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Diversity And Structure of Agbo Forest (Côte d'Ivoire)

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Original Research Article

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Abstract: Post-crop fallow is a fundamental component of agrarian landscapes in Côte d'Ivoire. Post-cultivation secondary succession was studied along a chronosequence of 89 fallows included in a dense forest matrix (Reserved forest of Agbo I, Côte d'Ivoire). After analyzing the local flora, which has 686 species, divided into 428 genus and 101 families, we used the ascending hierarchical classification to identify plant groups. This study made it possible to better understand the floristic diversity, the dynamics and the structure of the forest. The distribution of tree stems according to their diameter and height has a "J-inverted pattern" structure. This predominance of small diameter trees indicates a good future for this vegetation. However, this lower quantity of trees with large diameter would be as a result of human activities in the recent past.
Keywords: Forest management, Post-cultivation fallow, Vegetation dynamics, Anthropogenic pressure, Plant diversity.

INTRODUCTION

The degrading situation of forest ecosystems is one of the major causes of biodiversity loss worldwide [1]. The annual deforestation rate was estimated at more than 13 million hectares between 1990 and 2010 [2]. Developing nations record the highest rates of forest surface area reduction. In Côte d'Ivoire, the forest surface area that was about16 million hectares at the end of the 19th century [3] was estimated in 2014 to be 2.7 million hectares [4].The main causes are agricultural expansion mainly based on inappropriate farming techniques such as shifting cultivation on brulis [5].

In addition to farming, increased demand for firewood and coal and more recently mining is another factor contributing to this increased reduction in vegetation cover. Anthropogenic activities have already been reported as causes of deforestation [3], [6]. Thus, we have witnessed the disappearance or rarefaction of a large number of plant species sheltered by these ecosystems. In the face of the threat of reduced biodiversity, Côte d'Ivoire has based the conservation of its flora and fauna on reserved areas [5]. Unfortunately, these reserved areas are often invaded by neighboring populations for the development of illegal activities. This is the case of the Agbo I reserved forest, the subject of this study which has an agricultural occupancy rate estimated at more than 50% in 2012 [7]. In addition to its floristic diversity, the Agbo I reserved forest in the past sheltered a diversified fauna, the most remarkable being the presence of elephant population that no longer exists today. This rapid deforestation is therefore not a threat to flora alone [3]. Indeed, it is also a threat to the climatic condition by greenhouse gas (GHG) emissions and the conservation of biodiversity (plant and animal). Also, given the extent of deforestation of this reserved forest, one of the main concerns of the government agency in charge of its management and researchers, is to know the exact state of its vegetation and its flora. This concern is justified by the need to put in place a sustainable management policy for its biodiversity. The present study proposes to characterize the composition, the diversity and the structure of the vegetation of this reserved forest. More specifically, it consisted of: i) analyzing the floristic composition, the diversity and the structure of the woody vegetation of the Agbo I forest and then ii) identifying the plant groups and their indicator species.

MATERIALS AND METHODS

Study area

The Agbo I reserved forest (6 ° 24 '- 6 ° 41' North, 4 ° 50 '- 4 ° 09' West) is located in the Region of Mé in South-East Côte d'Ivoire and covers an area of 15,575 hectares. It is a semi-deciduous dense forest subjected to a tropical sub-humid climate, belonging to the mesophilic sector according to the subdivisions established by [6]. The climate (annual averages: 26.5 ° C and 1645.35 mm), which characterized a potential vegetation of humid dense semi-deciduous forest.

