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Can the Mangombe forest plantation contribute to restore and conserve biodiversity?

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ABSTRACT

This research, conducted in the tropical rainforest, is focused on restoration of tree diversity through natural regeneration mechanism in the 49 year-old Mangombe forest plantation. 12 plots were surveyed, 6 with large transects and the 6 others under regrowth. In each plot, two subplots with 400 m² each were demarcated for the inventory of all stems with diameter greater than 2.5 cm. A total of 2239 stems comprising 107 species distributed in 93 genera and 42 families were identified over 9600 m². There was a slight difference between species richness of plots with large transect (79 species, 72 genera and 35 families) and regrowth plots (85 species, 76 genera and 38 families) while the basal area in the plots with large transects (10.76 m²/ha) was significantly greater than that of regrowth (8.65 m²/ha). Species with high important value index have an affinity with forest undergrowth such as: *Tabernaemontana pachysiphon, T. crassa, Mallotus oppositifolius* and *Heinsia crinita*. The undergrowth is diversified with different life feature and a high number of small size trees indicating a vigorous regeneration. This can be favoured by: microclimate undergrowth, canopy gaps, abundance of litter fall that brings humus to the soil, type and age of plots, planted species and the complexity of spatial and vertical structure of the stand.

Keywords: Mangombé – Cameroon, Natural regeneration, dense humid forest, tree plantation, biodiversity.

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INTRODUCTION

In tropical rainforest, many research works have been developed on forest dynamics; this helped in improving the ecological knowledge on silvigenesis processes in the primary forest. This issue has been very little addressed in forest plantations where contradictory debates exist on the potential impact of forest stands on biodiversity (Brockerhoff et al., 2008; Quine et al., 2010). While some authors like Makino et al. (2007) and Barlow et al. (2007) indicate that tree plantations degrade and disturb biodiversity, others believe that plantations can contribute to the restoration and conservation of biodiversity (Cusack et al., 2004; Arrieta et al., 2006). Given that forest fragmentation affects the composition and dynamics of natural regeneration, the study of the diversity of undergrowth can help to understand the changes that occur in this environment after fragmentation (Xiao et al., 2010). What is the situation in Mangombe's forest plantation 49 years later? Can the mechanisms of regeneration reconstitute the biodiversity in this tree plantation?

MATERIALS AND METHODS

Study area

Mangombe's forest plantation (latitude 03°52 North and longitude 10°09 East) is located at 16 km in the north east of the nearest town of Edea and at about 40 km in the north east of the Atlantic ocean (Figure 1). At the origin, this ecosystem was an unlogged lowland forest growing under a sub-equatorial to tropical humid climate rich with *Lophira alata* Banks ex P. Gaertn (*Ochnaceae*), Azobé; *Sacoglottis gabonensis* (Baill.) Urb. (*Humiriaceae*), Bidou; *Cynometra hankei* Harms (Fabaceae), Nkokam; and *Coula edulis* Baill. (*Olacaceae*), Ewome (Letouzey, 1968, 1985). The forest had been submitted to a selective cut before installation of plantations in 1964. The topography ranges from undulating to rolling in the lowland area, altitude varies from 10 m above sea level in the eastern side to 40 m in the western part. The areas chosen for installation of the forest plantation are generally flat. The average annual rainfall is estimated at 2600 mm/year distributed within the 12 months with a short dry season in July. The average annual temperature is about 25 °C, with a little variation between the rainy and the dry season. The hydrography shows one river name Mangombe which represents the natural boundary at the northern part of the site. Mangombe's plantation is situated on a sedimentary shield of Pleistocene to upper cretaceous. Three main types of soils can be distinguished: i) Brown to yellowish soils, very clayey deep leached without coarse elements on the plateau; They cover 64% of the station and are the only ones used for the establishment of forest plantations; ii) Gravelly soils with lateritic gravel or quartz, covering 26% of the surface of the station; iii) Hydromorphic soils, often gravelly extending over 10% of the station (CTFT, 1969).

Sampling and measurements

A total of 12 plots have been surveyed in which 6 are being planted with large transects and the other with the regrowth method (Table 1). Tree distribution was analyzed using forest inventory data from 24; 400 m² forest inventory subplots covering about 9600 m^2. Two subplots were installed in each of the plots and all the trees with diameter greater than 2.5 cm were identified and their circumference measured at 1.30 m above the ground surface or at the level of the collar from shrubs, then the diameter at breast height was calculated from the circumference measured (1). The level of measurement was marked on the tree trunks using red paint. During the survey, samples of recorded species were collected for the confirmation and identification at the National Herbarium of Cameroon.

Data analysis

From the data collected, many parameters were estimated:

Descriptors of structural features

The parameters used to analyze the structural features are the stand density which represent the number of individuals per hectare, the mean diameter (Dbh_m) computed as the sum of diameter divided by the number of trees and the basal area (Ba) which is the total cross-sectional area of each tree at the height of measurement (m²/ha) (2).

