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Estimation of biomass and carbon sequestered in the Plant stand with *Dialium englerianum* Henriques. in the Bombo-Lumene hunting grounds, Bateke plateau / Kinshasa

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Abstract: An inventory in the midst of herbaceous formation was carried out on one hectare in a plant stand with *Dialium englerianum* in the Reserve and Domaine de Chasse de Bombo-Lumene, 125 km east of Kinshasa. This research made it possible to study above-ground biomass and to deduce the amount of atmospheric carbon sequestered. Allometric measurements were performed on trees ≥ 10 cm in diameter at 1.3 m breast height. Analysis of the results obtained show an overall phytomass of 45.28 ± 8.40 t.ha-1, corresponding to 21.11 ± 3.92 t.ha-1 of stored carbon and 70.07 ± 13 , 21 t.ha-1 of carbon equivalent. The specific contribution review assigns a phytomass of 32.14 ± 6 t.ha-1; 15 ± 2 t.ha-1 of carbon stored and 50.51 ± 7 t.ha-1 in *Dialium englerianum*, the main species of this stand. These results demonstrate the interest to be given to herbaceous tree formations in aerial biomass assessments and atmospheric carbon sequestration estimates from different plant landscapes.

Keywords: biomass, carbon, stand, *Dialium englerianum*, Bombo-Lumene hunting area, DR-Congo

Introduction

One of the environmental issues of concern to the international community is the increased levels of greenhouse gases in the atmosphere (RAVEN & al. 2009). Among these gases, carbon dioxide is the most important (KIDIKWADI, 2012; KIDIKWADI & al, 2015; KIDIKWADI & al, 2018). Our approach is part of the (REDD +) process, advocating the conservation and reforestation of degraded forest lands and secondary forests.

Climate change is today a matter of concern and concern for the entire international community, but at the same time a topic for the search for lasting solutions. Among ecosystems, forests in general and tropical forests in particular play an important role in reducing greenhouse gas levels (LUBINI, 2001; KIDIKWADI & al., 2020).

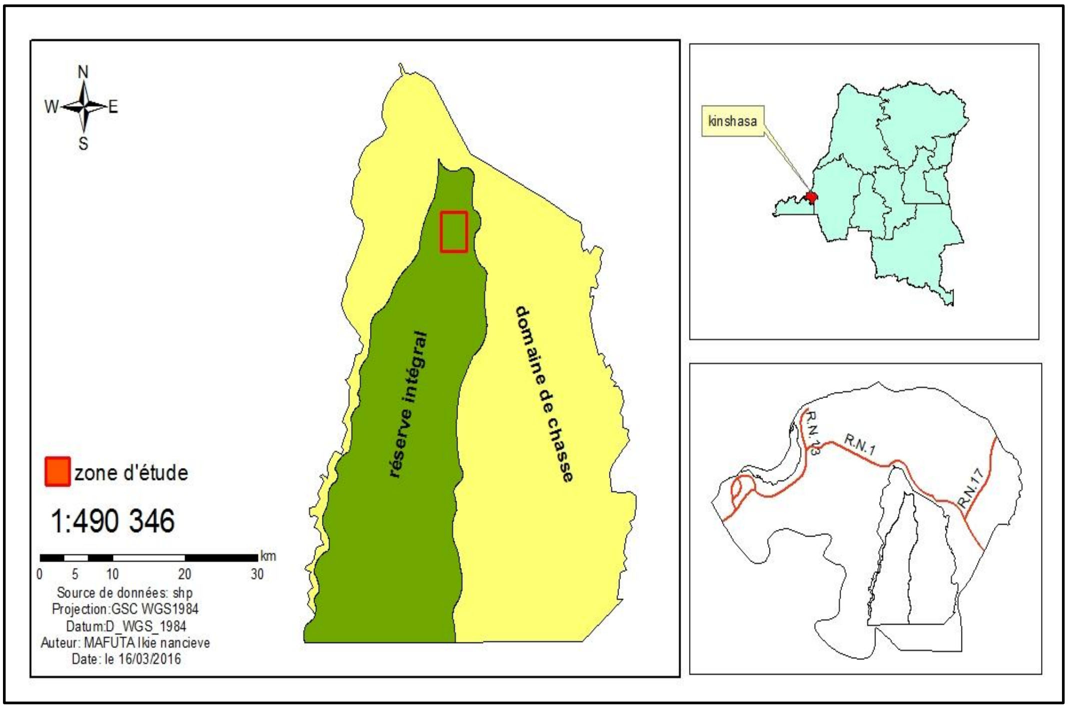
The Bombo-Lumene Hunting Estate, located east of Kinshasa is made up of two main plant formations: forest galleries and herbaceous formations commonly called savannahs include several facies: the grassy facies, the arborescent facies, the shrub facies, the tree facies. In order to continue the reforestation in progress in these herbaceous formations on the Bateke plateau, it is important to assess the phytomass of woody species and to deduce the mass of carbon sequestered in the tissues of these species.