Method

Based on the land cover map of the Agbo I Reserved Forest, supplemented by field surveys, vegetation survey sites were randomly placed in floristically homogeneous vegetation units. The sampling plan was therefore designed to have records of unexploited old forest remnants (n = 7), forests for timbercutting only (n = 9), fallow land corresponded to more or less mature stages of the post-cultivation secondary succession (fallow 1-5 years: n = 12, 6- 10 years: n = 14, 11-15 years: n = 13, 16-20 years: n = 15 , 21-25 years: n = 12, 26-30 years: n = 12, 31-40 years: n = 12). We considered that these three types of plant formations represented a gradient of increasing human pressure on vegetation. A total of 105 phytosociological surveys were carried out within plots of 100mx 20 m (*i.e* 2000 m ^{2}) following the Braun-Blanquet abundance-dominance method. The vegetation survey consisted of an exhaustive list of all the vascular species present in the sample surface according to the principles of phytosociology [9]. Complementary shifting surveys were conducted in all parts of the forest including crops. These inventories made it possible to complete the floristic list. All species have been identified. The nomenclature adopted for inventoried species was that of [10] and [11]. Combined phytosociological surveys and forest inventory were carried out from October 2016 to May 2017. We measured the height and circumference at 1.30 m above the ground using a measuring tape. Only woody trees with a diameter greater than 2.5 cm are being considered.

DATA ANALYZES

We compiled a floristic list of all the species found in the 105 vegetation surveys, to which we added a supplementary list of additional species found during shifting survey. The appreciation of the alpha diversity was performed following the determination of the richness of the species diversity, the calculation of the Shannon diversity index and the Pielou equitability. The similarity index of Morisita-Horn (MH) was also calculated. In order to identify vegetation communities, a data matrix consisting of 105 phytosociological records and 347 species was constructed. The hierarchical classification of the readings (Cluster Analysis) was carried out with the software R® using the Euclidean distance. The plant groups formed from the hierarchical classification were subjected to a second analysis using the R® software, in order to characterize the flora of each plant group and to identify the characteristic species. This option was used to calculate the indicator value of each species [12]. Thus, characteristic species have been used to name plant groups. To account for the population structure of woody plants, the distribution of individuals according to diameter and height was performed.

RESULTS

Floristic composition of the reserved forest

The floristic inventory of the vegetation of the Agbo I reserved forest showed 686 species divided into 428 genus and 101 families. With regard to the distribution of the families of the sample considered, *Fabaceae* (11.37%), *Rubiaceae* (6.84%), *Malvaceae* (5.10%), *Apocynaceae* (4.95%) and *Euphorbiaceae* (4.23%), are the most represented families (Figure 1). The other 96 families represent a total of 67.51%, some of which are represented by only one species. Of the 428 genus, only 4 have at least 10 species. These are the genus*Ficus* (15 species), *Salacia* (11 species) *Combretum* (10 species), and *Dioscorea* (10 species).

Hierarchical classification (AHC) and vegetation groupings

The dendrogram obtained from the hierarchical classification (Figure 2) made it possible to highlight the different plant groups. At the significance threshold of approximately

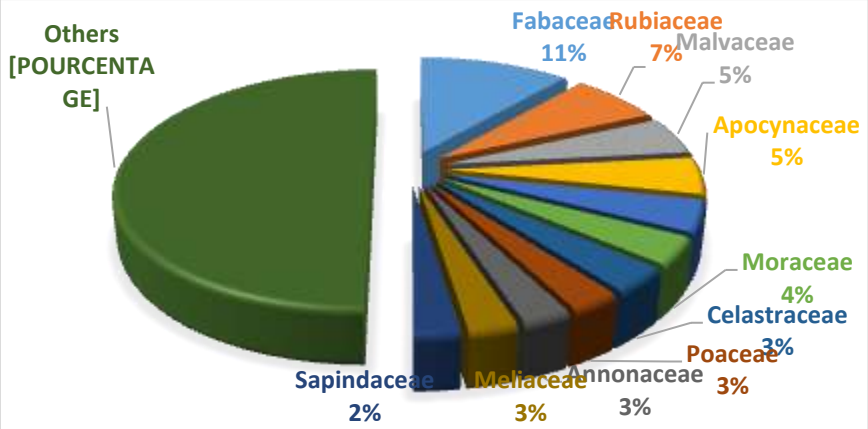

Fig-1: Distribution of families representation in the Agbo I reserved forest

30%, the analysis revealed five (5) large groups. We have 3 groups of fallows and two groups of forests. Group I consists of fallows of 1 to 10 yrs. Group II consists of fallow of 11 to 15 yrs. Group III consists of fallows from 16 to 30 yrs. Group IV consists of mature fallows (more than 30, *ie* fallows 31 to 40