(1) $C = \pi \, Dbh$ $Dbh = C / \pi$ with C: circumference in cm and Dbh (cm)

(2) $Dbh_m = \Sigma \, Dbh_i / N$, where Dbh_i: diameter of a tree and N: total number of tree.

$$Ba = \frac{\pi}{4}\sum_{i=1}^{n} Dbh_i^2 = \frac{1}{4\pi}\sum_{i=1}^{n} C_i^2$$

- ***Descriptors of floristic feature***

Many vegetation indexes were used to describe the floristic traits such as: the specific, generic and family richness which are the number of species, genera and families censured. The abundance of taxa is expressed as number of trees in the taxa, the importance value index (IVI) shows the most important taxa and it is the sum of the relative abundance and relative basal area (3). Shannon index (H') (1949) *in* Legendre and Legendre (1984) indicates the floristic richness of an area (4). In the formula, N_i/N is the relative frequencies of stems of species « i », N_i is the population of species i and N is the total number of stems. A high value of Shannon index indicates a rich community constituted by diverse species with almost equal frequencies (Frontier and Pichod-Viale, 1993; Senterre, 2005).

(3) $$IVI = \left(\sum_{i=1}^{n} \frac{Ni}{N} + \sum_{i=1}^{n} \frac{Bai}{Ba}\right) x\ 100$$

(4) $$H' = -\sum_{i=1}^{n} \frac{Ni}{N} \log_2 \frac{Ni}{N}$$

Descriptors of functional feature

In the framework of study of the dynamics of vegetation, the knowledge of floristic parameters and species biology provide additional information to that obtained from the analysis of structural parameters. Features are referred to as qualitative or quantitative characteristics measurable on trees; they can be divided into several modalities which are the different values of a feature. The features characterize species and reflect their response to environmental disturbances (Vile, 2005; Palla, 2011).

Four features were chosen with eighteen modalities for the analysis of the 107 censured species:

The biological spectrum was used to appreciate the health status of a forest. When work out at periodic intervals, biological spectrum may set the guidelines for eco-restoration and optimization of a community. Woody species were classified into three groups according to their height: Megaphanerophyte (Mgph), Mesophanerophyte (Msph) and Microphanerophyte (Mcph) (Tripti et al., 2011);

- Seeds dispersal. The plants have limited mobility. Consequently, they need dispersal vectors to transport their seeds away from the mother plant. Mostly, the patterns of seed dispersal are determined by the dispersal mechanism which has important implications on the structure of plant populations. It exists a variety of dispersal vectors: Pogonochory (Pog), Sclerochory (Scl), Pterochory (Pte), Balochory (Bal) and sarcochory (sar);

- Temperament of a given species can be defined as the series of development and growth responses to environmental conditions over the life cycle. Species temperament can be accessed as the trajectory of trees in the two dimensional plan of the radiative level of the environment versus the life stage. For example, pioneer species whose temperament is well known always appear in highly radiative environment such as forest gap or boundary at all life stages (Flores et al., 2006). According to their temperament to light, we have three main groups: shade intolerant species or pioneer (Pi), shade tolerant species (Sts), longest-lived late successional species (Lss)] and;

- Phytogeographic distribution: Down Atlantic Guinea (DAG), Pluri-regional african forest (PRA), Down Guinea (DG), Not attribute (Na), Guinea (G) (Hight G + Down G), TA: tropical African forest (At), Guinea-Congolese (GC)]. These informations were found in a botanical survey carried out in African tropical forest (Letouzey, 1969; 1970; Letouzey et al., 1970; Doucet, 2003; Tchouto, 2004; Palla, 2011; Momo, 2011).

The data collected were encoded and analyzed with Microsoft EXCEL®, and the software R, ADE-4 version 2.14.0.

RESULTS

Specific richness of the undergrowth in trees plantation

A number of 2239 trees constituted of 107 species divided into 42 woody families and 93 genera have been censured in the plots. The Shannon diversity index is estimated at 4.97. The richness of woody species in the plots with large transect were 1147 stems, 79 species, 72 genera and 35 families while plots in regrowth have 1092 stems, 85 species, 76 genera and 38 families. Table 2 summarises the biological parameters of the plots. In general, few large transect plots and all those in regrowth except *P. caribea* are quite diverse with a Shannon diversity index greater than 4. The densest plots in respect of large transects are *P. angolensis, A. klaineana* 1 and 2 and among the regrowth were *D. alatus* and *A. cunninghamii*.

Floristic composition of the plots

In all plots, *Fabaceae* (11 species), *Euphorbiaceae* (10), *Annonaceae* (9) and *Rubiaceae* (9) are the most abundant families. The most represented genera are *Diospyros* (6 species), *Anisophyllea, Beilschemedia, Berlinia, Cola, Drypetes, Garcinia, Maesobotrya, Strombosia* and *Tabernaemontana* with two species each.

In plots with large transects, the important families with high value of IVI are *Fabaceae*, *Apocynaceae* and *Euphorbiaceae,* while in the regrowth we have in decreasing order *Apocynaceae*, *Rubiaceae* and *Fabaceae*. Among the important species we have, *T. Pachysiphon* Stapf, *Polyalthia suaveolens* Engl. & Diels, *Mallotus oppositifolius* (Geiseler) Mull. Arg. and *Rinorea dentate* (P. Beauv.) Kuntze which appear in different order (Table 3). The basal area in plots with large transects (10.76 m²/ha) is significantly higher ($F2, 161 = 3.19$, $P < 0.05$) than that in regrowth (8.65 m²/ ha).

Grouping of plots based on biological parameters

Figure 2 shows the 12 plots and their classifications based on three biological parameters (density; number of species and mean diameter).The plot of *Pinus caribea* was considered in the development of the Hierarchical Ascendant Classification (HAC) despite the poor regeneration in the undergrowth. The HAC shows three groups with a partial effect of sylvicultural techniques. Within group 1 and 3, we can notice the individualisation of some plots, such as *P. caribea* which present a poor richness and density in the undergrowth. Some plots with large transect are grouped with those in regrowth except in group 2 which is constituted by plots with approximately an equal mean diameter.