The expected results will make it possible to compare the quantity of phytomass and carbon sequestered before and after possible reforestation. Thus, faced with the economic, ecological and environmental challenges linked to climate change, we propose to estimate the biomass of arborescent and shrub species of the grassy formations of the Bombo-Lumene hunting estate and to deduce the amount of atmospheric carbon sequestered.

Material and Methods

Study zone

The Bombo-Lumene hunting grounds and reserve is located on the Bateke plateau. This reserve is located in the semi-rural commune of Maluku, 125 km east of the city of Kinshasa, on national road n ° 1, connecting Kinshasa and Kikwit. The geographic coordinates are as follows: longitude 4 ° 15'45"S; 015 ° 45'16 '' East latitude. The altitude varies between 600 m to 700 m. The area thus delimited covers an area of 350,000 hectares, incised by deep V-shaped valleys. A motorable track, 6 km long in a southerly direction, connects the Bombo-Lumene Station and the national road n ° 1 at km 125 (KIDIKWADI, 2012; KAYUMBA & al., 2015). Map 1 locates the Reserve and the Bombo-Lumene hunting grounds. It was developed using Arc Gis software version 10.0.A.



Map 1: Geographical location of the Bombo-Lumene Reserve and Hunting Area.

A plot of one hectare of herbaceous shrub formation with local dominance of *Dialium englerianum* in the Reserve and Domaine de Chasse de Bombo-Lumene, 125 km east of Kinshasa was the subject of a phytomass study and estimate of carbon sequestered in tree tissue. This Guinean-Congolese-type herbaceous shrub, with a strong presence of Zambezian species occupying all of this vast Bateke plateau.

Only the largely open tree stratum was the subject of a floristic inventory in a device of ha (Figure 1).