yrs) and the list of forests used solely for their timber. These groups coincide with the four (4) classes of fallows (I to IV). Group V consists of the list of old forest. The age of the fallow is the main determinant of the groups (H = 25.54, p <0.04), with a clear separation between the younger fallows (groups I to II) from the others (of older forests plus two groups of older fallows). Groups I and II, which contains the younger stages of the fallows (1 to 15 years), are located in the first branch of the cluster. These young stages are unstructured, characterized by species of the sub-shrub layer in which height does not exceed five meters, especially in group I. These young fallows of group I, are largely dominated by an invasive species, *Chromolaena odorata* which alone occupies more than 90% of the vegetation cover.Group II is richer in shade tolerant woody species at seedling and young tree stage. The third group of fallows (16-30 yrs fallows) is clearly separated from the other two groups of young fallows.

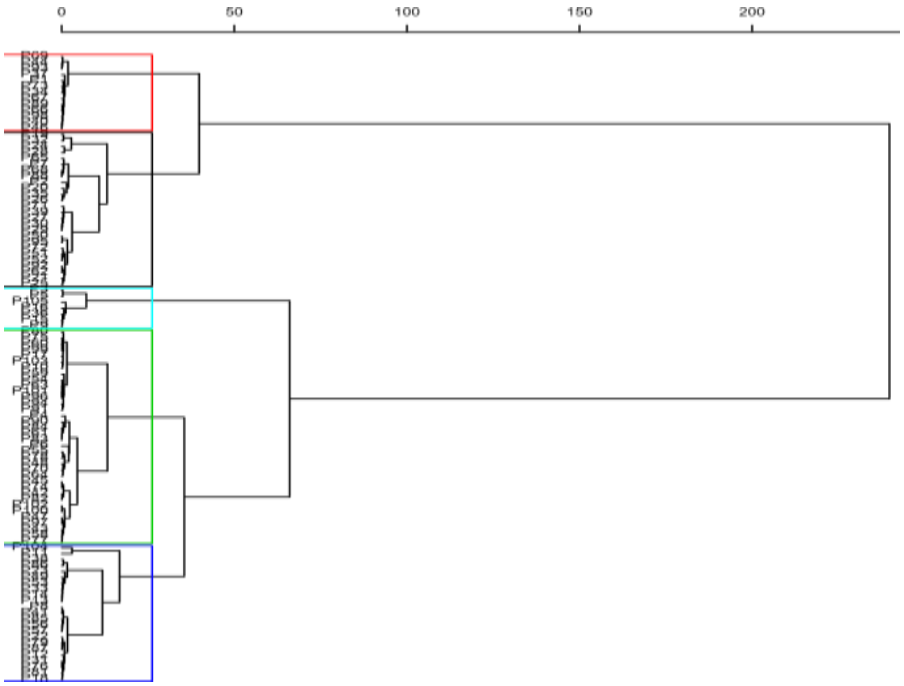

Fig-2: Dendrogram of the ascending hierarchical classification of the 105 survey

Fallow 11-15 yrs G II Fallow 1-10 yrs G I Old-growth forest Fallow 16-30 yrs G III Fallow 31-40 yrs and exploited forest G IV.

It is also located in the second branch of the cluster. This group is richer in species than the first two groups (groups I and II). The AHC clearly separates the forest data in a general way based on their uses (old vs exploited forests) since each of these two groups seems to have specificity in terms of the floristic composition. This is not necessarily the case for fallows of 31 to 40 yrs and exploited forests. It did not seem useful for us to divide them into two groups. We therefore grouped them in group IV (fallow group of 31-40 yrs and exploited forests).