Life feature of species

Biological spectrum

Analysis of a biological spectrum indicates that the megaphanerophytes (MgPh) (trees over 30 m of height) are poorly represented in all plots. The proportion of mesophanerophytes (MsPh) is important in all types of plot; their abundance is estimated at 71% in large transects plots and 47% in regrowth. The microphanerophytes (Mcph) are more represented in regrowth plots (37%) (Figure 3a).

Seed dispersal

The most abundant group of species corresponds to sarcochory (Sar), their value vary from 55% in the regrowth to 72% in the large transect plots. In the second rang, the sclerochory group (Scl) are estimated at 12% in regrowth and 6% in large transect. This group is followed by the ballochory (Bal). Pogonochory (Pog) and pterochory (Pte) are poorly represented. The above information indicates that zoochory is the most important mode of dispersion among the censured species, then comes the anemochory (Figure 3b).

Phytogeographical distribution of species

The Guinean-Congolese taxa (GC) represent more than 67% of the different types of plots (Figure 3c). This forest regeneration also contains between 6 and 12% of species endemic to Guinea (G) and less than 11% of species endemic to tropical African forest block (At). Other forest types have a very low contribution such as Down Guinea (3%) and Pluri-Regional African forest (PRA) (2%).

Temperament of species to light

The proportion of shade tolerant species (Sts) are more important in large transect plots (65%), where as pioneer species (Pi) are more represented in regrowth plots (25%). Regarding longest-lived late succession species (Lss), they were almost in equal proportions in large transect plots (23%) and in those in regrowth (25%) (Figure 3d).

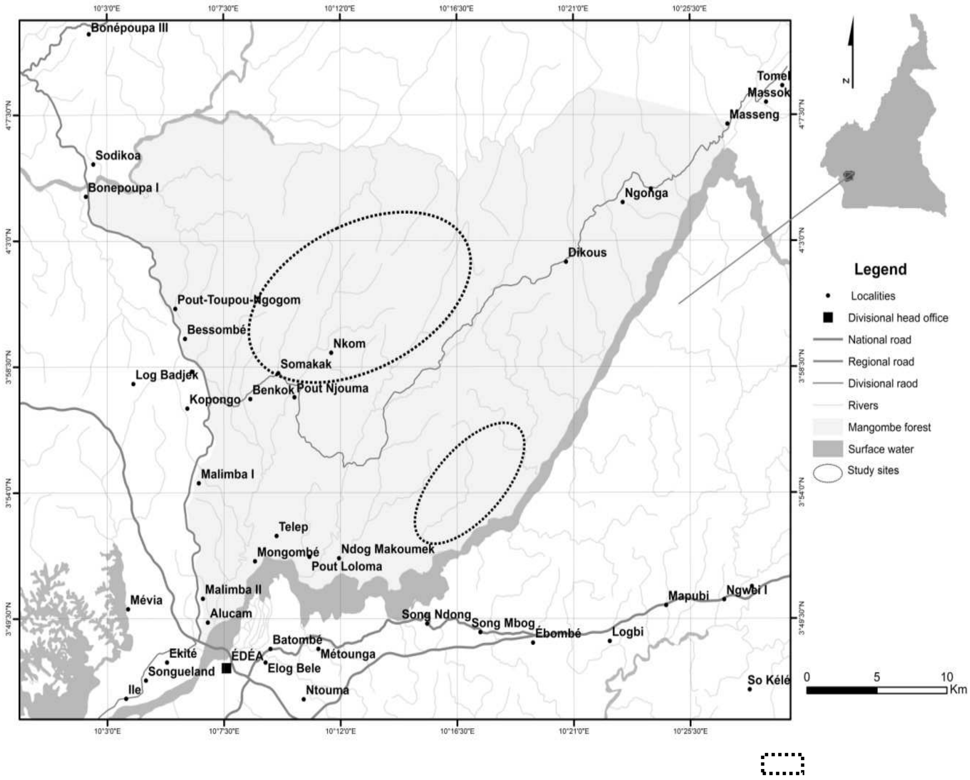


Figure 1: Geographic situation of the tree plantation in Mangombe's forest station.