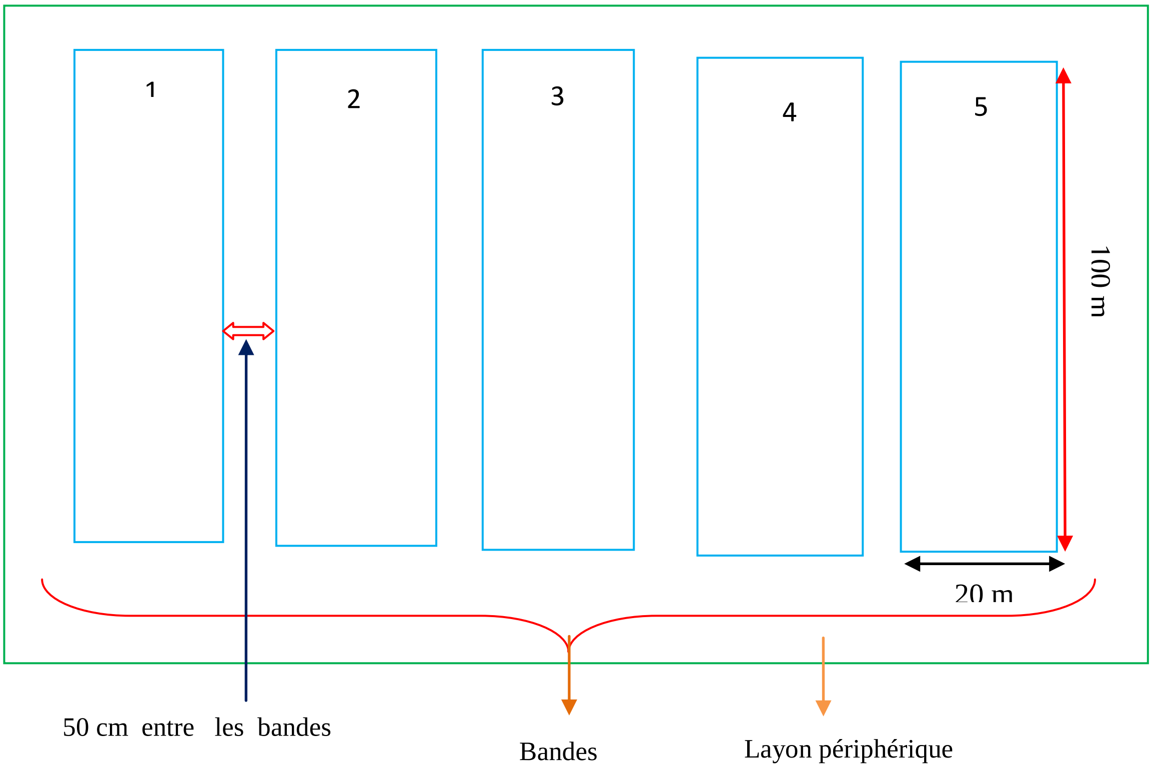


Figure 1. Inventory device installed in the study environment

The botanical samples collected enabled the constitution of a reference herbarium, followed by the identification of this material. Allometric measurements taken at 1.30 m above the ground made it possible to calculate the diameters and basal areas of all woody individuals reaching a diameter equal to or greater than 10 cm. The biomass of the trees studied is obtained using the allometric equations established by CHAVE & al., (2005); TOUNG (2010); KIDIKWADI (2018); KIDIKWADI & al., (2019; 2020).

The corresponding carbon stock is calculated on the basis of the relationship C = B.A. x k; with k = 0.47 and B.A = aboveground biomass and C = Carbon (RAVEN & al., 2009; KIDIKWADI, 2012; LUBINI & al., 2014).

To obtain the carbon equivalent, we multiplied the value of the carbon stock calculated by the coefficient 3.667 as proposed by the IPCC group (2007a, 2007b).

To estimate the amount of carbon dioxide (CO_2) that would be emitted into the atmosphere after tree cutting and combustion, the following formula was used:

C02 = AGBP * PMC02 / PMC.

With: AGBP = dry and living above-ground biomass; PMC02: molecular weight of carbon dioxide and PMC: molecular weight of carbon. The results obtained were analyzed using variance testing to verify the significant difference between measurements of aerial phytomass, carbon and carbon equivalent of each species studied.

Results

The results obtained are presented in the following order: floristic analysis of the stand, density and specific diversity of each species, aerial phytomass, carbon and carbon equivalent.

Floristic analysis

The examination of the inventoried botanical material makes it possible to analyze the floristic composition of the plant population studied. We will limit ourselves to arborescent and shrubby synusia. We identified 14 species belonging to 14 genera, 13 families and subfamilies (Table 1).

Table 1. Floristic composition of shrub and tree species of the *Dialium englerianum*

1.Euphorbiaceae
Maprounea Africana MuLL. ARG.
2.Fabaceae /Caesalpinioideae
*Dialium englerianum*H enriques.
3.Fabaceae/Faboideae
Millettia drastic Welwex. KSchum.
4.Fabaceae/Mimosoideae
Albizia adianthifolia Wight. Var *adianthifolia*
5.Phyllantaceae
Hymenocardi aacida Tul.
6.Myrsinaceae
*Syzygium guin*eense *(*Willd). DC.Subsp.
7.Hypericaceae
Psorospermum febrifugum Spach.
Sorospermum tenuifolium Hook.f.
8.Ochnaceae
Ochna afzelii R.Br.ex Oliv.
9.Passifloraceae
Paropsia brazzeana Bail..
10.Phyllanthaceae
Bridelia micrantha (HOCHST.) BAILL.
11.Polygalaceae
Securidacalonge pedunculata FRESEN.Mus.Senckeb.
12.Rubiaceae
Crossopteryx febrifuga (AfZel. ex G.Don) *Benth.*
13.Strychnaceae
*Strychnos cocculoides*Baker.

