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Early growth stages structure and distribution of *Pericopsis elata* (Harms) van Meeuven in a logging concession of South – East Cameroon

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Abstract

Pericopsis elata (Harms) van Meeuwen is a tropical Africa's timber of high economic value. In many countries its low natural regeneration rate does not favor the replacement of harvested populations, thus CITES and IUCN recommended a total protection of the species. This survey aimed to characterize the early growth stages and natural regeneration of *P. elata* through the determination of seedlings distribution and structure. Squared plots of 2500 m² were installed around stumps and seed-bearing trees respectively in the logged and unlogged forest concessions at Ouesso, near Yokadouma, South-East Cameroon. Stumps, seed-bearing trees and seedlings were counted and their structural parameters (diameter and height) were recorded. A total of 56 plots corresponding to 14 ha were surveyed and 1069 seedlings were recorded. The rate of regeneration was 56% around stumps and 24.13% around seed-bearing trees. The spatial distribution of seedlings appears to be aggregated. Germination and seedling growth have shown that early growth stages of *Pericopsis elata* are not representing a relevant limiting factor for the evolution of population. However, the limited number of saplings and the lack of poles suggest that light could play and important role in the evolution of the early stages.

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Introduction

The loss of forest biodiversity via anthropogenic disturbance is severe in tropical countries and its consequences to ecological functions are of global concern. Selective logging is one of the main causes of tropical forest degradation (Hosaka *et al*., 2014). Issuing and enforcing strict guidelines on sustainable forest management is no guarantee for preserving species composition in tropical forests (Karsten *et al*., 2013). Logging and timber trade have largely contributed to the impoverishment of the forest biodiversity in Central and Western Africa (White, 1994; ITTO/UICN, 2009), without a detailed attention being paid to the long-term consequences of the habitat modification on the recruitment of new individuals in the logged areas (Baraloto and Forget, 2004).

The recent registration of a certain number of plant species to the appendices of the Convention on International Trade in Endangered Species of Wild fauna and flora (CITES) arouses a growing interest to reduce the incidences of the forestry production on biodiversity (ITTO/UICN, 2009). *Pericopsis elata* (Harms) van Meeuwen also called Assamela or Afrormosia, is a Fabaceae, sub-family of Faboïdeae which produces wood of very high quality. This species was recorded in the Appendix II of the above-cited Convention and on the "red list" of the IUCN as an endangered species threatened of extinction (A1cd criteria) since 1998 (CITES, 2003). Often used as the substitute of *Tectonia grandis* Linné f., its wood is highly appreciated on the international market for multiple uses.

This integral protection on an international scale marked a watershed in Cameroon for its engagement to implement a sustainable management of this species through studies in logging concessions and rehabilitation of old plantations. The data obtained on the population density, the legal steps and management and the positive impacts of ITTO-CITES project entitled "sustainable management of *Pericopsis elata* in forest concessions and rehabilitation of the old plantations in Cameroon" were the activators for changing the status of the species for which trade must be considered as "not detrimental to the survival of the species". For conservation measures and environmental care, Cameroon had adopted in the years 2000, some protection actions by fixing the Minimum Logging Diameter (MLD) to 100 cm. Since June 2010, the MLD has been dropped to 90 cm; however, this value remains higher to MLD generally used by other African countries producers of this wood (Bourlans *et al*., 2012).

Although this reduction in MLD is important for the forest industry, it does not resolve the issue of sustainability that must be based on a sylvicultural approach of the species. According to Tiscar and Linares (2011), natural regeneration should always be the first management option, amongst other reasons, because it will let natural selection act and will result in trees well adapted to the site. Potential advantages of natural regeneration include preservation of local genotypes and greater structural diversity of the resulting woodland, high seedling density as well as increased cost-effectiveness (Sparcklen *et al*., 2013).
To initiate this process, knowledge of the life cycle of the species is crucial. Recent research on the anatomical characteristics and regeneration in natural environments made in Ghana and Cameroon have increasingly relied on adult individuals to explain the spatial allocation and the distribution of tree species diameter classes (Bourlans *et al*., 2012.), while the evolution of these parameters seems to occur very early in the life of a plant (Jesel, 2005).
In undisturbed natural conditions, the diametric structure of *P. elata* follows the normal distribution indicating a low rate of regeneration (Boyemba, 2011). In this context, the control of the evolution of early growth stages appears crucial to the regeneration of the species in the wilderness especially in logging concessions.

