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Preliminary note on the study of aerial phytomass and carbon of the Kitshanga forest massif, at Kenge in Kwango

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Abstract: This note consisted in estimating the aerial phytomass and the mass of carbon contained in the woody tissues of the Kitshanga forest, Kwango Province in DR-Congo. The general objective is to quantify the production of above-ground biomass and to deduce the mass of carbon contained in this gallery forest. We used the observation method (description, analysis and inventory) supported by allometric equations. For the biomass estimates, we used the allometric equations of Fayolle and *al*., (2013) and Djomo and *al*., (2010). The estimate of the carbon stock corresponding to the above-ground biomass at our study site was obtained by multiplying the biomass by the conversion factor (0.47) recommended by the IPCC (2006). A one-hectare experimental set-up identified all trees with a diameter at chest height ≥ 10 cm. The data thus obtained were subjected to statistical processing. The main results obtained for the whole flower show 85 species belonging to 27 genera grouped into 29 families and subfamilies among which are the Fabaceae, Rubiaceae, Apocynaceae, Euphorbiaceae, Malvaceae, Annonaceae, and Meliaceae predominate. Regarding the estimates, only trees and shrubs with a diameter greater than or equal to 10 cm were studied. Grasses and lianas were excluded. A density of 473 trees per hectare; the basal area measurements amount to 27.19 m² / ha, the total above-ground biomass (AGB) is 433.28 t / ha for a sequestered carbon stock of 203.64 t / ha and carbon equivalent of 746 , 76 t / ha following the model of Fayolle and*al*., (2013) while a biomass of 274.46 t / ha is observed for a sequestered carbon stock of 128.99 t / ha and carbon equivalent 473, 02 t / ha according to the model of Djomo and*al*., (2010). The Kitshanga massif is a relatively important site for sequestering atmospheric carbon, thus contributing to the fight against climate change. These results foresee the continuation of a project on the estimation of the above-ground biomass of semi-evergreen rainforest on the outskirts of the city of Kinshasa.
Keywords:aerial phytomass, carbon, Kitshanga, DRC

1. Introduction

Tropical forests are among the richest protected areas on the planet. Boyemba (2011) qualifiers them as “museums of diversity”. These forests occupy an essential place in human life in general, both locally and internationally. They also produce a large amount of above-ground plant biomass. They therefore have a strong capacity to sequester atmospheric carbon (Chave and *al*., 2001; Chave and *al*., 2005). In addition, these are, after the ocean, the main sinks of carbon dioxide, a gas which is one of the causes of global warming.

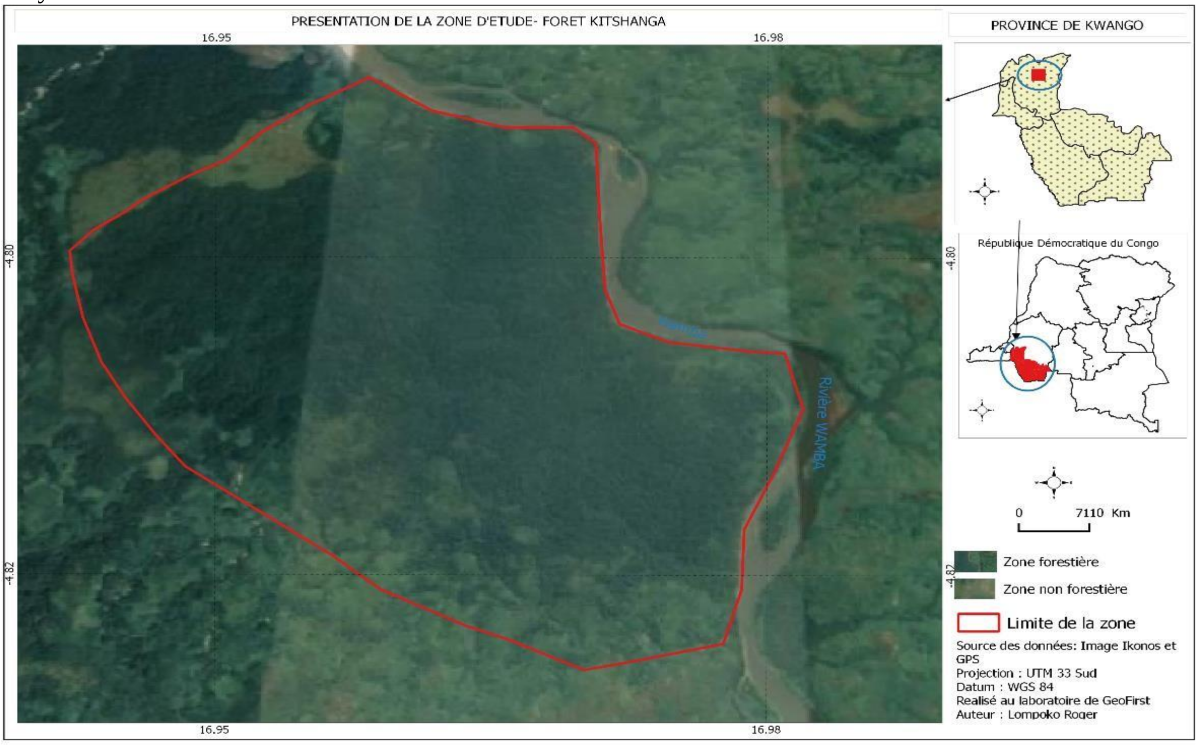
Climate change is today a subject of concern and concern for the entire international community, but at the same time a theme for the search for lasting solutions. Among ecosystems, forests in general and tropical forests in particular play an important role in reducing greenhouse gas levels (Lubini, 2001; Lubini and *al*., 2014, Kidikwadi and *al*., 2020). To remedy this situation, the United Nations Convention on Climate Change has provided for the REDD + mechanism to which the Democratic Republic of the Congo has subscribed because of its large forest area, its richness and its high floristic diversity.

