurthii</i> | 0.8 | 6.6 | 80 | 87.4 |
| <i>Carapa procera</i> | 0.9 | 0.3 | 100 | 101.2 |
| <i>Celtis</i> sp. | 0.8 | 0.3 | 40 | 41.1 |
| <i>Celtis tessmannii</i> | 1.1 | 0.4 | 80 | 81.5 |
| <i>Cola</i> | 0.3 | 0.4 | 20 | 20.7 |
| <i>Cola</i> sp. | 0.6 | 0.2 | 40 | 40.8 |
| <i>Cordia africana</i> | 0.2 | 0.2 | 20 | 20.4 |
| <i>Dacryodes buttnerii</i> | 4.5 | 8.7 | 100 | 113.2 |
| <i>Draceana arborea</i> | 0.3 | 3.7 | 40 | 44 |
| <i>Entandrophragma angolensis</i> | 0.2 | 1.3 | 20 | 21.4 |
| <i>Erythrophleum suaveolens</i> | 0.2 | 0.7 | 20 | 20.9 |
| <i>Ficus abscondita</i> | 0.3 | 0.1 | 20 | 20.4 |
| <i>Ficus exasperata</i> | 3.4 | 6.5 | 100 | 109.9 |
| <i>Ficus glumosa</i> | 0.5 | 0.9 | 60 | 61.4 |
| <i>Ficus</i> sp. | 0.5 | 0.3 | 40 | 40.7 |
| <i>Ficus vogeliana</i> | 0.6 | 1.2 | 60 | 61.8 |
| <i>Funtumia elastica</i> | 0.3 | 0.1 | 20 | 20.4 |
| <i>Garcinia punctata</i> | 4.3 | 1.4 | 80 | 85.7 |
| <i>Garcinia smeathmannii</i> | 2.3 | 0.6 | 60 | 62.9 |
| <i>Garcinia</i> sp. | 0.5 | 0.2 | 60 | 60.7 |
| <i>Holoptelea grandis</i> | 0.3 | 0.1 | 20 | 20.4 |
| <i>Homalium dolichophyllum</i> | 0.2 | 0.0 | 20 | 20.2 |
| <i>Maesa lanceolata</i> | 0.3 | 0.1 | 40 | 40.4 |
| <i>Mammea africana</i> | 0.2 | 0.2 | 20 | 20.3 |
| <i>Markhamia lutea</i> | 0.2 | 0.1 | 20 | 20.3 |
| <i>Markhamia</i> sp. | 3.9 | 1.4 | 80 | 85.3 |
| <i>Markhamia tomentosa</i> | 7.1 | 2.4 | 100 | 109.5 |
| <i>Milicia excelsa</i> | 3.3 | 2.7 | 60 | 65.9 |
| <i>Millettia dushesnei</i> | 0.8 | 0.6 | 40 | 41.4 |
| <i>Monodora myristica</i> | 0.2 | 0.1 | 20 | 20.3 |
| <i>Octolobus angustatus</i> | 0.5 | 0.1 | 20 | 20.6 |
| <i>Pentacletra</i> sp. | 0.2 | 0.1 | 20 | 20.2 |
| <i>Persea americana</i> | 1.1 | 1.6 | 20 | 22.7 |
| <i>Podocarpus milanjana</i> | 0.2 | 0.4 | 20 | 20.5 |
| <i>Polyscias fulva</i> | 6.3 | 3.7 | 100 | 110 |
| <i>Pycnanthus angolensis</i> | 1.1 | 0.8 | 60 | 61.9 |
| <i>Rauvolfia vomitoria</i> | 1.4 | 1.3 | 80 | 82.7 |
| <i>Rinorea</i> sp. | 0.3 | 0.1 | 20 | 20.4 |
| <i>Sorindeia grandifolia</i> | 0.2 | 0.1 | 20 | 20.3 |
| <i>Spathodea campanulata</i> | 5.9 | 6.3 | 80 | 92.2 |
| <i>Stereospermum acuminatissimum</i> | 0.2 | 2.1 | 20 | 22.2 |
| <i>Strombosia grandifolia</i> | 1.4 | 1.5 | 40 | 42.9 |
| <i>Synsepalum cerasiferum</i> | 0.3 | 0.2 | 20 | 20.5 |
| <i>Terminalia superba</i> | 0.2 | 0.1 | 20 | 20.3 |
| <i>Tetracarpidium conoforum</i> | 0.2 | 0 | 20 | 20.2 |
| <i>Tetrapleura tetraptera</i> | 0.6 | 0.2 | 20 | 20.9 |
| <i>Trelipisium madagascariensis</i> | 2.0 | 0.9 | 20 | 22.9 |
| <i>Trema orientalis</i> | 0.6 | 0.4 | 40 | 41 |
| <i>Tricaliscia</i> sp. | 0.2 | 0.1 | 20 | 20.3 |
| <i>Trilepisium madagascariense</i> | 10.1 | 5.5 | 80 | 95.5 |