From this table it appears that this stand is very poor in species: 14 species / ha, belonging to 13 different families, especially since it is a herbaceous formation, naturally poor in species. However, it should be noted that this floristic inventory covered only the arborescent and shrub synusia.

Specific diversity of species per hectare

The results on the number of individuals per species / ha are shown in Figure 2. We recorded 375 individuals for all of the constituent species. The contribution of *Dialium englerianum* totals 164 trees. The following histogram shows the distribution of individuals by species.

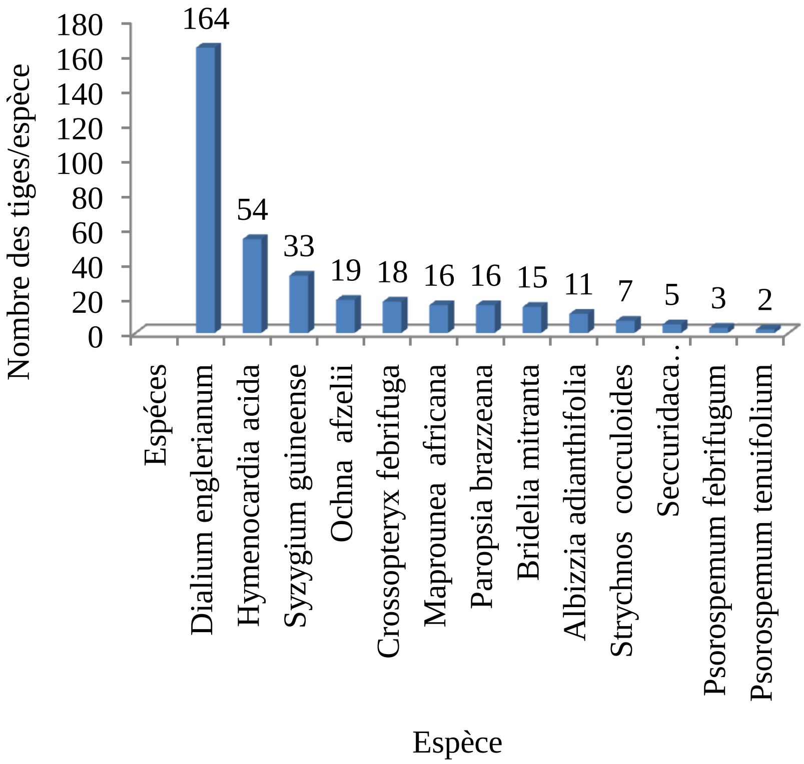


Figure 2. Specific diversity in a *Dialium englerianum* stand in the shrubby herbaceous formation of the Bombo-Lumene / Kinshasa Reserve and Hunting Area

The appearance of this figure shows that *Dialium englerianum* has a very high number of individuals, namely 164 stems, 54 *Hymenocardia acida* individuals and 33 *Syzygium guineense* individuals. *Dialium englerianum* is characterized by a high number of individuals compared to other species. Indeed, this species forms quite frequent facies near the forest-herbaceous formation edges. It induces a favorable microclimate for forest species including *Gaertnera paniculata*, *Chaetocarpus africanus*, etc.

Analysis of stand diameter classes

Analysis of the distribution of individuals of different inventoried species makes it possible to establish diameter classes. Data from four subplots reported per hectare are presented in Figure 2. They allow us to conclude that *Dialium englerianum* is dominant in all diameter classes. The resulting figure is in the shape of an inverted J, that is to say a high density for the small diameter classes. The larger diameter classes are very poorly supplied with individuals. It seems that the middle classes register a very high mortality, probably due to the annual bush fires which ravage young seedlings or individuals (Figure 3).