The data from the same group are closer floristically to each other, than any other readings. The analysis of the indicator species made it possible to identify the species to characterize the five (5) identified plant groups: the groups with *Chromolaena odorata* (L.) R. King & H. Robinson, with *Ficus exasperata* Vahl, with *Millettia zechiana* Harms, *Trichilia prieureana* A. Juss. *Subsp. Prieureana* and *Triplochiton scleroxylon* K., *Schum*, with *Annickia polycarpa* (DC) Engl. and Diels and *Nesogordonia papaverifera* (A. Chev.) Cap. Table I presents the characteristic species (indicator species and indicator value) of each of the 5 plant groups in the Agbo I reserved forest, identified by the classification. Thus, only those species whose statistical binding is significant (Monte carlo test on the indicator value with p <0.05) are given. To name the plant groups, the indicator species with the highest value was selected. It should be noted that a plant group could be characterized by several indicator species. In this study, we chose for each vegetation group only the indicator species with the highest value.

Table-1: Indicator species identified and used to name the 5 vegetation groups

Code Groupements	Indicator specie identified	Indicator Value	Pvalue (Test of Monte Carlo)
GI	*Chromolaena odorata*	85.64	0.001
GII	*Ficus exasperata*	38.73	0.04
GIII	*Millettia zechiana*	44.60	0.05
GIV	*Trichilia prieureana*	31.47	0.05
GV	*Annickia polycarpa*	67.7	0.001

Similarity index of Morisita-Horn (MH)

The Morisita similarity index was calculated for the 5 plant groups. This index shows several cases of similarity in the floristic composition of the habitat inventories. The greatest similarity with a percentage of (92.4%) lies between the group consisting of fallows of 16-30 yrs and those of fallow 31-40 yrs coupled with exploited forests. The fallows of 1-10 years and those of 11-15 also show a strong resemblance with a rate of 87.1%. Older forests and fallow of 1-10 years have the smallest resemblance with a percentage of (46.50%).

Specific diversity indices

Two indices were calculated from the plots arranged in the different biotopes covered and following the assemblage resulting from the ascending hierarchical classification: the Shannon index and the Pielou equitability index (Table 2). The calculated Shannon indices range from 3.78 for old-growth forests to 2.44 for fallows 1-10 years old. Statistically, all biotopes visited do not have the same diversity. The calculated evenness index tends towards 1 across all biotopes. Values range from 0.87 in old forests to 0.75 in fallows 1-10 years old. These different values reveal that there is no dominance of one species with respect to another within the biotopes. Statistically, there is a difference in the distribution of species of these different plant groups.

Tab-2: Comparison of diversity index (mean ± standard deviation) and evenness of plant communities of the Agbo I. Reserved Forest

Plant Grouping	Number of plots	Specie Richness	Diversity Index			
			Shannon Index		Evenness Index	
			Kruskal-Wallis test		Kruskal-Wallis test	
			Chi Square	p-value	Chi square	p-value
			60.55	0.0001< 0.05	33.95	0.0001< 0.05
Fallow (1-10 yrs)	26	143	2.44± 0.57 ^{a}		0.75±0.11 ^{a}	
Fallow (11-15 yrs)	13	147	2.78± 0.58 ^{ab}		0.77±0.11 ^{a}	
Fallow (16-30 yrs)	38	241	3.22±0.28 ^{b}		0.80±0.04 ^{a}	
Fallow (31-40 yrs) and exploited forest	21	242	3.51±0.34 ^{c}		0.85±0.02 ^{b}	
Old-growth forest	7	210	3.78±0.23 ^{c}		0.87±0.02 ^{b}	

Legend: In columns, averages with the same letters are statistically equal or similar ($\alpha = 0.05$).