Our approach is part of the (REDD +) process, advocating the conservation and reforestation of degraded forest lands and secondary forests.

The forest areas of the Wamba Valley in Kwango have not been studied for biomass. It appears interesting to have baseline information on which to consider a development plan to ensure the conservation of biological diversity and environmental services. This is why, as part of our research, we undertook this study on the estimation of above-ground biomass and carbon sequestered by the Kitshanga forest in Kwango in the DRC.

2. Study Environment

This study was carried out in the Kitshanga forest massif in the Wamba valley, a tributary of the Kasai River, one of the main left tributaries of the Congo River. The following map locates this forest massif in the study area.



Map 1. Location of the study area (Source: this study)

3. Materials and Methods

3.1 Hardware

We prospected the land by carrying out ecological observations and by collecting botanical material in order to constitute a reference herbarium. These harvests were made during the inventory in the field.

3.2 Methods

Research carried out in the Kitshanga forest. It is a forest developed on a slope and valley, This massif is of the dense humid type that develops along the Wamba river and streams. A device of one hectare was the subject of an inventory.

Inventories were limited to trees with dbh ≥ 10 cm at 1.3 m from the ground conventionally accepted (Lubini andal., 2014; Kidikwadi, 2018). The tree circumference was measured using a circumferential tape in cm.

By converting the circumferences of all individuals to diameter, the diameter classes were established.

The basal area corresponds to the sum of the areas of the sections 1.3 m above the ground of all the trees with dbh ≥ 10 cm inventoried in the inventory system. It is expressed in m² / ha. The formula used looks like this:

G = πdhp2 / 4; Where: G = basal area; dbh = diameter at 1.3 m from the ground of the tree; π (pie) = 3.14 (; Sonké, 2004; Belesi, 2009; Boyemba, 2011; Lubini and *al*., 2014; Kidikwadi and*al*., 2015; Kidikwadi and*al*., 2019; Mayanu and*al*., 2019) .

The calculations of the above-ground biomass of trees were made by applying the allometric equations established by Fayolle and *al*., 2013 and Djomo and al., 2010.

The estimated amount of carbon is multiplied by a coefficient of 3.667 in order to calculate the carbon equivalent as established elsewhere (IPCC, 2007a, 2007b).

Pearson's correlation test was used to establish the relationship between the parameters studied: diameter, biomass.

4. RESULTS

4.1 Floristic composition of Kitshanga forest massif

The flora of Kitshanga was studied in order to inventory and identify the species in order to estimate the aerial phytomass and carbon sequestered in this massif. The examination of the biological material inventoried during the surveys made it possible to characterize the floristic composition. The floristic inventory reported 86 species belonging to 29 families and subfamilies, 71 genera. After analysis of data, Fabaceae, Rubiaceae, Apocynaceae, Euphorbiaceae, Annonaceae, Meliaceae and Malvaceae predominate. However, lists of this Kitshanga forest flora have been drawn up (appendix).

4.2 Specific wealth

We identified a total of 473 trees throughout the study area. Petersianthus macrocarpus predominate, ie 87 individuals; followed by Antrocaryon nannanii 58 individuals; Staudtia kamerunensis 31 individuals and Ongokea gores 30 individuals. For the rest of the species the density is low. Figure 1 gives the details of the results obtained.