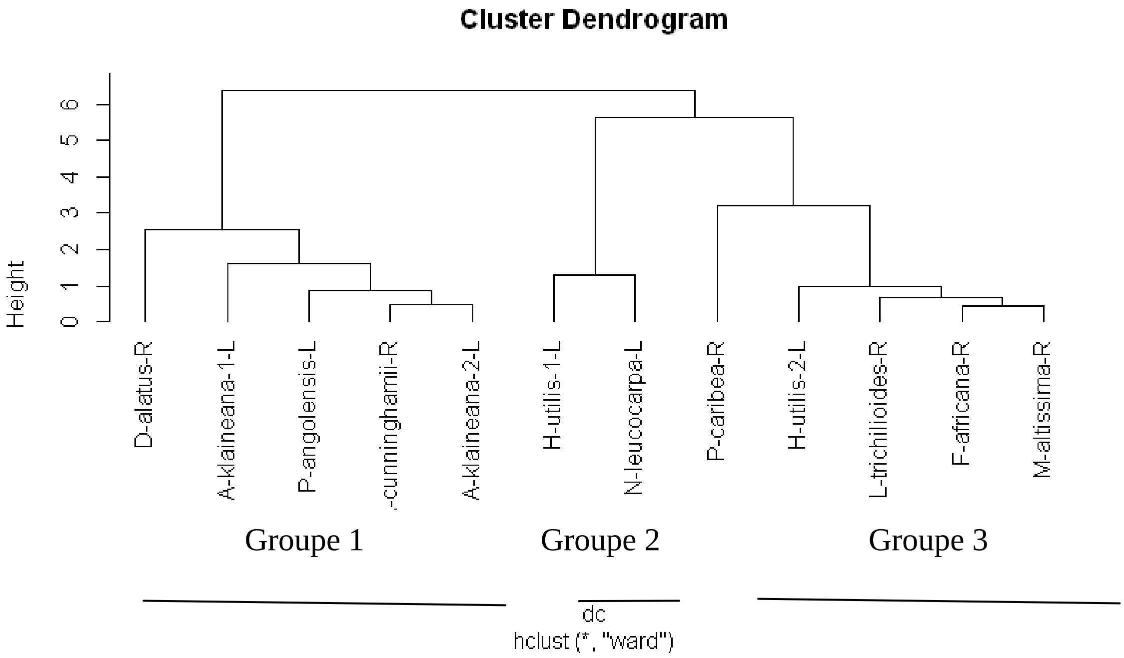
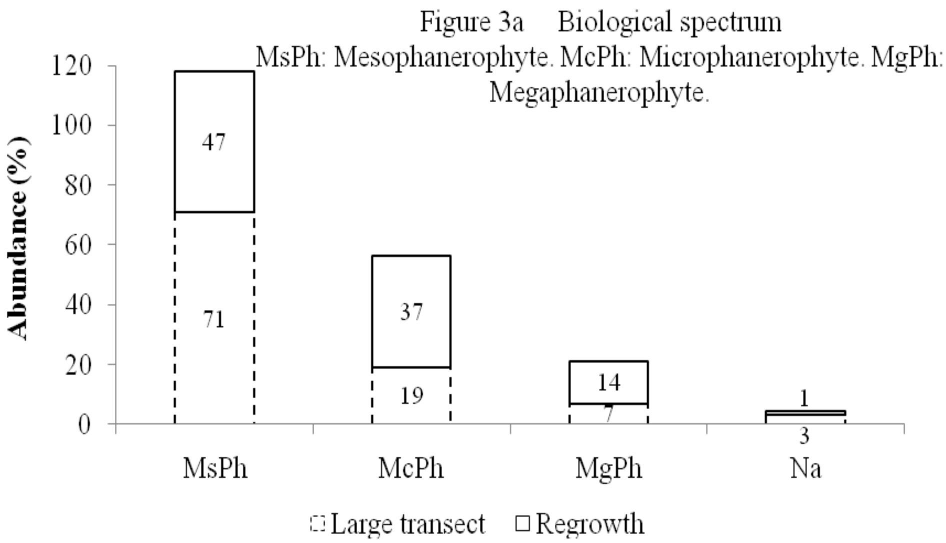


Figure 2: CAH of the analysis of 12 plots of Mangombe forest plantation based on three biological parameters (density, Number of species, mean diameter). *D. alatus* – R: Plot of *D. alatus*, planted at the Regrowth method, *A. klaineana*-1-L: Plot of A. klaineana, number one, planted at the Large transect method