This survey aimed to characterize the early growth stages of *P. elata* in natural environment to effectively consider its restoration in disturbed environments. The specific objectives are: (i) assess the structure of stumps and seed-bearing trees of *P. elata*; (ii) determine the structure and distribution of early growth stages of the species; and (iii) identify the other species accompanying the seedlings of *P. elata* that may influence its juvenile plant communities' evolution.

Methodology

Study site

The study was carried out in a logging concession located in Ouesso, between Yokadouma and Lomié (South East Cameroon) within the forest management unit (FMU) 10 021 covering an area of 71 533 hectares whose geographical coordinates are: 3 ° 08 ' - 3 ° 21 'N latitude and 14 ° 31' - 14 ° 52 'E longitude (Fig. 1). This area has been successively classified in the Dja Congolese district, evergreen rainforest domain (Letouzey, 1985) and the "Dja-Odzala-Minkébé" landscape (De Wachter *et al.*, 2009). This forest has suffered very little of human influence because of its isolation between the Boumba River and its tributaries. This particular localization may justify its high floristic diversity and timber species quality.

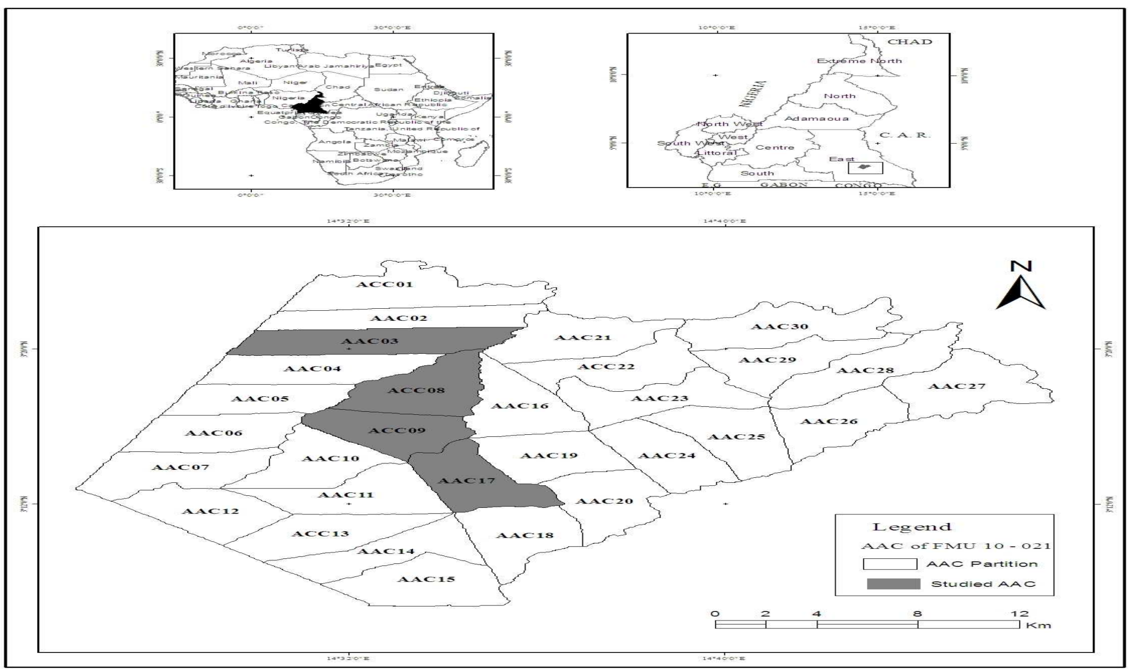

Fig. 1. Map of the Forest Management Unit 10 021: location of study area at Ouesso (70 km to Yokadouma, Cameroon).