| Species | Relative abundance | Relative dominance | Relative frequency | IVI |
|-----------------------------------|--------------------|--------------------|--------------------|-------|
| <i>Vitex grandifolia</i> | 4.6 | 5.9 | 100 | 110.5 |
| <i>Voacanga grandifolia</i> | 2.6 | 1.2 | 40 | 43.9 |
| <i>Voacanga</i> sp. | 2.8 | 0.9 | 40 | 43.7 |
| <i>Voacanga thouarsii</i> | 0.2 | 0 | 20 | 20.2 |
| <i>Xylopia rubescens</i> | 1.5 | 0.8 | 20 | 22.4 |
| <i>Zanthoxylum</i> sp. | 0.2 | 0.2 | 20 | 20.3 |
| <i>Zanthoxylum zanthoxyloides</i> | 1.2 | 0.5 | 40 | 41.7 |
| Hedgerows | | | | |
| <i>Aucoumea klaineana</i> | 6.3 | 18.3 | 9.1 | 33.6 |
| <i>Cola acuminata</i> | 4.2 | 22.1 | 11 | 37.3 |
| <i>Cordia africana</i> | 2.1 | 3.7 | 1.8 | 7.6 |
| <i>Dacryodes buttnerii</i> | 18.8 | 32.3 | 16.2 | 67.2 |
| <i>Dacryodes edulis</i> | 6.3 | 3.5 | 1.7 | 11.5 |
| <i>Ficus glumosa</i> | 4.2 | 1.1 | 0.5 | 5.7 |
| <i>Markhamia lutea</i> | 10.4 | 5.4 | 2.7 | 18.5 |
| <i>Markhamia tomentosa</i> | 37.5 | 7.8 | 3.9 | 49.2 |
| <i>Pycnanthus angolensis</i> | 2.1 | 0.3 | 0.2 | 2.6 |
| <i>Shefflera mannii</i> | 6.3 | 1 | 0.5 | 7.8 |
| <i>Spathodea campanulata</i> | 2.1 | 4.6 | 2.3 | 9 |
| Eucalyptus Plantation | | | | |
| <i>Eucalyptus saligna</i> | 100 | 100 | 100 | 300 |

3.2. Distribution of Trees According to Diameter and Height Classes

Figure 2 shows the distribution of the number of trees.ha⁻¹ according to the diameter and height classes of the three lands use. In the Kouoghap sacred forest as in hedgerows, this abundance (N.ha⁻¹) is greater in the smaller diameter class [10-20] and lower in the larger diameter classes (diameter > 60 cm). Thus, in general, the number of trees.ha⁻¹ decreases with the increasing of the diameter classes in these two types of lands use; hence the appearance in

"J reversed" of the curve. On the other hand, in *Eucalyptus* plantations, the curve has an irregular shape. However, the trees.ha⁻¹ remains higher in classes [10-20] and [40-50].

According to the trees.ha⁻¹ in function of height classes, the general shape of the curves is that of an inverted bell (Gaussian curve). Indeed, the abundance of trees.ha⁻¹ in these three types of lands use increases from class ≤ 5 m to reach an optimum for class [5,6,7,8,9,10] and then decreases for higher height classes. However, neglecting the height class ≤ 5cm, the general trend is a decrease with increasing of the height classes.

