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PHYTOSOCIOLOGICAL CHARACTERIZATION OF THE UNDERGROWTH OF BANCO NATIONAL PARK FOREST

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ABSTRACT

The Diversity of the understory is an important factor in predicting the future of forest ecosystems. It is of great interest for the development and conservation of biodiversity. The main objective of this study is to investigate the impact of disturbances in the undergrowth of Banco National Park. To this end, the phytosociological characterization of the undergrowth of the old disturbed sites and the forest reserve was carried out. The method used is that of phytosociology under its synusial approach. 91 surveys (82 in the former silvicultural treatment sites and 9 in forest reserve) identifies 302 species of phanerophytes distributed among 210 genera and 70 families. The dendrogram resulting from ascending hierarchical classification of readings revealed three syntaxa, two of which consist essentially of surveys of old disturbed sites and one of the surveys of the forest reserve. These syntaxons are characteristic of understory of pre-climacic formations at different stages of development. The impact of disturbances is still felt in the undergrowth of Banco National Park Forest in terms of floristic richness and the distribution of species abundance in the former disturbed sites and in forest reserve.

Keywords: Banco National Park, Undergrowth, Phytosociology.

1. INTRODUCTION

Forest ecosystems are recognized for their essential role in climate regulation and biodiversity conservation. Their floristic composition and structure vary according to the rainfall regime. This variation is further modified by soil, orographic, biotic and historical conditions (Fournier & Sasson, 1983). In addition, the vertical stratification of these forests highlights several vital spaces defining the broad categories of synusia or strata, including the arborescent stratum, the high shrub stratum and the low shrub, herbaceous and muscinal strata, which constitute the undergrowth (Meddour , 2011). This undergrowth is an important entity because in addition to being a wildlife support, it is the nursery of the forest which would otherwise disappear. It also plays an important role in forest regeneration and the evolution of plant biodiversity (Kavira et al. 2012).

In Côte d'Ivoire, the evergreen forest has been described on the basis of floristic differences and ecological variations. This work discriminated five associations constituting the five types of forests, including the Turraeanthus africanus forest and Heisteria parvifolia (Mangenot, 1955; Guillaumet & Adjanohoun, 1971). Banco National Park, the only formation characteristic of this type of forest, is small and highly threatened (Guillaumet & Adjanohoun, 1971). From 1924 to 1953, several forestry activities and village plantations carried out in this forest formation deeply

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disturbed its natural balance (De Koning, 1983). The contribution of local or exotic species and the opening of the canopy constitutes sources of threat and may alter the structure and the floristic composition of this forest (Dupuy, 1998). Today, these old disturbed sites occupy an important place in the landscape of the park, with about three quarters (3/4) of its area (De Koning, 1983). In addition, natural cataclysms (Chablis) occur fairlyregularly witin the forest (De Beaufort, 1972). These constant agitations may contribute to the establishment of species other than those characteristics of this forest. This raises questions about the future of this type of training in Côte d'Ivoire. This study therefore proposes to investigate the impact of these disturbances in the undergrowth of Banco National Park. Specifically, the aim of the study is to characterize the old disturbed sites and the forest reserve in terms of plant sociology and to investigate the different stages of development of syntaxa of this synusia.

2.METHODOLOGY

2.1 Study site

Covering an area of 3 438.34 hectares, Banco National Park (PNB) is located in the district of Abidjan. This district is located between 5°21' and 5°25' north latitude and between 4°01' and 4°05' west longitude (Décret, 2018). It is surrounded by five communes namely, Adjamé, Abobo, Attécoubé, Songon and Yopougon (Figure 1). The climate is of the equatorial transition type, divided annually into four seasons (Tastet, 1979). In general, these seasons are divided into a major rainy season (april to july), a minor dry season (august to september), a minor rainy season (october to november) and a major dry season from december to march (Sako & Beltrando, 2014). The ecological functioning of the forest is under the control of the hydrological regime of Banco river with its tributaries, the main watercourse which crosses the forest and flows into Ebrié lagoon (Cougny et al., 1995).