This area is influenced by a classic equatorial climate with 4 seasons (2 rainy and 2 dry seasons) and steady temperatures (annual mean temperature in the region oscillate around 25°C with a monthly temperature range of 3.5°C). Three months (December to February) are to be considered environmentally as dry. The annual mean rainfall varied between 1550 and 2000 mm with maxima recorded in May and October. The topography is flat but punctuated by hills that peak up to 640 m above the sea level and shallow valleys with possibly enough groundwater near to the surface throughout the year in swampy areas.

Sampling and data collection

Data collection was conducted from March to April and from August to September 2009, which corresponded to the period of fruiting of *P. elata*. A FMU in Cameroon get organized around annual allowance cut (AAC), which correspond to an area where logging activities are allowed along a specific year (Fig. 1). Four AAC of different characteristics were selected for sampling:

- An AAC exploited six years ago, allowed to observe the growth of the samples at least five years after the disturbance (AAC 03);
- An AAC exploited two years ago, permitted to assess the early growth stages (AAC 08);
- An AAC under logging, favoured to track the germination and growth of first stages of regeneration during the disturbance (AAC 09);
- An untapped AAC allowed the monitoring of samples under undisturbed natural conditions (AAC 17).

In each AAC, all stumps and seed-bearing trees were identified and geo-referenced using a GPS Map 60 Cx *Garmin* brand; their structural parameters (diameter and height) were measured or estimated. Considered as a central point, the seed-bearing tree or the stump was surrounded by a squared plot of 50 m² on each side. To facilitate counting, the plot was divided into four even quadrats or sub-plots (Fig. 2). In each sub-plot, all seedlings of *P. elata* were identified, counted and recorded; each individual diameter (20 cm from the soil) and height were assessed. All seedlings with diameter greater or equal to 10 mm were labelled in order to continue observations over a long period of time. Each label indicates the number of seed-bearing tree or stump, the plot and seedlings.

Morphological observations of seedlings leaves (perforations, yellowing, burning) were also performed. Other species accompanying *P. elata* were recorded in each plot. During the above monitoring operations, no withdrawals or no human disturbance has been authorized in the study plots, even the seeds and dead shrubs were kept on site.

Data analysis

To facilitate the processing of data collected, aclassification of empirical thresholds derived from observations and measurements in the field (Din *et al.*, 2002) and the principles of classification of the seedlings by Dupuy (1998) were used in describing seedlings' development stages (Table 1). Several statistical parameters of plants were calculated including mean, variance, density and dispersion index.

The dispersion index (I) calculated on n plots can be tested using the value (n-1) × I which follows a χ^2 with significant (n-1) degree of freedom, an even dispersion when the value is less than 1, a random index equal or close to 1, in other cases aggregative (Bariteau, 1992). The detection of the spatial structures mathematically appeared relatively complex. Mapping has been used as an additional tool necessary in some cases for the interpretation of results. In this purpose, Cartesian coordinates of all seedlings were recorded. Maps and modelling in the sub-plots were performed using Arcview 3.2a software.

Results and discussion

Distribution of stumps and seed-bearing trees

A total of fifty-six individuals of which 27 stumps and 29 seed-bearing trees were recorded. It was found that there were more seed-bearing trees in one annual allowance cut than the stumps in three AAC. The number of stumps found decreases with time (Table 2). The decreasing gradient of the stumps' identification over time can be linked to the vegetation dynamics but also and especially to the lack of referenced individuals in prior years that made it difficult to identify stumps. Additionally, the number of individuals of *P. elata* whose MLD (at the period of the field work) was greater or equal to 100 cm was low. However, the relatively large number of seed-bearing trees identified in a single AAC (52%) compared to the number of stumps recorded in 3 AAC (48%) could be also explained by the value of the diameters involved in the first inventory including individuals below the MLD, but able to produce fruits and seeds that germinate normally.