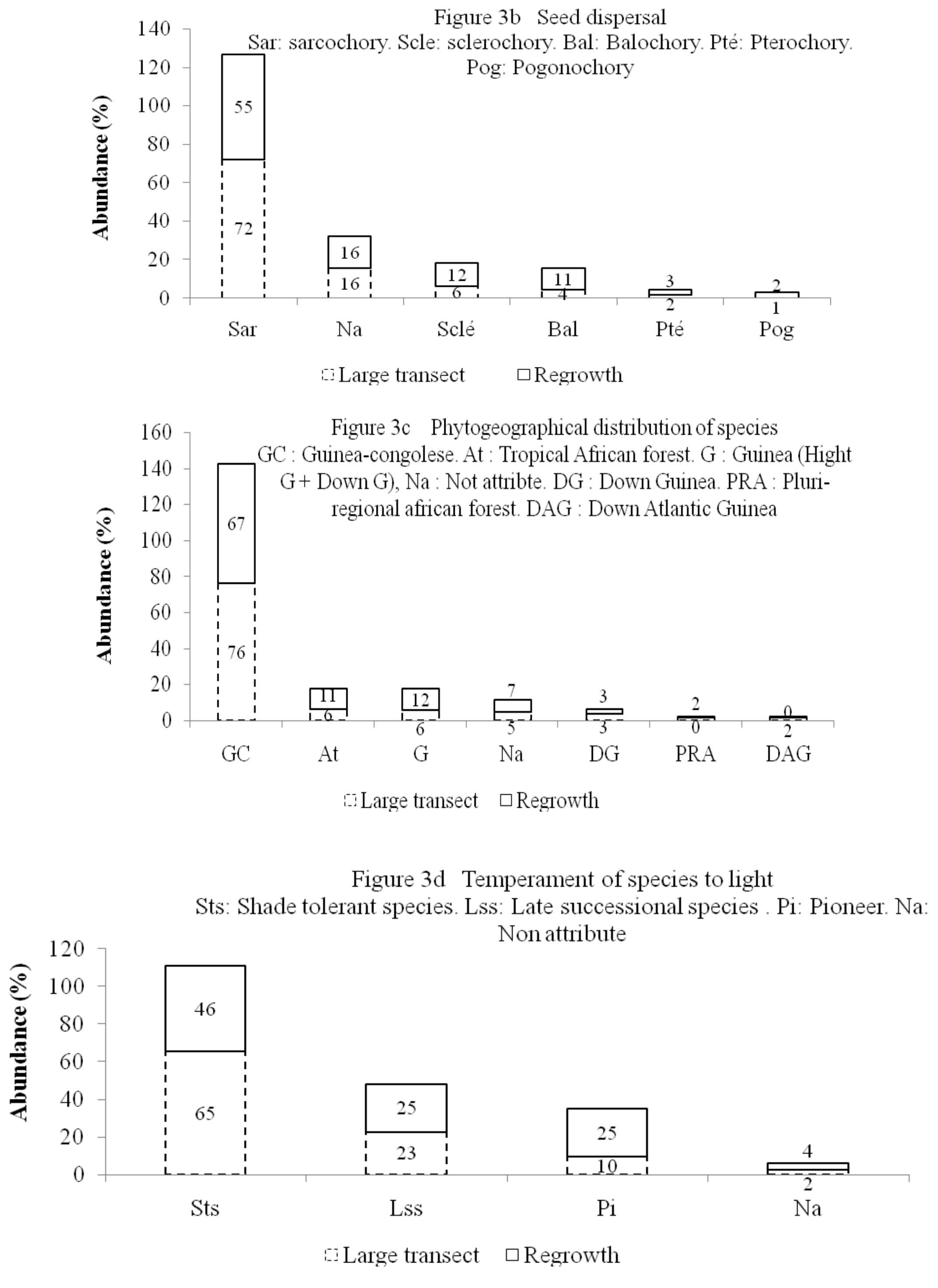


Figure 3: Live story of woody species censured in plots with large transect and regrowth within Mangombe's forest station.

Table 1: Characteristics of the studied plantations in Mangombe's forest station.

Silvicultural Technic	Plots	Common name	Family	Year of plantation	Density (stems/ha)
Large transects	*Aucoumea klaineana Pierre*-1	Okoume	Burseraceae	1965	500
	Aucoumea klaineana Pierre-2	Okoume	Burseraceae	1965	400
	Heritieraútilis (Sprague) Sprague-1	Niangon	Sterculiaceae	1966	400
	Heritieraútilis (Sprague) Sprague-2	Niangon	Sterculiaceae	1966	500
	Newtonia leucocarpa (Harms) G.C.C. Gilbert & Boutique	Newtonia	Fabaceae	1967	500
	Pycnanthus angolensis (Welw.) Warb	Ilomba	Myristicaceae	1971	500
Regrowth	*Araucaria cunninghamii Aiton ex D.Don*	Araucaria	Araucariaceae	1974	1111
	Dipterocarpus alatus Roxb. ex G. Don.	Dipterocarpus	Dipterocarpaceae	1972	625
	Funtumia africana (Benth.) Stapf	Funtumia	Apocynaceae	1986	1111
	Lovoa trichilioïdes Harms	Bibolo	Meliaceae	1987	625
	Mansonia altissima (A.Chev.) A.Chev.	Bete	Sterculiaceae	1989	1666
	Pinus caribaea var hondurensis (Sénéclauze) W. H. Barrett & Golfari	Pin	Pinaceae	1973	1111

A. klaineana Pierre-1: plantation number one of *A. klaineana*. *A. klaineana Pierre*-2 : plantation number two of *A. klaineana*

Table 2: Biological parameters characterising Mangombe's forest plantations.

Silvicultural technic	Plots	N	$N_{species}$	N_{genera}	N_{family}	H'
Large transects	*A. klaineana*-1	214	52	47	27	4.66
	A. Klaineana-2	216	42	37	22	3.82
	H. utilis-1	132	30	28	20	3.26
	H. utilis-2	168	31	27	18	3.06
Regrowth	*N. leucocarpa*	181	39	36	22	4.22
	P. angolensis	236	45	41	26	4.33
	A.cunninghamii	214	37	36	21	4.09
	D. alatus	335	49	45	27	4.31
	F. africana	144	36	33	18	4.46
	L. trichilioïdes	154	42	40	25	4.61
	M. altissima	166	37	32	19	4.18
	P. caribea	79	20	20	13	3.00

(N: number of trees, $N_{species}$: species richness, N_{genera}: Genera richness, N_{fa}: Family richness, H': Shannon Index)

Table 3: Biological parameters of the nine most important families (a) and species (b) in the different types of plots.

3a) Families

Large transect				Regrowth			
Families	**N**	**G**	**IVI**	**Families**	**N**	**G**	**IVI**
Fabaceae	446	8	75	*Apocynaceae*	253	2	51
Apocynaceae	413	7	69	*Rubiaceae*	170	1	31
Euphorbiaceae	162	4	31	*Fabaceae*	128	1	24
Annonaceae	115	2	21	*Euphorbiaceae*	145	1	24
Ebenaceae	64	2	14	*Annonaceae*	71	1	13
Rubiaceae	56	1	9	*Violaceae*	83	1	14
Olacaceae	28	1	6	*Ebenaceae*	32	1	9
Violaceae	40	1	6	*Meliaceae*	20	0	4
Myristicaceae	38	1	6	*Olacaceae*	34	0	5

(N: number of trees, G: basal area, IVI: important value index)