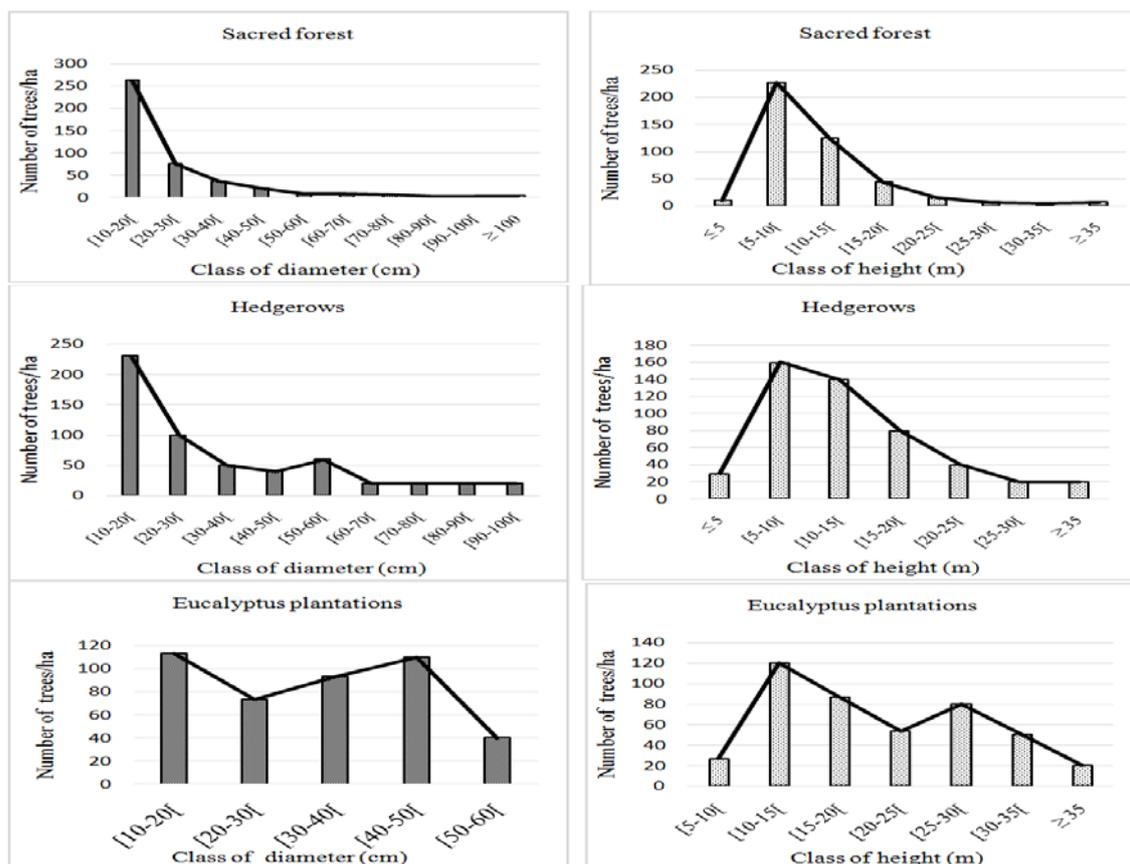


Figure 2. Distribution of number of stems according to diameter and height classes in the three sampled land use

Table 3. Number of trees.ha⁻¹, basal area (m².ha⁻¹), mean diameter (cm) and mean height (m), carbon stock (tC.ha⁻¹) of the three types of lands use

| Types of lands use | Number of trees (N.ha ⁻¹) | Basal area (m ² .ha ⁻¹) | Mean diameter (cm) | Mean Height (m) | Carbone stocks (tC.ha ⁻¹) | | |
|------------------------|---------------------------------------|--|--------------------|-----------------|---------------------------------------|--------------------------|-------------------------|
| | | | | | aboveground | belowground | litter |
| Sacred forest | 429±121 ^a | 28.59±8.66 ^a | 22.98 | 10.07 | 129.78±44.89 ^a | 31.15±10.77 ^a | 6.40±2.11 ^a |
| Hedgerows | 480±28 ^a | 44.18±14.82 ^a | 27.98 | 12.46 | 196.45±109.81 ^a | 47.15±26.35 ^a | 9.39±6.24 ^b |
| Eucalyptus plantations | 380±53 ^a | 30.88±10.49 ^a | 29.47 | 18.26 | 168.30±69.47 ^a | 40.39±16.67 ^a | 10.96±4.76 ^b |

3.3. Abundance, Basal Area and Carbon Stocks in the Three Types of Lands Use

An average tree abundance per hectare was higher in the hedgerows (480 trees.ha⁻¹) and lower in the *Eucalyptus* plantations (380 trees.ha⁻¹). In the Kouoghap sacred forest, despite the average abundance of 429 trees.ha⁻¹, the basal area was lower 28.59 m².ha⁻¹. This basal area was higher in hedgerows (44.18 m².ha⁻¹). The same trends were found for aboveground carbon stocks meaning that diameter and height are higher in *Eucalyptus* plantations and lower in the Kouoghap sacred forest (Table 3).