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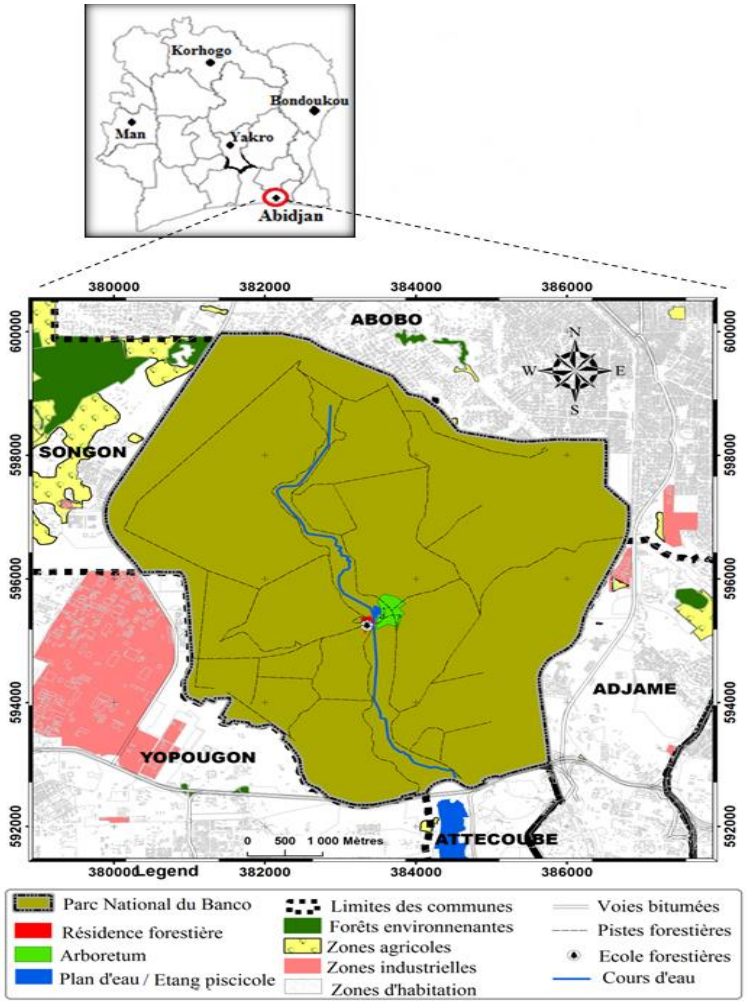

Figure 1: Geographical location of Banco Forest National Park

2.2 Data collection

On the basis of the treatment map (De Koning, 1983), supplemented by field surveys, 91 plots (82 in the former silvicultural treatment sites and 9 in the forest reserve) were installed randomly in units of floristically homogeneous vegetation. The phytosociological method under its synusial approach developed by Gillet et al. (1991) and Gillet (1998) was used to carry out the

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surveys, carried out in areas of 400 m² (20m x 20m). The geographic coordinates of each survey were recorded. Within this area distributed in the former silvicultural treatment sites and in the forest reserve, the rate of cover of the species of the sub-shrub synusia was estimated according to the Braun-Blanquet scale (1964) modified by (Gillet et al., 1991):

5: Number of any individuals, covering more than 3/4 of the surface;
4: Number of any individuals, covering more than 1/2 to 3/4 of the surface;
3: Number of any individuals, covering more than 1/4 to 1/2 of the surface;
2: Abundant or very abundant individuals covering 1/20 to 1/4 of the surface;
1: Few or fairly abundant individuals, low coverage, less than 1/20 of the surface;
+: Rare individuals, very low recovery;
r: Very rare individuals, negligible overlap

Species were identified directly in field using Hawthorne & Jongkind (2006) field manual. Undetermined species have been herborized and identified with herbaria of the Swiss Center for Scientific Research. Most species were collected at least once to confirm field identification.

2.3 Data analysis

A species-survey matrix was produced by transforming the abundance-dominance values of 91 surveys taken in the field with Braun-Blanquet scale (1964) into an ordinal value in accordance with Van der Maarel scale (1979), see Table 1. The data of the matrix were subjected to an ascending hierarchical classification (Ward's method, relative Euclidean distances) for the construction of the dendrogram with the R software. The number of groups or elementary syntaxons was sought beforehand by using method developed by Kassambara & Mund (2020).

The Indicator Species Analysis (IndVal) method proposed by Dufrêne & Legendre (1997) was used to find indicator value of each species. However, this work has limited to searching for singletons and pairs of species as suggested by De Cáceres & Legendre (2009), using the "Combinespecies" function and the "max order" argument of R software version 3.6.1. The significance test was performed with 9999 permutations (Monte Carlo test, $p < 0.05$), using the permute package (Simpson, 2019). The syntaxa are named using taxon pairs whose indicator value is significant and having a species specific to the sub-shrub stratum. The stage of development of syntaxons was assessed using the different classes of the Pioneer Index (Table 2) proposed by Hawthorne (1996). To do this, the temperament of each species was researched. These different values were used to calculate the value of the Pioneer Index (PI) of each syntaxon according to the following formula:

$$IP = \left[\frac{(2Pi + nPi)}{(Nb)} \right] \times 100$$

In this equation, Pi = number of pioneer species; n Pi = Number of non-pioneer, but heliophilous species and Nb = total number of site species (Hawthorne, 1996).