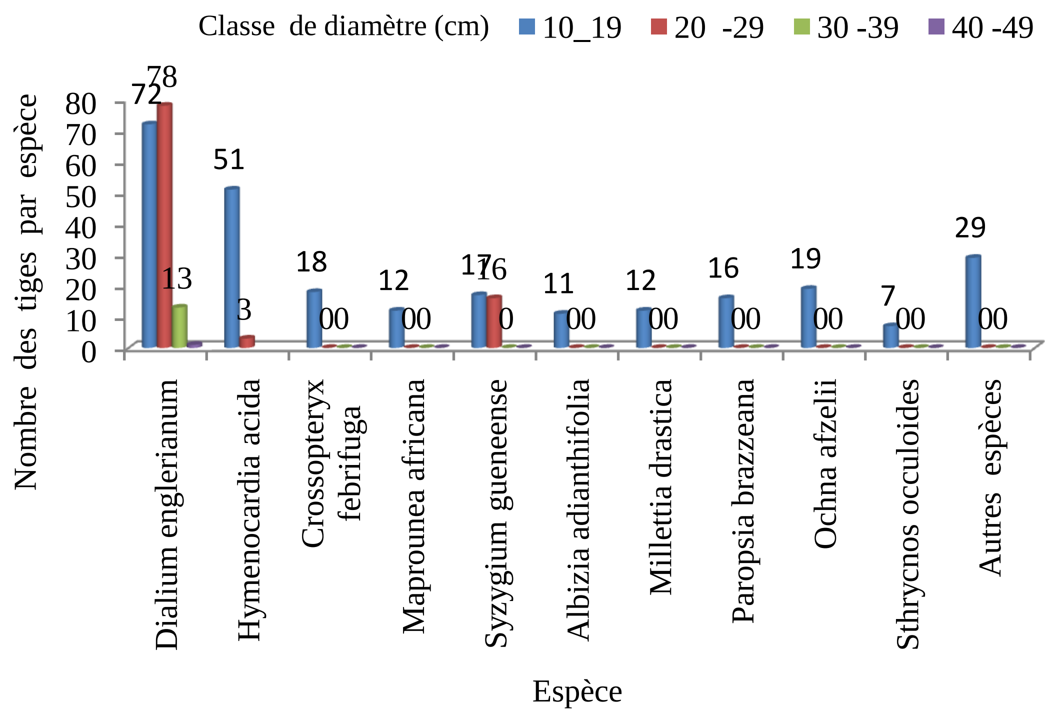


Figure 3: Diameter class of the stand studied

Measurement of phytomass, carbon and carbon equivalent

Overall, we totaled 45.28 ± 8.40 t / ha of aerial phytomass; 21 ± 3.92 t / ha of carbon mass sequestered and 70.07 ± 13.21 t / ha of carbon equivalent. *D. englerianum* has a very high amount in terms of aerial phytomass, carbon and carbon equivalent, ie 32.14 ± 6 t / ha; 15 ± 2 t / ha and 50.51 ± 7 t / ha (Figure 4). The variance test applied reveals a significant difference between the above-ground biomass, carbon and carbon equivalent measurements of each species studied. With ANOVA (F = 0.7799, df = 3.295, p = 0.5281).

This difference is due to the fact that this shrubby herbaceous formation is characterized by the dominance of *D. englerianum* in the western part of the Bombo –Lumene hunting area.

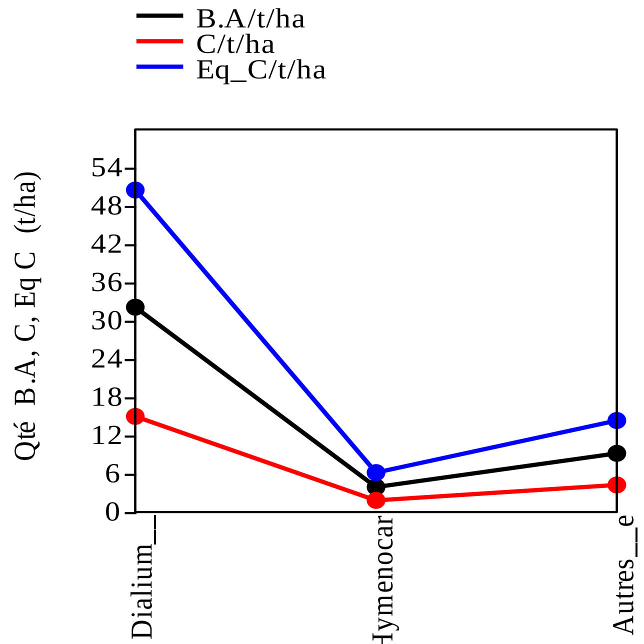


Figure 4: Aerial phytomass, carbon and carbon equivalent (t.ha-1.)