3b) Species

Large transect				Regrowth			
Species	**N**	**G**	**IVI**	**Species**	**N**	**G**	**IVI**
T. pachysiphon	350	3	59	*T. pachysiphon*	177	2	36
Polyalthia suaveolens	96	1	15	*Cynometra hankei*	84	1	16
Mallotus oppositifolius	66	1	15	*Mallotus oppositifolius*	92	1	16
Dichostemma glaucescens	61	1	10	*Rinorea dentata*	83	1	14
T. crassa	46	0	8	*Heinsia crinita*	91	0	13
Rinorea dentata	40	0	6	*Brenania brieyi*	43	0	9
Julbernardia seretii	31	0	6	*Rauwolfia vomitoria*	40	0	9
Diospyros simulans	31	0	6	*Polyalthia suaveolens*	48	0	8
Diospyros dendo	10	0	5	*Diospyros vermoesenii*	18	0	7

(N: number of trees, G: basal area, IVI: important value index)

DISCUSSION

The undergrowth in Mangombe forest plantations is rich and diverse (107 species, H' = 4.97). Among the species inventoried, 105 species belong to small size trees with 2.5 ≤ dbh < 10 cm and 60 species have dbh ≥ 10 cm. Trees with dbh lower than 10 cm represent 98% of the diversity. Generally, in the tropical rainforest, small trees (1.5 cm ≤ dbh <10 cm) represent approximately 80% of species diversity. This species richness is higher than that of large trees (dbh ≥ 10 cm) (Tchouto et al., 2006). The natural regeneration observed in Mangombe's plantation let us agree with Peng (2003) the possibility for some plots to contribute to the restoration of biodiversity after a few decades. This confirms that forest plantations can serve as habitat to many plant species (Humphrey et al., 2000; Gauquelin 2001; Carnus et al., 2006; Marien et al., 2004; Quine et al., 2010). Changes in land use, favour the development of fast growing species. This restoration of vegetation that is dependent on the type of disturbance, the seed bank in soil, water and nutrient availability of the soil, may persist for several decades before a gradual establishment of primary forest species (Calderon-Aguilera et al., 2012). Regeneration in the under storey of pine plots is poor, this may result from the large thickness of the litter on the ground or to a phenomenon of allelopathy. Some plants synthesize tannins and phenols which are contained in the leaves or trunk and also in the soil, these chemicals are likely to prevent other species from germinating in their litter (Rice, 1979).

The natural regeneration in plots is constituted by many species which shows different response to light such as pioneer species generally met in canopy gap; they comprise *Macaranga hurifolia* Beille, *Mallotus oppositifolius* (Geiseler) Mull. Arg., *Heinsia crinita* (Afzel.) G. Taylor, *Rauwolfia vomitoria* Afzel, *Zanthoxylum gilletii* (De Wild) P.G. Waterman, *Alstonia boonei* de Wild, *Anthocleista sp*.; some are shade tolerant species composed by species which grow under the canopy of tree : *Tabernaemontana pachysiphon* Stapf, *T.* Stapf, *Barteria fustilosa* and longest-lived late succession species for example *Cynometra hankei* Harms is normally encountered in old forest. These observations confirmed that, the species said of old forest are able to appear in the initial stages of succession (Franklin et al., 2007). The shade-tolerant species that are installed after the canopy closure have a slow growing; they are more abundant in old forests than in secondary forests (Chazdon et al., 2010). We also have evidence that, the secondary forest marks the starting point for the regeneration of the original biodiversity (Zapfack et al., 2002). The most important families: *Fabaceae, Euphorbiaceae, Annonaceae, Rubiaceae* are common to tropical forests (Xiao et al., 2010).

Natural regeneration in forest plantation is poor in large trees (height > 30 m) while the trees of the average storey (mesophanerophytes) and shrubs (microphanerophytes less than 8 m in height) are better represented. The richness and vegetation composition in large transects plots (80 species, 10% of pioneer species, 71% of shade tolerant species and 23% of longest-lived late successional species) differ from those of regrowth (86 species, 25% pioneer species, 46% of shade tolerant species and 25% longest-lived late successional species). These important differences between the type of plots may be due to several factors including the age of the plots, the planted species, level of disturbances, the spatial and vertical heterogeneity related to tree size, site preparation, physical barriers due to litter fall (such as those of pine) that can prevent seed germination and the canopy of tall trees which considerably limits the light that reaches the undergrowth (Kasenene, 2007) and the temporal evolution and internal dynamics occurring in each plot.

In general, after a disturbance, species can present different responses depending on the level of disturbance, the environmental factors and their capacity to adapt in the new milieu. Thus, the vegetation that settles after a disturbance does not necessarily have a composition close to that of the pre-existing milieu (Lindenmayer et al., 2008). Leah et al. (2010) observed that biodiversity settles more favourably in the plantations of native species located on degraded lands as compared to plantations of exotic species created after clearing of natural forest. This author considers the loss of species richness as a result of land use change: savannah - forest (-35% ± 7%), old growth forest - plantation (-35% ± 6%) and a significant gain in the transition secondary forest - plantation (35% ± 8%).

The basal areas are low, particularly in regrowth plantations, indicating a high number of small size trees and vigorous regeneration. The dynamics of regeneration presents heterogeneous structure that can be assimilated to a mosaïc of stems which form small units which differ in their ages, the size of the stems and their floristic composition. The settlement of rural populations at the edge of plantations facilitates access to the site and recurrent harvesting. The damages on forest stand are directly related to the mode, intensity and recurrence of harvesting that can lead to disturbances and important changes in vegetation (Durrieu de Madron et al., 1998).