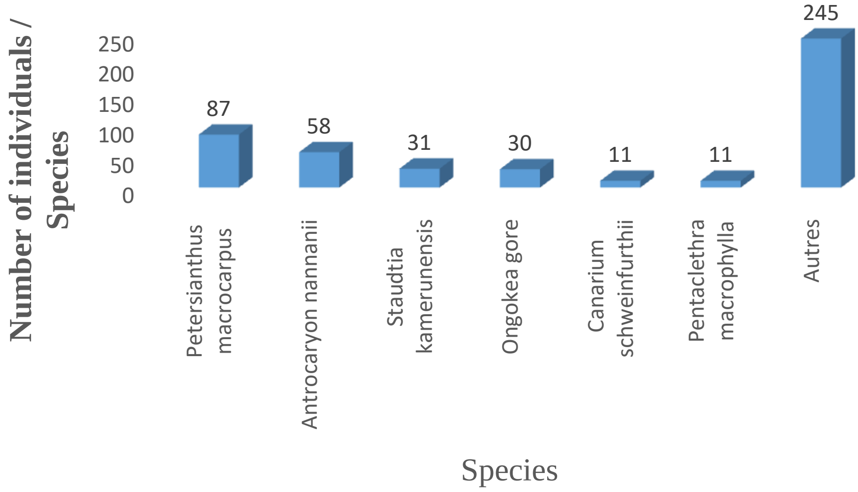


Figure 1: Specific richness of species in the study area

4.3 Basal area

Basal area measurements were calculated for all the trees inventoried, is 27.22 ± 0.10 m2 / ha. From this value, Antrocaryon nannanii prime is 6.16 ± 0.09 m2 / ha. Figure 5 gives the basal area details of the main species.

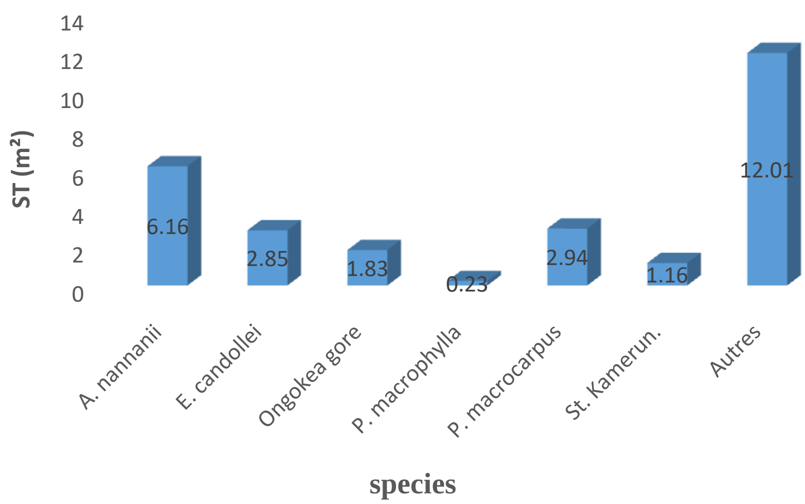


Figure 2: Basal area of main species

4.4 Diameter and biomass relationship

The production of above-ground biomass contained in a tree depends on its growth in diameter. Thus, the larger the diameter, the more biomass increases. The applied Pearson test shows that there is a relationship between the diameter and the above-ground biomass of the trees measured, with the Pearson correlation coefficient r = 0.95; p-value <0.0008. Figure 3 indicates the correlation between the diameter and the biomass of the trees inventoried.