Over 52% of the stumps observed were surrounded by seedlings. The rate of stumps with seedlings was higher in AAC 03 (80%), followed by AAC 08 (70%) and AAC 09 (33.33%). The average recovery was 56% for stumps and 24.13% for the seed-bearing trees. This difference in number of seedlings and regeneration rates between logged and unlogged areas can be explained by the fact that the logging of individuals of large diameters leads to the opening of canopy gaps that create the conditions for germination and seedlings growth through optimal lighting conditions and also by soil disturbance (reversal of the litter) that can favour the regeneration of plant species (Jesel, 2005, Toledo-Aceves *et al.*, 2009).

Table 1. Measurement criteria used to classify growth stages. A and C: seedlings; B, D, E and F: thickets; H and I: poles; G has no individual.

Height	Diameter (mm)		
(cm)	< 5	5 ≤ d < 10	≥ 10
< 40	A	C	G
40≤ h< 80	B	D	H
≥ 80	E	F	I

Structure and distribution of seedlings

Each stump and seed-bearing tree identified as having instituted a plot of 2500 m², the total area covered by this work is 14 ha (Table 3). Seedling density by AAC varies from 5 individuals per hectare (AAC of the year) to 368.8 individuals per hectare (AAC exploited 2 years ago). The density of seedlings per plot varies from 0 to 860 individuals per ha. The distribution of seedlings per plot and AAC shows a significant difference. This could be justified by variable delays of germination within the population of scattered seeds that characterize several forest species like *P. elata* (Vázquez-Yanes and Orozco-Segovia, 1993). Other biological factors such as seeds and seedlings predation and abundance or seed variation can also affect these parameters (Beckage *et al.*, 2005).

Table 2. Number of seed-bearing trees and stumps recorded AAC, Annual allowance cut; NI: Not in the inventory.

AAC identification	Stumps		Seed-bearing trees		Total
	With seedlings	Without seedlings	With seedlings	Without seedlings	
AAC 03	4	1	NI	NI	5
AAC 08	7	3	NI	NI	10
AAC 09	4	8	NI	NI	12
AAC 17	0	0	7	22	29
Total	15	12	7	22	56
	27		29		

Taking into account the classification criteria adopted in Table 1 above, the mean densities decrease significantly from seedlings (49.68 ± 16.50 ind/ha) to saplings (4.73 ± 4.25 ind/ha) (Fig. 3). The relatively high density of seedlings can be explained by the accumulation of young individuals over several years, a latency strategy (for shade tolerant species) before activating their development when optimal conditions are met (Toledo-Aceves *et al.*, 2009). Similar results were obtained in aggregate logging of *Dicorynia guianensis* in a Guyanese forest (Jesel, 2005). St-Denis *et al.* (2013) also pointed out that many studies have shown major differences between germination and seedlings emergence in abandoned field which is a harsh environment with wide fluctuations in temperature and moisture and often with compacted soils.

Table 3. Distribution and abundance of seedlings in the plots and AAC. The surface area of each plot is 0.25 ha. Plots without any seedling of *P. elata* (abundance = 0) have not been illustrated in the table but have been taken in account in the assessment.

AAC and surface area (ha)	Number of plots	Number of seedlings		Abundance (seedlings/ha)	
		Plots	AAC	Plots	AAC
AAC 03 (1,25 ha)	05	15	66	60	52.8
		2		8	
		46		184	
		3		12	
AAC 08 (2,5 ha)	10	168	922	672	368.8
		215		860	
		151		604	
		9		36	
		148		592	
		134		536	
		97		388	
AAC 09 (3 ha)	12	4	15	16	5
		2		8	
		8		32	
		1		4	
AAC 17 (7,25 ha)	29	4	66	16	9.10
		50		200	
		1		4	
		4		16	
		2		8	
		1		4	
		4		16	
Total	52	1069		76.36	
Mean		48.59± 16.69		27.82± 11.42	

The absence of young stems of *P. elata* with more than 20 mm in diameter suggests that the growth of individuals having germinated after the logging has not yet exceeded this threshold after 6 years. Meanwhile, in unlogged forests, high mortality of young individuals should be attributed to unfavourable lighting conditions starting from the poles structure. Canopy cover is known to offer protection against temperature extremes and excessive evapotranspiration, although drought might be increasingly harmful under shadier conditions because water absorption and light capture cannot be maximized simultaneously (Tiscar and Linares, 2011). Seedling growing in full light died more rapidly than seedlings growing under vegetation cover. Mortality could be due to several interacting factors, mainly predation and desiccation under extremes temperatures (Montes-Hernández and López-Barrera, 2013).