Calculation of CO2 emissions for a deforested area

The amount of carbon dioxide (CO2) that would be emitted into the atmosphere was calculated for all the trees that were listed, ie 375 trees. After the trees are burned, the mass of CO2 that will be emitted is 166.02 t.ha-1. . Only *D. englerianum* prime or 117.84 t.ha-1 of carbon dioxide emitted into the atmosphere (Figure 5).

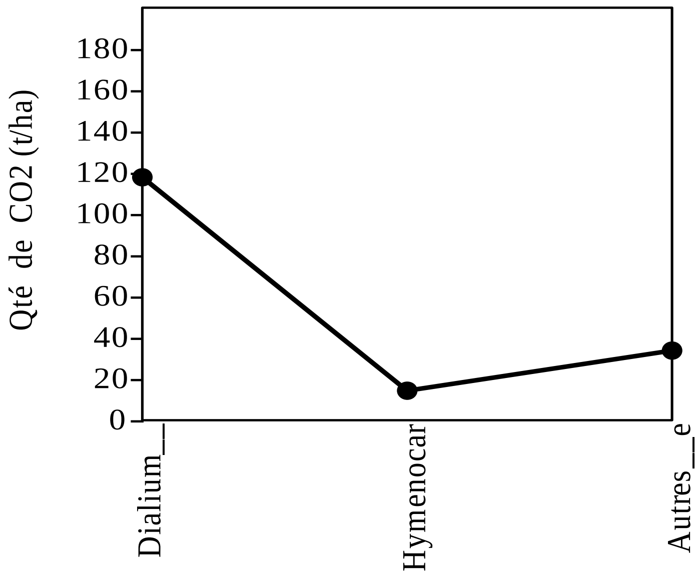


Figure 5: Amount of carbon dioxide released into the atmosphere after trees are burned

Discussion

Analysis of the inventory reveals 375 individuals per hectare, belonging to 14 species grouped into 14 genera, 13 families and subfamilies. We note the preponderance of Fabaceae species with a large spatial occupation. The other families are less represented. The very large presence of *Dialium englerianum* indicates a wide spread of the species.

The site studied is a facies of a tree-like herbaceous formation, locally dominated by *Dialium englerianum* with a very widely open arborescent synusia. The density of *Dialium englerianum* is 164 individuals per ha. These values are comparable to those obtained in certain types of dense humid forests (LUBINI, 1997).

Our results approach those of work carried out in herbaceous shrub and tree formations in Uganda which are the object of circumference measurements of 316 shrubs and trees in Uganda (UNESCO, UNEP and FAO, edicts, 1981). The work carried out in herbaceous formations in Congo Kinshasa by DUVIGNEAUD (1952), Devred (1956), LUBINI (1988, 1997 and 2006), BELESI (2007 and 2009) report results that are quite comparable to ours. Likewise, WHITE (1983) describes the herbaceous formations of intertropical Africa in which the one we study here is included.

Likewise, the work of MALOTIMA (2011), reports a density of 256 individuals per hectare, distributed to 10 species in a shrub and arborescent herbaceous formation subjected to the regime of bush fires of Manzongi in Bas-Congo.

The results obtained in the four subplots show the total absence of *Dialium englerianum* seedlings. Indeed, in a tree or shrub herbaceous formation, the regeneration of this species is almost zero, because under the regime of bush fires, adult pyrophyte trees can continue to develop, but without ensuring regeneration, and the young are often destroyed by fire as confirmed by LOUPPE & OLIVIER (1995); KIDIKWADI, (2018). The grasses form a large clump, retaining some of the seeds from reaching the soil and being able to germinate.

CLEMENT (1982), MALOTIMA (2011), assert that in the tree or shrub herbaceous formation, subjected to the regime of bush fires, the original tree vegetation does not recover. But without the passage of fire, this regeneration is progressive.