Conclusion

Comparing our results to other studies conducted in the rainforest may suffer from some imperfections since most plant inventories concern stems of dbh ≥ 10 cm. Nevertheless, the biodiversity inventoried in the plots is rich and diversified; it differs by its composition and structure to the surrounding natural forest. The importance of flora with different life features consolidates the possibility for natural regeneration to restore in long-term biodiversity in plots. This restoration of biodiversity would be favoured by the micro climate created in the undergrowth by the planted trees, the abundant litter which brings humus to the soil and the complexity of the spatial and vertical structure of the stand. An appropriate management may allow plantations to contribute to the restoration and conservation of biodiversity. The partial demonstration of the effect of silvicultural techniques is certainly due to many factors of disturbance including logging prior to the installation of plantation, the age, the evolution in time of plots and frequent harvesting currently observed in the site.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

JRN initiated the research project, did the data collection, data analyses and the writing of the manuscript; LZ did the correction of the research protocol and manuscript, the data collection and identification of species; NVN contributed to the data collection, identification of species and correction of the manuscript; JMO contributed to the identification of species and the correction of the manuscript; DO contributed to the data collection, identification of species, correction of the manuscript; JLB did the correction of the research protocol and manuscript, the data collection, identification of species;

SG participated in the correction of the manuscript; BR contributed to the correction of the research proposal, methodology and manuscript, the data collection and the identification of species.

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REFERENCES

Arrieta S, Suarez F. 2006 Scots pine (*Pinus sylvestris* L.) plantations contribute to the regeneration of holly (*Ilex aquifolium* L.) in mediterranean central Spain. *Eur J Forest Res.*, **125**: 271–279.

Barlow J, Gardner TA, Araujo IS, Avila-Pires TC, Bonaldo AB, Costa JE, Esposito M C, Ferreira LV, Hawes J, Hernandez M, Hoogmoed MS, Leite RN, Lo-Man-Hung NF, Malcolm JR, Martins MB, Mestre L, Miranda SR, Nunes GAL, Overal WL, Parry L, Peters SL, Ribeiro JMA, Da Silva MNF, Da Silva Motta C, Peres CA. 2007. Quantifying the biodiversity value of tropical primary, secondary, and plantation forests. *Proc Natl Acad Sci*-USA, **104**: 18555–18560.

Brockerhoff EG, Jactel H, Parrotta JA, Quine CP, Sayer J. 2008. Plantation forests and biodiversity : oxymoron or opportunity? *Biodiv. Conserv,* **17**: 925 – 951.

Carnus JM, Parrotta J, Brockerhoff EG, Arbez M, Jactel H, Kremer A, Lamb D, O'Hara K, Walters B 2006. Planted forests and biodiversity. *J For,* **104**(2): 65–77.

Calderon-Aguilera LE, Rivera-Monroy VH, Porter-Bolland L, Martinez-Yrizar A, Ladah LB, Martinez-Ramos M, Alcocer J, Santiago-Pérez AL, Hernandez-Arana HA, Reyes-Gomez VM, Pérez-Salicrup DR, Diaz-Nunez V, Sosa-Ramirez J, Herrera-Silveira J, Burquez A. 2012. An assessment of natural and human disturbance effects on Mexican ecosystems: current trends and research gaps. *Biodiv. Conserv*, **21**: 589–617.

Chazdon RL, Finegan B, Capers RS, Salgado-Negret B, Casanoves F, Boukili V, Norden N. 2010. Composition and Dynamics of Functional Groups of Trees During Tropical Forest Succession in Northeastern Costa Rica. *Biotropica,* **42**(1): 31–40.

Cusack D, Montagnini F. 2004. The role of native species plantations in recovery of understory woody diversity in degraded pasturelands of Costa Rica. *For Ecol Manag,* **188**: 1–15.

CTFT (Centre Technique Forestier Tropical). 1969. Plantations expérimentales dans la région de la Mangombé, étude pédologique. Rapport CTFT, Nogent sur Marne, France.

Doucet JL. 2003. L'alliance délicate de la gestion forestière et de la biodiversité dans les forêts du centre du Gabon. Thèse de doctorat, communauté française de Belgique, Faculté universitaire des sciences agronomiques de Gembloux. 323p + annexe.

Durrieu de Madron L, Forni E, Mekok M. 1998. Les techniques d'exploitation à faible impact en forêt dense humide camerounaise. CIRAD - Forêt, Montpellier France, 29p.

Flores O, Gourlet FS, Picard N. 2006. Local disturbance, forest structure and dispersal effects on sapling distribution of light demanding and shade tolerant species in a French Guianian forest. *Acta oecologica,* **29**: 141-154.

Franklin J, Rey SJ 2007. Spatial patterns of tropical forest trees in Western Polynesia suggest recruitment limitations during secondary. *J. Trop. Ecol*., **23**: 1–12.

Frontier S, Pichod-viale D. 1993. *Théorie des Ecosystèmes: Structure, Fonctionnement, Evolution. Collection d'Ecologie 21,* 2ème édn. Paris, Masson ; 287-311.

Gauquelin T. 2001. Impact d'une plantation d'eucalyptus sur la Biodiversité en région toulousaine. Rapport pour l'AFOCEL, 34p.

Humphrey JW, Newton AC, Peace AJ, Holden E. 2000. The importance of conifer plantations in northern Britain as a habitat for native fungi. *Biol. Conserv.*, **96**: 241–252.