Structure of the vegetation in the Agbo I Reserved Forest

The distribution of different individuals by diameter according to group clearly shows that young fallows (1 to 15 years) are richer in individuals of small diameters hence the structure of "inverted J Pattern" indicating a young population in full recovery after the abandonment of agricultural activities (Figure 3), this during all stages of the evolution of post fallows cultivation. The presence of individuals of large diameters is due to the presence of the individuals spared during the creation of the plantation on one hand, and the rapid regeneration of some pioneer species in the post fallows cultivation on the other hand for example: *Albizia adianthifolia (Schum.)* WF Wright, *Albizia zygia (*DC) JF Macbr., *Antiaris toxicaria* Lesch. var. *africana* Engl., *Ceiba pentandra* (L.) Gaertn, *Ficus exasperata* Vahl., *Musanga cecropioides* R. Br., *Millettia zechiana* Harms. The diametric structure is characterized by a decreasing distribution of tree stems from small diameter classes to large diameter classes. Figure 3 shows that in all habitat, the class of small diameters (diameters between 2.5 and 5 cm) is the most abundant. This distribution of woody species according to diameter has a direct impact on that of heights.

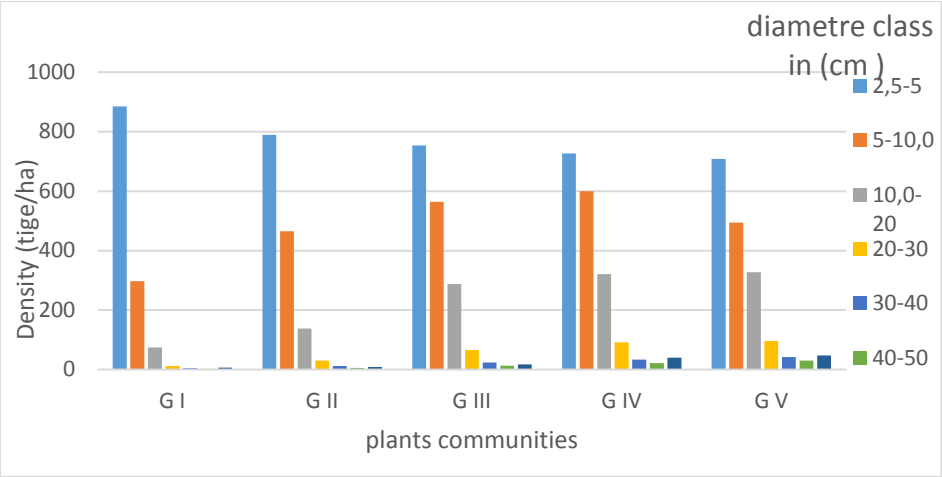

Fig-3: Distribution of stems classed by diameter in the different groups

The distribution of trees by height shows that taller trees are lower (Figure 4) in the early stages of post-cropping succession. This distribution shows that individuals in the less than 4 meters tall range are most represented in young fallows. The number of individuals in the other range of diameters increases with the age of the fallows.