The Krustals-Wallis test showed that there is no significant difference between trees abundance, basal area, above and below ground carbon stocks in the three types of lands use ($p > 0.05$). On the other hand, litter carbon stocks were highly significant ($p = 0.000$) between land use. However, the two-by-two comparison of Wilcoxon test showed no difference between litter carbon stocks of *Eucalyptus* plantations (10.96 tC.ha⁻¹) and hedgerows (9.39 tC.ha⁻¹) which was not the case between these two types of lands use and that of the Sacred forest (6.40 tC.ha⁻¹) (Table 3).

4. Discussion

Given the small area of the Kouoghap Sacred forest, the number of 70 species of trees of dbh ≥ 10 cm identified in this land use is already measuring its character in the conservation of biodiversity. However, this species richness remains lower than the 90 species identified by Noumi [19] in this same sacred forest for the simple reason that the sampling design used by this author is different from that used in this study. Indeed, this author [19] used 10 plots of 25 x 100 m whereas we are using 5 transects of 800 x 5 m. This confirms the contact of Asase [32] which for them, the plots of inventories along transects gave satisfactory results as well as in West Africa.

The richness of 70 species found in the sacred forest is similar to the work of Rakotomalaza [33] who think that the trees floristic diversity of montane forests ranges from 38 to 146 species. However, this diversity is much lower than that of other forest ecosystems of the East and South regions of Cameroon where diversity is greater than 250 species [34-37]. In fact, western Cameroon is an area of high altitudes (> 2500m) generally unfavorable for a rich trees diversity in comparison to the South and East regions of Cameroon which are favorable for the trees diversity and where the altitude does not exceed 1000 m [38].

However, the diversity of sacred forest remains high compared to 11 species identified in the hedgerows. It is

in fact a landscape that people put in place and use for the development of rural space, the dominant technology of defense of cultures and also for their socio-cultural value such as land boundaries [16,38]. According to this author [39], these hedgerows are also an important reservoir of wood products (firewood, service and work), food and medicinal product for farmers in Western Cameroon. As a result, the trees present are often conditioned by the choice of the farmers [2], because it is decisive for the improvement of the trees diversity of the agrarian space and contributes to the increase of the rate of natural regeneration and taking into account the level of motivation of farmers to plant exotic species and local forest species [3,16]. For Torquebiau [39], hedgerows have always been an important source of wood, food and medicinal products for the farmer. According to Njoukam [2], these hedgerows have been progressively enriched with various species of cuttings or slices of foot including: *Dracaena* sp., *Croton macrocarpus*, *Ficus thonningii*, *Schefflera barteri*, *Canarium schweinfurthii*, *Vernonia amygdalina*, *Khaya grandifoliola*, *Kigelia*. Thus, even if the contribution is not important, hedgerows contribute to the conservation of endogenous biodiversity because of the 11 species in this land use, 70% were present in the Kouoghap sacred forest.

In the case of *Eucalyptus* plantations, given their monospecific woody nature (consisting only of the *Eucalyptus saligna* species), their contribution to the preservation of floristic diversity is lower or more still absent. This hybrid exotic species was introduced in Cameroon in 1920; its acclimatization with the environmental conditions of Western Cameroon has favored its large-scale extension [2,3,17]. The primary goal pursued by the peasants is the production of timber and firewood.

The density of 429 stems.ha⁻¹ found in the sacred forest where human activities are prohibited is close to 426 and 460 stems.ha⁻¹ found by Djuikouo [35] and Lewis [40] respectively in the Dja Wildlife Reserve and the undisturbed African tropical forests. In addition, this abundance decreases with the increasing of diameter classes indicating natural regeneration in the study area. This justifies the appearance of the "J reversed" curve which is a sign of ecological vigor and the guarantee of the sustainability of the population in an ecosystem [41]. Although hedgerows are artificially implemented, this same trend has been found in this type of land use. On the other hand, in *Eucalyptus* plantations where nearly 380 stems.ha⁻¹ have been recorded, its distribution of diameter classes is irregular. In fact, they are *Eucalyptus saligna* trees of the same age, due to the fact that there were planted at the same period; depending on the vigor of the plants, some are distinguished from others. However, after

flowering of the litter, seeds once on the ground grow to ensure the regeneration of the species, hence the abundance of small diameter individuals.