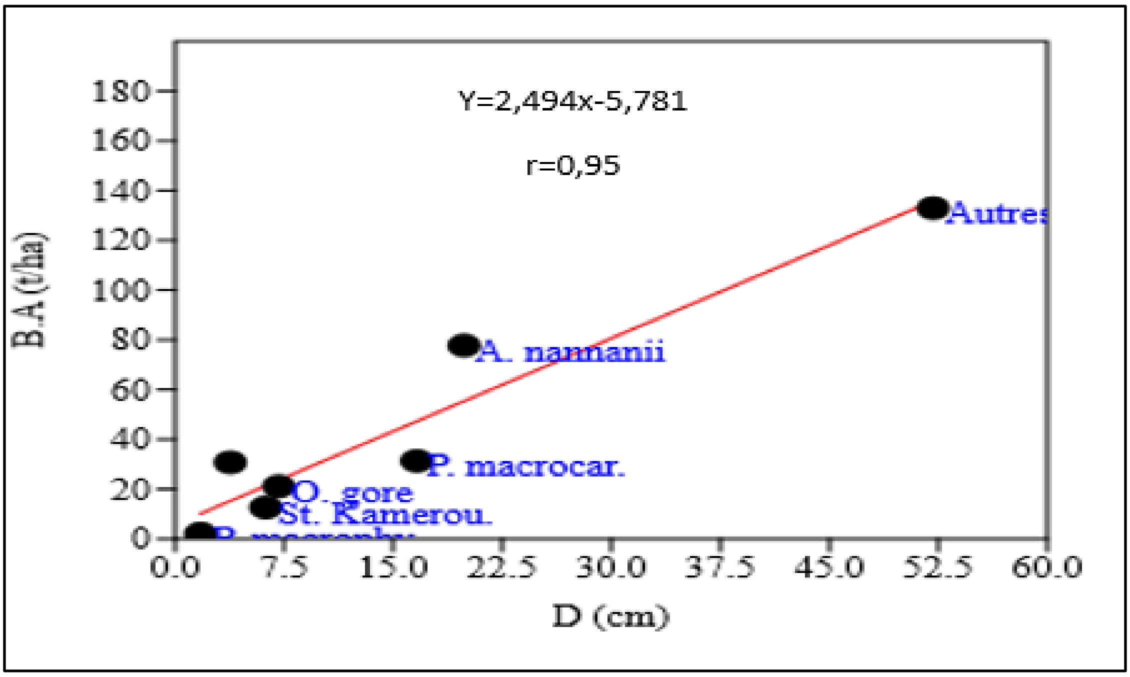


Figure 3: Relationship between diameter and biomass

4.5 Above-ground biomass, carbon stock and carbon equivalent of the species studied

The results relating to the above-ground biomass according to each species are given in the table in the appendix. Observations made show that Antrocaryon nannanii is the species with a high aerial biomass value. It is followed by Ficus mucuso, Entandrophragma candollei, Petersianthus macrocarpus, and Ongokea gore.

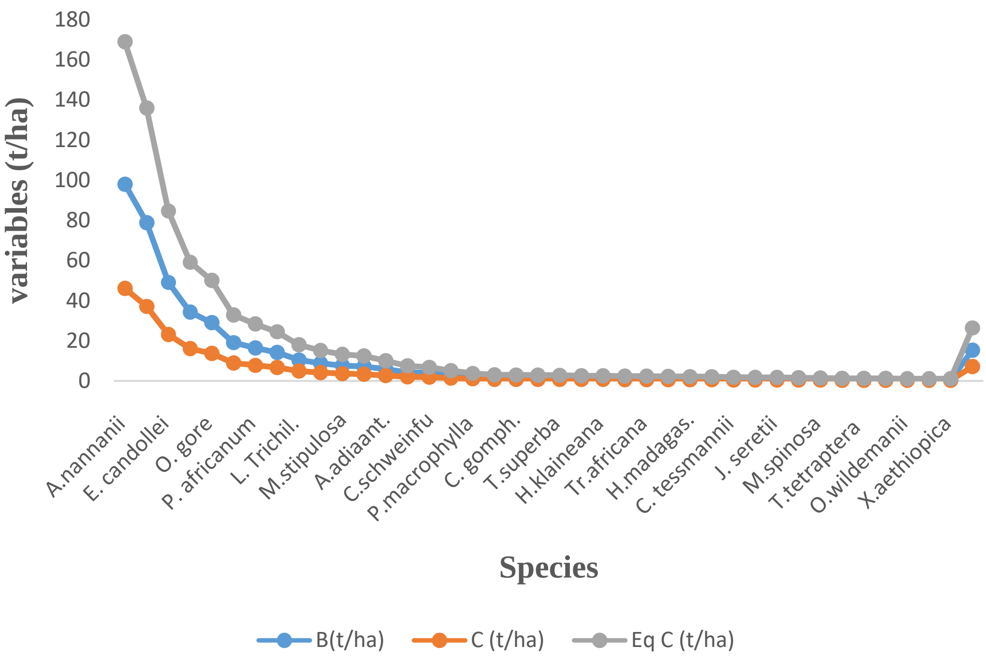


Figure 4 Above-ground biomass, carbon stock and carbon equivalent of the species studied

4.6 Above-ground biomass, carbon stock and equivalent carbon according to two analysis models: Djomo and*al*., (2010) and Fayolle and*al*., (2013)

To estimate the above-ground biomass, the carbon stock and the carbon equivalent of species in this forest massif, two analysis models were taken into account: Djomo and*al*., 2010 and Fayolle and*al*., 2013. Of these two analysis models emerge from the observation that the biomass values obtained by the two models (Fayolle and *al*., 2013, Djomo and*al*., 2010) are significantly different. The same is true for the stock of carbon or sequestered carbon and the carbon equivalent. The following figure shows the results of biomass, carbon stock and carbon equivalent according to the two analysis models.