Kasenene JM. 2007. Impact of exotic plantations and harvesting methods on the regeneration of indigenous tree species in Kibale forest, Uganda. *Afr. J. Ecol*., **45** (Suppl. 1): 41–47.

Leah LB, Kathleen AF. 2010. Does plantation forestry restore biodiversity or create green deserts? A synthesis of the effects of land-use transitions on plant species richness. *Biodiv. Conserv*., **19**: 3893–3915.

Legendre L, Legendre P. 1984. *Ecologie Numérique : le Traitement Multiple des Données Ecologiques.* Tome 1. Masson, Paris, France ; 260p.

Letouzey R. 1968. *Etude Phytogéographique du Cameroun. Encyclopédie Biologique 69.* Ed. Paul Lechevalier : Paris, France, 511p.

Letouzey R. 1969. *Manuel de Botanique Forestière, Afrique Tropicale*, Tome 1. Centre Technique Forestier Tropical, Nogent sur Marne : France ; 189p.

Letouzey R. 1970. *Manuel de Botanique Forestière, Afrique Tropicale*, Tome 2A. Centre Technique Forestier Tropical, Nogent sur Marne : France. 210p.

Letouzey R, White F. 1970. *La Flore du Cameroun. Ebenaceae, Ericaceae*. Museum National d'Histoire Naturelle : Paris ; 207p.

Letouzey R. 1972. *Manuel de Botanique forestière, Afrique Tropicale*, Tome 2B. Centre Technique Forestier Tropical, Nogent sur Marne : France ; 217 – 461p.

Letouzey R. 1985. Notice de la carte phytogéographique du Cameroun, vols. 1–5. Institut de la Carte Internationale de la Végétation, Toulouse.

Lindenmayer DB, Fischer J, Felton A, Crane M, Macgregor MD, Montague-Drake C, Manning AR, Hobbs RJ. 2008. Novel ecosystems resulting from landscape transformation create dilemmas for modern conservation practice. *Conserv Lett.*, **1**:129–135.

Makino S, Goto H, Hasegawa M, Okabe K, Tanaka H, Inoue T, Okochi I. 2007. Degradation of longicorn beetle (Coleoptera, Cerambycidae, Disteniidae) fauna caused by conversion from broad-leaved to manmade conifer stands of Cryptomeria japonica (Taxodiaceae) in central Japan. *Ecol. Res.*, **22**: 372–381.

Marien JN, Mallet B. 2004. Nouvelles perspectives pour les plantations forestières en Afrique centrale. *Bois et Forêts des Tropiques*, **282**(4). 67-79.

Momo SMC. 2009. Influence des activités anthropiques sur la végétation du mont Oku (Cameroun). Thèse de doctorat en Biologie-Santé, Faculté de Pharmacie, Université de Picardie Jules Vernes, Amiens, France, 271p.

Palla F. 2011. Caractérisation et distribution spatiale des groupements végétaux de la mosaïque forêt-savane du parc national de la Lopé (Gabon) : apport des traits caractéristiques de la végétation (traits d'histoire de vie) et des images Radar PALSAR. Thèse de doctorat de l'université Pierre et Marie Curie, 277p.

Senterre B. 2005. Recherches méthodologiques pour la typologie de la végétation et la phytogéographie des forêts denses d'Afrique tropicale. Thèse de doctorat, Université Libre de Bruxelles, Laboratoire de Botanique systématique et de Phytosociologie, 345 p. + annexes.

Torras O, Gil-Tena A, Saura S. 2011. Changes in biodiversity indicators in managed and unmanaged forests in NE Spain. *J. For. Res.*, **17**: 19 – 29.

Tripti B., Ambarish M. 2011. Biological spectrum of Bankati forest areas in Burdwan district, west Bengal. *Indian J. Sci. Res*., **2**(4): 57-60.

Peng SL. 2003. *Study and Application of Restoration Ecology in Tropical and Subtropical China*. Science Press: Beijing.

Quine CP, Humphrey JW. 2010. Plantations of exotic tree species in Britain: irrelevant for biodiversity or novel habitat for native species? *Biodiv. Conserv.*, **19**: 1503–1512.

Rice EL. 1979. Allelopathy. An update. *Bot. Rev*., **45**(1): 15 – 109.

Tchouto MPG. 2004. Plant diversity in a Central African rainforest: implications for biodiversity conservation in Cameroon. PhD thesis, department of plant sciences, Wageningen University, the Netherlands, 206p.

Tchouto MGP, De Boer WF, De Wilde J, Van der Maesen LJG. 2006. Diversity patterns in the flora of the Campo-Ma'an rain forest, Cameroon: do tree species tell it all? *Biodiv. Conserv.,* **15** : 1353–1374.

Vile D. 2005. Significations fonctionnelle et écologique des traits des espèces végétales : exemple dans une succession post culturale et généralisation. Thèse, Université de Monpellier et Université de Sherbrooke, 151p.

Xiao-Tao Lü, Jian-Wei Tang. 2010. Structure and composition of the understory treelets in a non-dipterocarp forest of tropical Asia. *Forest Ecology and Management,* **260**: 565–572.

Zapfack L, Engwald S, Sonke B, Achoundong G, Birang à Madong. 2002. The impactof land conversion on plant biodiversity in the forest zone of Cameroon. *Biodiversity and Conservation,* **11**: 2047–2061, 2002.