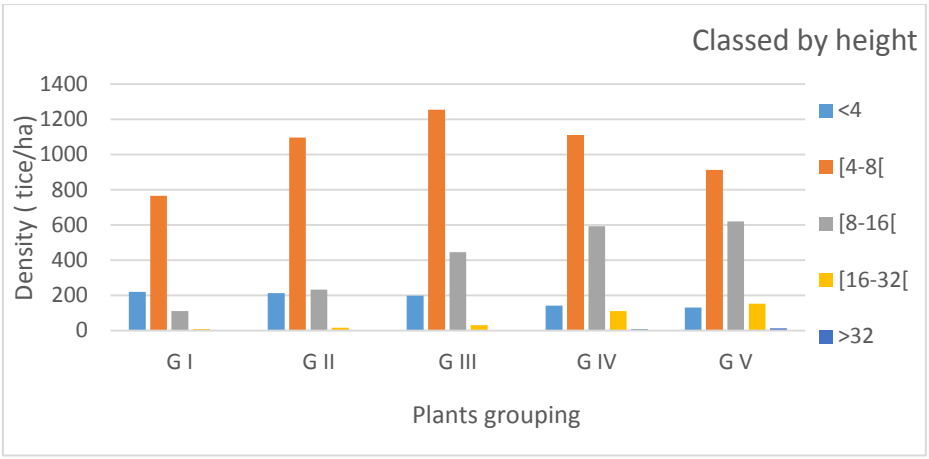

Fig-4: Distribution of stems by height in different groups

DISCUSSION

Richness of the flora of the Agbo I Reserved forest

A total of 686 plant species belonging to 101 families have been inventoried. The floristic richness of the Agbo I reserved forest is lower than that reported by some work carried out in other reserved areas in Côte d'Ivoire. In fact, in the Yapo-Abbé reserved forest, which is the closest, 794 species have been inventoried by [13]. South of Taï National Park, 1,233 species were inventoried by [14]. This difference would be due to the protective effort of these reserved areas at the time, the more favorable climatic conditions and the size of these reserved areas. Note that the flora of Côte d'Ivoire comprises of 3,882 species divided into 1,218 genus and 192 families [6]. Our results also showed that of the 101 families identified, *Fabaceae, Rubiaceae, Malvaceae, Apocynaceae and Euphorbiaceae* dominated. These families are common in most forests in Côte d'Ivoire and in African forests [15].

Diversity of the plant communities in the reserved forest

The various indices of diversity allowed us to evaluate the diversity of different fallow groups from the AHC of the different types of forest. The Shannon diversity index is higher in older fallows. Recently anthropogenic formations have the lowest values due to the impact of agricultural activities on plant diversity. According to [16], low evenness in young fallows indicates a strong dominance of a few species and particularly of *Chromolaena odorata* in this study. For some authors [1], low values of the Shannon index are observed only when the soils are saturated with water and these environments allow only a small number of species adapted to moisture to grow.

Structure of the Plant Assemblage in the Agbo I Reserved Forest

Our results on the diametric structure of all plant groups indicated an "inverted J patern"

distribution characteristic of multi-species stands with predominance of young or small-diameter individuals ([17]. The presence of small diameter individuals in all plant groups can be said to show a good vegetation health in these groups. According to [18], the high densities of small diameter stems ensure the future of natural forest development. Such a distribution is typical of stable populations, likely to be renewed by the natural regeneration [19]. According to [15] this situation is justified in the different populations of species constituting the grouping because of the particular pressure that weighs on certain species. However, this needs to be qualified because large diameter trees resulting from natural selection are actually the seeds providers that ensure the perennial of the forest [18]. This strong dominance of small diameter individuals has been observed by [20] in savanna formations of the reserved forests of Ouli and Wélor in Senegal. The small number of large diameter individuals may be related to human activities, especially logging and cultivation. During the collection of our floristic data, we unfortunately observed fallows of less than five years inside the reserved forest and some carbonization pits within the reserved forest. But under certain conditions, it is the floristic composition that imposes this structure [20].

CONCLUSION

The purpose of this work was to improve knowledge of the composition, structure and diversity of woody vegetation in the Agbo I reserved forest. The results show that the richness of the species in the Agbo I forest is high. This floristic richness of the Agbo I forest is sufficient enough to justify its protection and sustainable management for the conservation of the country's biodiversity. This study also revealed a predominance of Fabaceae, Rubiaceae, Malvaceae, Apocynaceae and Euphorbiaceae families. The Agbo I reserved forest is dominated by small diameter individuals and has a small proportion of large diameter individuals. This predominance of small diameter individuals predicts a good future for these plant communities. But this poor in large diameter individuals is linked to human activities in the recent past (cutting of wood for energy, cocoa plantation and coffee plantation) within the reserved forest.

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