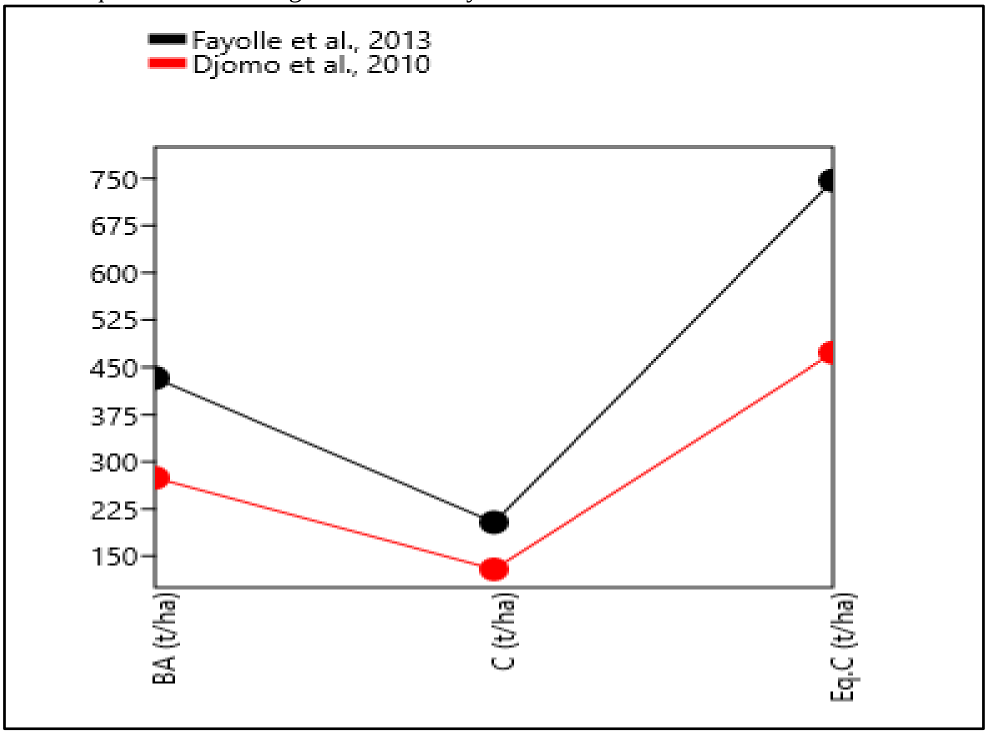


Figure 5 Above-ground biomass, carbon stock and carbon equivalent according to the model of Djomo and*al*., 2010 and Fayolle and *al*., 2013

4. 7 Results relating to the type of forest

After analyzing the equations used, mature forest species better sequester carbon with a value of 141.4 t / ha according to the equation of Fayolle and*al*., (2013) and 90.2 t / ha according to the equation from Djomo and*al*., (2010). In contrast, in secondary forest, the estimated value of 62.2 t / ha according to the equation of Fayolle and*al*., 2013 and 38.8 t / ha according to Djomo and al., 2010. Details are given below

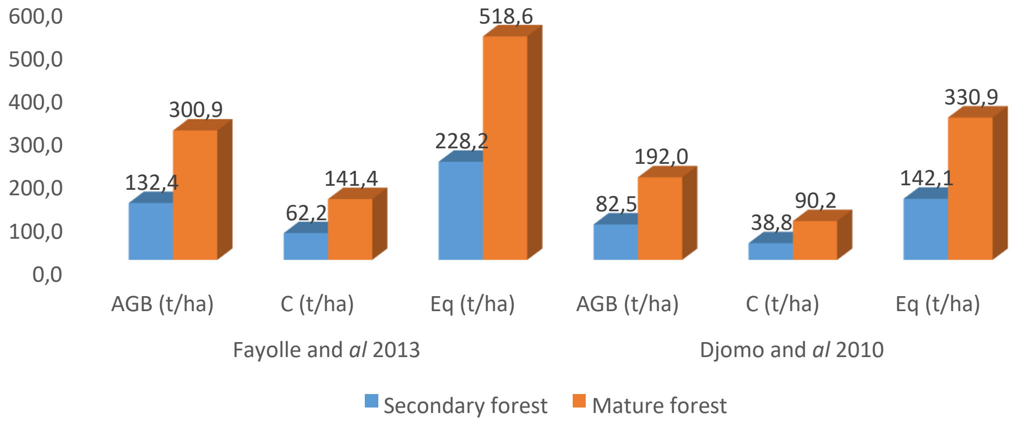


Figure 6: Estimation of above-ground biomass according to forest type

4.8 Independent variables on mature forest and secondary forest species

Figure 8 shows the ordination of the factors (B.A, C, Eq C) that influence the variables on the species of the forests studied. Principal component analysis (PCA) highlights the influence of these variables. Only the first factorial axis on the ordinate is to be interpreted. Analysis of this figure shows that the above-ground biomass, carbon stock and carbon equivalent of the species studied differ depending on the type of forest.