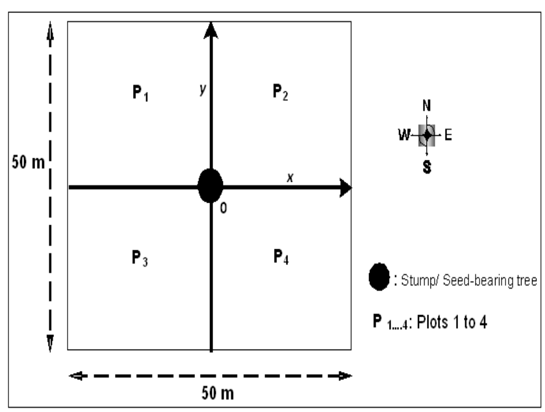

Fig. 2. Data collected system around stumps and seed-bearing trees.

The aggregated distribution of seedlings under tree producing stems and the size of plots can also justify the absence of saplings. Indeed, for some tropical species, the full development of young individuals can only be achieved if the seed germinates at a certain distance from the mother stem, usually beyond the projection of its crown on the ground (Din *et al.*, 2002).

Morphology of leaves and seedlings dispersion

Observations of individuals of *P. elata* at the seedling and adult stages revealed a leaf dimorphism also known as heterophylly (Judd *et al.*, 1999), character illustrated in plants where leaves of young individuals have a different structure compared to those of mature trees to the point that without clear indication, it is difficult to determine that type of plant at the earlier stage of development (Wilhelm and Miesch, 1998). Seedlings and thickets have simple alternate leaves; progressively as they grow, there is a gradual emergence of odd pinnate compound leaves (Figure 4). Morphological observations on leaves of seedlings have shown that 18.4% of individuals presented damaged leaves.

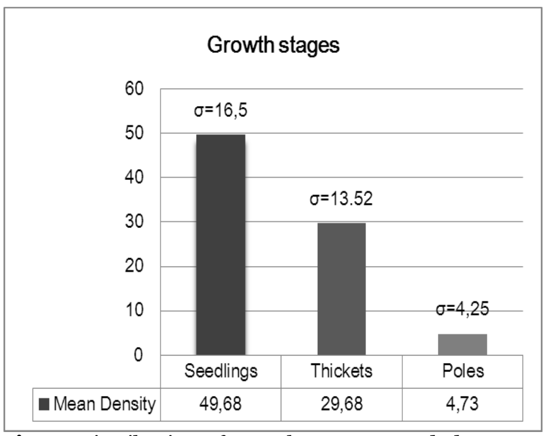

Fig. 3. Distribution of growth stages recorded.

The spatial distribution has shown that the number of seedlings varies from 1 to 215 in the plots, with an average of 48.59 ± 19.69. The distribution index (I) is 7.98 (Test index distribution, $\chi^2 = 387.89$; 21ddl, P <0.025); thus, I > 1, it can be concluded that the distribution of seedlings is aggregative. The mapping of seedlings in the plots confirmed this distribution (Fig. 5). The aggregated distribution is characterized by the dormancy of some seeds and a shade tolerance of early development stages (Baraloto and Fourget, 2004).

Fig. 4. Heterophylly recorded in juvenile plant of *Pericopsis elata*; the right branch presents simple alternate leaves while the left branch shows odd pinnate compound leaves.