As for the number of stems per hectare, the basal area of 28.59 m².ha⁻¹ recorded in the Kouohap sacred forest is close to 30.3 m².ha⁻¹ obtained in the African rainforests [40]. However, this basal area is low compared to 44.18 m².ha⁻¹ found in hedgerows. This is explained by the fact that in addition of having more trees per ha, hedgerows have 80 trees.ha⁻¹ of diameter greater than 60 cm whereas in the sacred forest, we have only 29 trees of diameter greater than or equal to 60 cm. So, bigger would be a tree and more important would be its basal area. For *Eucalyptus* plantations, although they do not have trees greater than 60 cm in diameter, their basal area of 30.88 m².ha⁻¹ is correlated to their high mean diameter, unlike that of the Kouohap sacred forest.

Tsaléfac [11] in the Baleng Forest Reserve (West Cameroon) found a carbon content of 120 tC.ha⁻¹ which is similar to the 128 tC.ha⁻¹ found in the Batoufam Kouohap sacred forest in this study. However, carbon stocks were lower in the sacred forest compared to the two other types of lands use. In fact, these carbon stocks were higher in the sacred forest where the basal area was high, thus showing a correlation between these two variables [42]. However, trees carbon stocks in this study ranged from 130 to 196 tC.ha⁻¹ between land use in the range found by several authors in Cameroon's forest ecosystems [40,42,43,44]. On the other hand, litter biomass was lower in the sacred forest and higher in hedgerows. Indeed, in different types of lands use bright enough, microbial activities in the soil are intense because the temperature is favorable and this contributes to a rapid degradation of the litter. This could be the reason why the litter in the Kouohap sacred forest was lower compared to other types of lands use i.e. hedgerows and *Eucalyptus* plantations [45]. However, litter carbon stocks found ranging from 7 to 10 tC.ha⁻¹ which are high compared to those recorded by Adu-Bredu [46] in the fallow land of Ghana (3.4 tC.ha⁻¹). This high carbon stock value in fallow land could be explained by the fact that, under favorable conditions, the light arriving at the level of the lower layer favors the microbial activity of the soil and therefore the degradation of the litter [47]. In fact, litter is the main source of food for soil microfauna [47]. On the other hand, in different sampled types of lands use in Western Cameroon, in addition to the sampling period which was not favorable for microbial activities, very little light arrives on the soil, and the degradation of the litter by these micro-organisms remains low and the carbon stocks of this high carbon pools.

Knowledge's about below ground carbon stocks are essential for the understanding of terrestrial carbon storage in ecosystems. Given the difficulties in estimating their carbon stocks by destructive method, in this study, their biomass was estimated in a non-destructive method. Thus, below ground carbon stocks an average of 39.6 tC.ha⁻¹ in the study area; which is similar to the 39.7 tC.ha⁻¹ found by Bocko et al. [48] in the Congo forests. However, several authors have reported that below ground carbon stocks in tropical ecosystems and agrosystems are similar [46,48,49].

5. Conclusion

The agrarian landscape of the Western region of Cameroon is plagued by many socio-spatial changes. Due to the high population growth observed in this region, the so-called original vegetation is seriously degraded in favour of the various types of lands use whose importance in the conservation of biodiversity and the sequestration of carbon is not negligible. In this study, the locality of Batoufam represents an edifying case. Therefore, this study has shown that the Kouohap sacred forest although reduced to a hundred hectares today is the ecosystem that contains the greatest trees diversity of the locality of Batoufam. To achieve this, field surveys in addition to laboratory data's that enabled us to collect the above results. With its 70 trees species identified, the Kouohap sacred forest makes it possible to measure the endogenous form of conservation of biodiversity by traditional means in comparison with hedgerows and *Eucalyptus* plantations where only 11 and 1 species have respectively been identified. However, from the point of view of trees carbon stocks, even if the contribution of the Kouohap sacred forest is lower compared to those of hedgerows and *Eucalyptus* plantations, no significant difference was found between these different types of lands use. However, since the quantities of carbon stored by these three types of lands use are not insignificant, they constitute carbon pools that must be taken into account in REDD+ policies given their capacity to mitigate the effects of climate change.

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