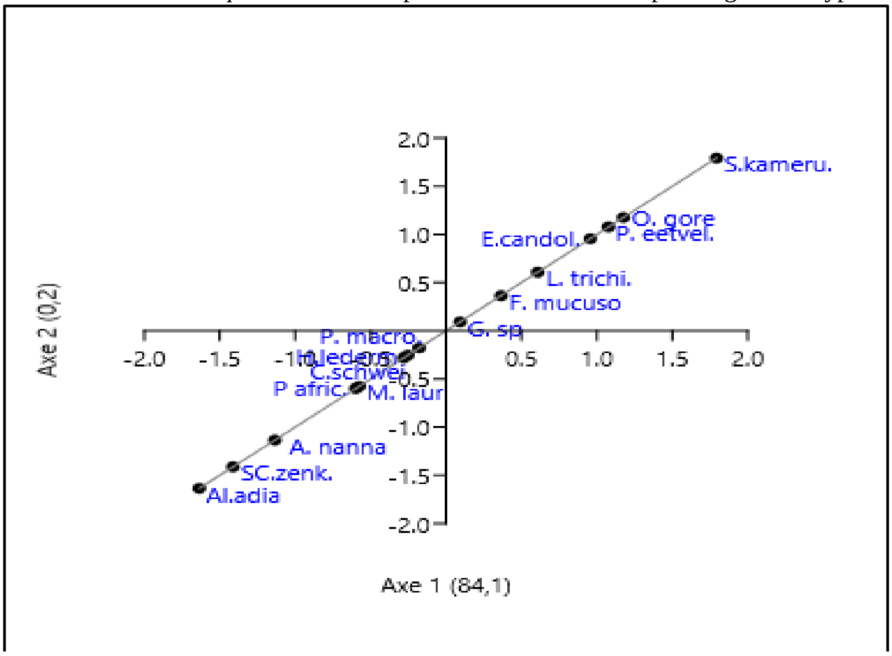


Figure 7 : Variables indépendantes sur les espèces de forêt mature et forêt secondaire

3.2 Discussion

This study consisted in estimating the above-ground biomass and the carbon stock sequestered by the Kitshanga forest in the Kwango province. Observations and inventories were made in a device of one ha.

The inventory of species populating the study area which showed a predominance of seven (7) families: Fabaceae, Rubiaceae, Apocynaceae, Euphorbiaceae, Annonaceae, Malvaceae and Meliaceae predominate with a total of 473 individuals belonging to 86 inventoried species. These were variably distributed in the study plot which was subdivided into 4 subplots for this study. With regard to the standards given by Pascal (2003) for dense humid tropical forests (between 450 and 750 trees / ha, dbh ≥ 10 cm) and compared to the estimates of average densities per hectare established by Rollet (1974) in Central Africa (481feet / ha, dbh ≥ 10cm), the densities observed in the forests studied are in the same range.

The results obtained for the study plots are superior to that of Loubota and al. (2016), i.e. 535t / ha. This difference could be explained by the precision of the formulas used. Indeed, the latter used the equations of Feldpausch and*al.* (2012) which are different from those of Fayolle and*al.* (2013). The low number of trees sampled (n = 26), all trees with a diameter of less than 50 cm can also explain the underestimation of the biomass induced by the equation. Indeed, according to Nasi and al. (2008), at least 100 trees must be sampled to obtain a good predictive model of biomass.

The sequestered carbon stock was estimated at 203.64 t / ha (Fayolle and*al*., 2013); 128.99 t / ha (Djomo and*al*., 2010). When compared to the results of FAO (2010), Pearson and Brown (2005) who estimate the carbon sequestered in a tropical forest at 82.2 t / ha. Even higher figures, 400 t / ha, were reported by Chave (2005) in a tropical rain forest. However, our estimate of this value is lower than that found by Chave (2005).

By comparing the aboveground biomass values and the carbon mass of mature forest species and that of secondary forest, we notice that mature forest species have a higher aboveground biomass than that of secondary forest. The secondary forest species are small compared to the mature forest species, there is also the age factor which can explain this difference; the older the species, the higher the amount of biomass.