Floristic inventory

In both temperate and tropical ecosystem, many endogenous factors, such as the type and density of competing vegetation, the presence or not of predation, soil type and exogenous factors, such as climatic conditions interact with seed size and shade tolerance to affect the overall success of direct seeding to restore abandon fields. Effects of vegetation on seedling emergence vary with plant litter and surrounding vegetation types. In general, grasses have more negative effects and are stronger competitors than forbs (St-Denis *et al.*, 2013).

The inventory of accompanying species has found seventy species distributed in 23 families. The Fabaceae dominates the flora with 14 species. Seven species (10%) were encountered only around stumps, 46 species (66%) only in plots of unlogged forests and 17 species (24%) were common to both environments. *Terminalia superba* Engler & Diels and *Triplochiton scleroxylon* K. Schum are the most common species. In unlogged forest, 63 species identified around the seed-bearing trees are dominated by *T. superba*, *Celtis tesmannii* Rendle, *Voacanga africana* Stapf., *Mansonia altissima* (A. Chev.) A. Chev., and *Erythrophleum suaveolens* (Guillemin & Perrolet)

Brenan. The vegetation composition shows that this factor has limited effect on *P. elata* seedling development.

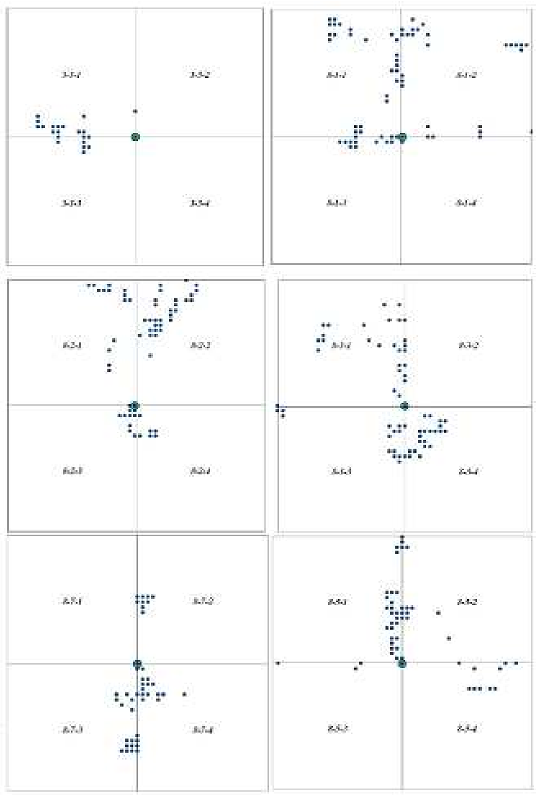

Fig. 5. Some spatial distribution models of seedling recorded in the plots.

These results confirmed the composition of the forest already described as a dense semi-deciduous forest rich in Meliaceae, Ulmaceae and Sterculiaceae families (De Wachter *et al.*, 2009). The high number of species found in unlogged forest could be explained by the fact that logging activities, by boarding, the creation of roads and tracks and the selective cutting down of species have a significant impact on residual populations, including its species richness (Hosaka *et al.*, 2014). In general, the rejuvenation of an ecosystem is always accompanied by a decrease in biodiversity (Frontier and Pichod-Viale, 1993).

Conclusion

As the majority of plant species of tropical rainforests, the growth of *P. elata* depends closely on openings in the canopy. Regeneration rate and seedling density in exploited annual allowance cut are greater than those obtained in the unlogged forest. The uneven distribution of seedlings and bushes assumes the existence of varying germination delays, probably due to the type of fruit disseminated and/or to certain biological factors. The absence of saplings of more than 20 mm in diameter implies a high mortality of young individuals under the shade of trees and perhaps also their position relative to the seed-bearing trees. The good sprouting of *P. elata* seeds and seedling growth showed that the early growth stages do not institute a first order limiting factor in the evolution of populations of this species. However, the very small number of poles and the absence of saplings showed that absence of light must play a critical role. Logging appeared as a factor stimulating the regeneration of *P. elata*, but much more knowledge is still needed on internal and external regeneration factors of the species which could explain the drastic reduction in its population density in Cameroon from the thicket stage.

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