The distribution of species in relation to diameter classes is different according to the species studied. The diameter classes (10-19 and 20-29) seem to be better supplied than the others. *Dialium englerianum* occurs in all structures of diameter classes. With 10 cm in diameter, some species have erratic distributions (Fig. 2). CAUSSINUS & al. (1969,1970) studied the structures of certain species and propose a general expression which gives the types of structures by species. These tree structures by diameter categories correspond to the density of the species / ha (KIDIKWADI & al, 2019). Irregularities can be noted in the distribution histograms and these are sometimes due to the geological history of the site, to the morphological and ecological characteristics and to the flora richness of each of the species in the environment studied. *D. englerianum* also has a density of 164 individuals / ha, against 54 individuals / ha of *Hymenocardia acida*, while for the other species, these parameters are very low.

From the work of LUBINI (2006), it generally emerges that the density of woody plants seems higher in the forest-herbaceous transition zones of the north than those of the south. Of the four subplots studied, *Dialium englerianum* reached a circumference of 130 cm (Figure 2b). Three hundred and seventy-five individuals were used to assess biomass, carbon and carbon equivalent. All the species studied present a total aerial phytomass of 45.28 ± 8.40 t.ha-1, corresponding to 21.11 ± 3.92 t.ha-1 of stored carbon and 70.07 ± 13, 21 t.ha-1 of carbon equivalent. From this value, *Dialium. englerianum* is the only one that wins over the other species with 32.14 ± 6 t.ha-1 of aerial phyomass; 15 ± 2 t.ha-1 of carbon stored and 50.51 ± 7 t.ha-1 of carbon equivalent. This is explained by its higher abundance-dominance than the others. A phytosociological and ecological study of the shrub formations of the IBI Station on the Bateke plateau was carried out by LUBINI (2006). Phytomass measurements vary from station to station. The highest mass is recorded in the low herbaceous formation dotted with a few shrubs, ie about 20 t / ha of dry organic matter and 10 t / ha of carbon; the lowest mass being obtained in another with 10 t / ha of dry organic matter. Likewise MALOTIMA (2011), in the arborescent and arboreal grassy formation subjected to bush fires in Manzonzi (Bas congo), the measurements obtained for phytomass amounted to 8.2 t / ha and the quantity of carbon sequestered 4, 1t / ha.

In the herbaceous formation, shrub facies of Lamto, in Ivory Coast, LAMOTTE (1981) obtains 13 to 16t / of dry matter per hectare.

According to CRACE & al. cited by MALOTIMA (op.cit.), the carbon stock in herbaceous formations varies considerably depending on the extent of the vegetation cover. It ranges from 1.8 t of carbon per hectare where shrubs are scarce, to over 30 t / ha of carbon in dense shrub canopy.

Along the same lines, LAMOTTE (1981) underlines that in herbaceous shrub and arborescent formations, the aerial phytomass depends on the density of the woody cover; it is 10 to 11 t / ha in a less dense cover.

In the forest-herbaceous border zone, *Dialium englerianum* forms sometimes large stands in the study area and therefore contributes to the sequestration of atmospheric carbon. It is therefore necessary to think of effective measures to protect the site which will thus contribute to the objectives of the process of Reducing Emissions from Deforestation and Forest Degradation, and including conservation, sustainable forest management, and increasing carbon stocks (REDD +) and the Clean Development Mechanism (CDM).

Thus, it seems interesting to generalize this experiment on other sites bearing the same stand on this vast plateau in order to obtain more representative data allowing to assess the biomass and the quantity of carbon stored in this plant stand and therefore, the contribution of herbaceous formations to the REDD + mechanism.

Conclusion

This article is devoted to tests on the evaluation of above-ground biomass and the estimation of the mass of atmospheric carbon stored in a mixed stand dominated by *Dialium englerianum*at the Bateke Plateau. This is an approach aimed at determining the contribution of wooded herbaceous formations to the reduction of greenhouse gases. The results obtained pave the way for the evaluation of the contribution of arborescent herbaceous formations in a humid tropical climate to the reduction of greenhouse gases and above-ground biomass. They can also encourage a decision to afforest and / or reforest a large area of this ecosystem, in order to increase the capacity to fight against the much maligned global warming.

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