Conclusion and suggestions

The Wamba Forest Massif made a pioneering study on the production of plant biomass in the context of a study underway. The delimitation of an equivalent area of one hectare, identification and inventory of trees and shrubs with a diameter of 10 cm dbh were the subject of measurement of biomass, specific richness, basal area, carbon and carbon equivalent have been analyze. The results give a quantified value from which we can deduce a relatively high production, thereby demonstrating the interest of conserving the forest area threatened by increasing human pressure, and of foreseeing the possibility of creating a protected area for guarantee the sustainability of this massif.

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Appendices

Table 1 Floristic composition of the forest massif studied

Familles	**Espèces**
Anacardiaceae	*Antrocaryon nannanii* De wild. *Pseudospondias microcarpa* (A.Rich.)Engl.
Annonaceae	*Greenwayodendron swaviolens* *Anodium mannii* (Oliv.) Engl.et Diel. *Xylopia* aethiopica (Dunal)A. Rich. *Uvariospis congensis* Robyns et Ghesq *Annickia affinis* (Exell) Versteeg et Sosef
Asparagaceae/Dracenoideae	*Draceana mannii* Bak.
Bignoniaceae	*Kigella africana* (Lam.) Benth
Bombacaceae	*Cieba pentadra*(L)Gaertn.
Burseraceae	*Canarium schweinfurthii* Engl. *Dacryodes edulis* (G. Don) H.J Lam.
Cannabaceae	*Trema orientalis* (L) Blume
Combretaceae	*Terminalia superba* Engl.et Diels
Clusiaceae	*Garcinia kola* Hecke *Mammea africana* Sabine
Chrysobalanaceae	*Parinari excelsa* Sabine.
Dichapetalaceae	*Dichapetalum germainii* Hauman
Euphorbiaceae	*Alchornea cordifolia* (Schum. Et Thonn.) *Macaranga spinosa* Mull. Arg. *Maesobotrya floribunda* Benth
Fabaceae/Faboideae	*Millettia laurentii* De Wild. *Millettia versicolor* Welw. ex Baker
Fabaceae/Mimosoideae	*Albizia adianthifolia* (Schumach.) W. Wight *Pentaclethra eetveldeana* De Wild. *Pentaclethra macrophylla* Benth. *Tetrapleura tetraptera* (Schumach.et Thonn.) Taub. *Piptadeniastrum africanum* (sHook.f.) Brenan.
Fabaceae/Caesalpinioideae	*Amphimas ferrugineus*Pierre ex Pellegr. *Cassia angolensis* Welw.ex Hiern. *Julbernadia seretii* (De Wild.) *Paramacrolobium coeruleum* (Taub) *Prioria oxyphylla* (Harms) Breteler *Prioriabalsamifera* (Vermoesen) Breteler *Scorodophleus zenkeri* Harms *Tessmannia africana.* Harms
Flacourtiaceae	*Homalium africanum*(Hook.f.) Benth.
Hypéricaceae	*Harungana madagascariensis* Lam. Ex Poir
Irvingiaceae	*Irvingia gabonensis* (Aubry-LeComte ex O'Rorke) Baill. *Khainedoxa gabonensis* Peirre ex Engl.K.
Malvaceae/Sterculiaceae	*Cola acuminata* (P. Beauv.) Schott et Endl. *Pterygota bequaertii* De Wild. *Pterygota macrocarpa* K. Schum. *Sterculia bequaertii* De Wild.
Moraceae	*Milicia exelsa* (Welw.) C.C. Berg *Ficus mucuso* Welw.
Myristigaceae	*Pycanthus angolensis* (Welw.) Warb. *Staudtia kamerounensis* Warb.
Lecythidaceae	*Petersianthus macrocarpus* (P.Beauv.)Liben
Meliaceae	*Entandrophragma candollei* Harms E*ntandrophragma cylindricum* (Sprague)Sprague *Lovoa trichilioides* Harms.
Rubiaceae	*Mitragyna stipumosa* (K. Krause) Verdc.

	Gardenia imperialis K. Schum. *Nauclea didevrichii* (De Wild et T.Durand)Merr. *Pausinystalia johimbe* (K. Schum) Pierre *Psydrax palma* (K. Schun.)
Rubiaceae	*Zanthoxylum gilletii*(Aubrev. Et Pellegr.) P.G.Waterman
Olacaceae	*Olax subscorpioides* Oliv. *Olax wildemanii* Engl. *Ongokea gore* (Hua) Pierre
Salicaceae	*Paropsia guineensis* Oliv. *Oncoba welwitschii* Oliv.
Sapotaceae	*Chrysophyllum lacourtianum* De Wild.
Sapindaceae	*Allophylus africanus* P. Beauv. *Allophyslus lastourvellensis Pellegr.*
Simaroubaceae	*Hannoa klaineana* Pierre et Engl.
Ulmaceae	*Celtis gomphophylla* DeWild.
Urticaceae	*Musanga cecropioides* R.Br. *Myrianthus arboreus* P. Beauv.
Palmeae	*Elaeis guineensis* Jacq.
Passifloraceae	*Barteria fistulosa* Mast.
Phyllanthaceae	*Hymenocardia ulmoides* Oliv.

Table 2 Above-ground biomass (AGB), Carbon stock (C) and carbon equivalent at species level

Espèces	**Fayolle et *al.*, 2013**			**Djomo et *al.*, 2010**		
	AGB (t/ha)	**C (t/ha)**	**Eq C (t/ha)**	**AGB (t/ha)**	**C (t/ha)**	**Eq C (t/ha)**
Antrocaryon nannanii	98,07	46,09	169,02	62,76	29,50	108,17
Ficus mucuso	78,90	37,08	135,98	43,85	20,61	75,57
Entandrophragma candollei	49,13	23,09	84,67	27,40	12,88	47,22
Petersianthus macrocarpus	34,31	16,13	59,13	24,38	11,46	42,02
Ongokea gore	29,07	13,66	50,10	18,49	8,69	31,86
Pentclethra eetveldeana	19,09	8,97	32,90	11,38	5,35	19,61
Piptadeniastrum africanum	16,47	7,74	28,38	10,13	4,76	17,46
Staudtia kamerunensis	14,20	6,68	24,48	9,93	4,67	17,11
Lovoa trichilioides	10,49	4,93	18,07	6,64	3,12	11,44
Griffonia sp	8,79	4,13	15,14	5,12	2,41	8,83
Mitragyna stipulosa	7,67	3,60	13,21	5,04	2,37	8,69
Scordophleus zenkeri	7,24	3,40	12,47	4,75	2,23	8,19
Albizia adiaantifolia	5,86	2,75	10,09	3,88	1,82	6,69
Milletia laurentii	4,34	2,04	7,49	3,07	1,44	5,29
Canarium schweinfurthii	3,95	1,86	6,81	2,88	1,35	4,96
Prioria oxyphylla	2,98	1,40	5,13	2,22	1,04	3,82
Pentaclethra macrophylla	2,18	1,02	3,75	1,68	0,79	2,89
Funtumia africana	1,79	0,84	3,08	1,37	0,64	2,36

Celtis gomphophylla	1,71	0,81	2,95	1,15	0,54	1,98
Allophyllus africana	1,65	0,78	2,85	1,22	0,57	2,10
Terminalia superba	1,61	0,76	2,78	1,17	0,55	2,02
Pterygota bequaertii	1,50	0,71	2,59	1,09	0,51	1,88
Hannoa klaineana	1,49	0,70	2,57	1,12	0,53	1,93
Pterygota macrocarpa	1,39	0,65	2,39	0,99	0,46	1,70
Treculia africana	1,37	0,64	2,36	1,07	0,50	1,85
Alchornea cordifolia	1,29	0,61	2,23	0,88	0,41	1,51
Harungana madagascariensis	1,25	0,59	2,15	0,93	0,44	1,60
Pseudospondias microcarpa	1,20	0,57	2,08	0,91	0,43	1,56
Celtis tessmannii	1,06	0,50	1,83	0,73	0,34	1,26
Barteria fistulosa	1,01	0,48	1,75	0,78	0,37	1,35
Julbernadia seretii	1,00	0,47	1,73	0,73	0,34	1,26
Mammea africana	0,94	0,44	1,61	0,70	0,33	1,21
Macaranga spinosa	0,82	0,39	1,42	0,61	0,29	1,05
Spathodea campanulata	0,74	0,35	1,28	0,57	0,27	0,98
Tetrapleura tetraptera	0,73	0,34	1,26	0,58	0,27	1,00
Musanga cecropioides	0,72	0,34	1,24	0,54	0,26	0,94
Olax wildemanii	0,67	0,31	1,15	0,52	0,24	0,89
Hymenocardia ulmoides	0,64	0,30	1,11	0,51	0,24	0,88
Xylopia aethiopica	0,64	0,30	1,10	0,50	0,23	0,85
Autres espèces	15,33	7,21	26,43	12,19	5,73	21,01
Total	**433,28**	**203,64**	**746,76**	**274,46**	**128,99**	**473,02**