Shannon's diversity index (H') was used to compare syntactic diversity. It is calculated according to the following formula:

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$$H' = \sum\left(\frac{ni}{N}\right)\ln\left(\frac{ni}{N}\right)$$

With ni the density of species i and N the density of all species in the community. Diversity is low when H' is less than 3 bits, medium if H' is between 3 and 4 then high when H' is greater than or equal to 4 bits. Pielou's equitability (E) whose formula is , reflects the way in which individuals are distributed across species. It is maximal if the individuals are distributed in the same way across the species. It varies from 0 where one species has a very high abundance to 1 where all species have the same importance (Frontier & Pichod-Viale, 1995).

Table 1: Transformation of abundance-dominance (AD) scores into ordinal values ,AD: Abundance dominance, VDM: Van der Maarel (1979) scale

AD	VDM	Meanings
5	9	Number of any individuals, covering more than 3/4 of the surface
4	8	Number of any individuals, covering more than 1/2 to 3/4 of the surface
3	7	Number of any individuals, covering more than 1/4 to 1/2 of the surface
2	5	Abundant or very abundant individuals covering 1/20 to 1/4 of the surface
1	3	Few or fairly abundant individuals, low coverage, less than 1/20 of the surface
+	2	Rare individuals, very low recovery
r	1	Very rare individuals, negligible overlap

Table 2: Value classes of the Pioneer Index (PI) according to Hawthorne (1996)

Classes of IP	Meanings
[0 – 25[	undisturbed to minimally disturbed sites
[25 – 50[	weakly disturbed sites
[50 – 100[	moderately disturbed sites
[100 – 150[	fairly disturbed sites
[150 – 200[	highly disturbed to completely transformed sites

3. RESULTS

All of the 91 surveys have identified 302 species of plants divided into 210 genera and 70 families. At a relative distance which corresponds to 60% of the remaining information (Ward method, relative Euclidean distances), the Ascending Hierarchical Classification (CHA) obtained with the matrix of the 91 readings revealed 3 elementary syntaxons (Figure 2). These groups are characteristic of undergrowth of pre-climax formations at different stages of evolution. This is G1 group or the Cola heterophylla and Culcasia liberica syntaxon, characteristic of a slightly disturbed environment (IP = 48.97) or the undergrowth of a moderately evolved pre-climax forest, the G2 group or the syntaxon to Culcasia angolensis and Drypetes chevalieri, characteristic of a slightly disturbed environment (IP = 45.45) or of the undergrowth of a more evolved Pre-climax forest and syntaxon to Cola heterophylla and Palisota hirsuta, characteristic of a site moderately disturbed (PI = 50.61), undergrowth of a poorly evolved pre-climax forest.

Different geographical coordinates of recordings projected on treatment map of De Koning (1983) show that the syntaxon recordings for Cola heterophylla and Culcasia liberica mainly come from food ex-plantations and vine removal, those of the syntaxon for Culcasia angolensis and Drypetes chevalieri, the forest reserve and the planting of valuable species. Syntaxon to Cola heterophylla and Palisota hirsuta results from total destruction of vegetation, devine stripping and food planting (Figure 3). In the Culcasia angolensis and Drypetes chevalieri syntaxon, the juveniles of the shrub Drypetes chevalieri are very strongly represented with a frequency of 67%. Then, the Araceae, Culcasia angolensis with a frequency of 100%, and the juveniles of Cola chlamydantha, (44%) constitute the flora commonly encountered. While in the syntaxa of old disturbed sites, juveniles of Cola heterophylla (87%), Strombosia pustulata (64%), Microdesmis keayana (56%), Rubiaceae Geophila obvallata (81%), Arecaceae, Laccosperma laeve (68%) are the most common species.

The quantitative floristic diversity presents low values and a regular distribution in the plant communities of the synatxon with Cola heterophylla and Culcasia liberica (H'= 2.72 ± 0.035; E= 0.94±0.003) and of the syntaxon with Culcasia angolensis and Drypetes Chevali (H'= 2.13 ± 0.156; E= 0.905 ± 0.008). Whereas in the plant community of syntaxon with Cola heterophylla and Culcasia liberica, the diversity index is average (H'= 3.01 ± 0.055, E= 0.908 ± 0.006).

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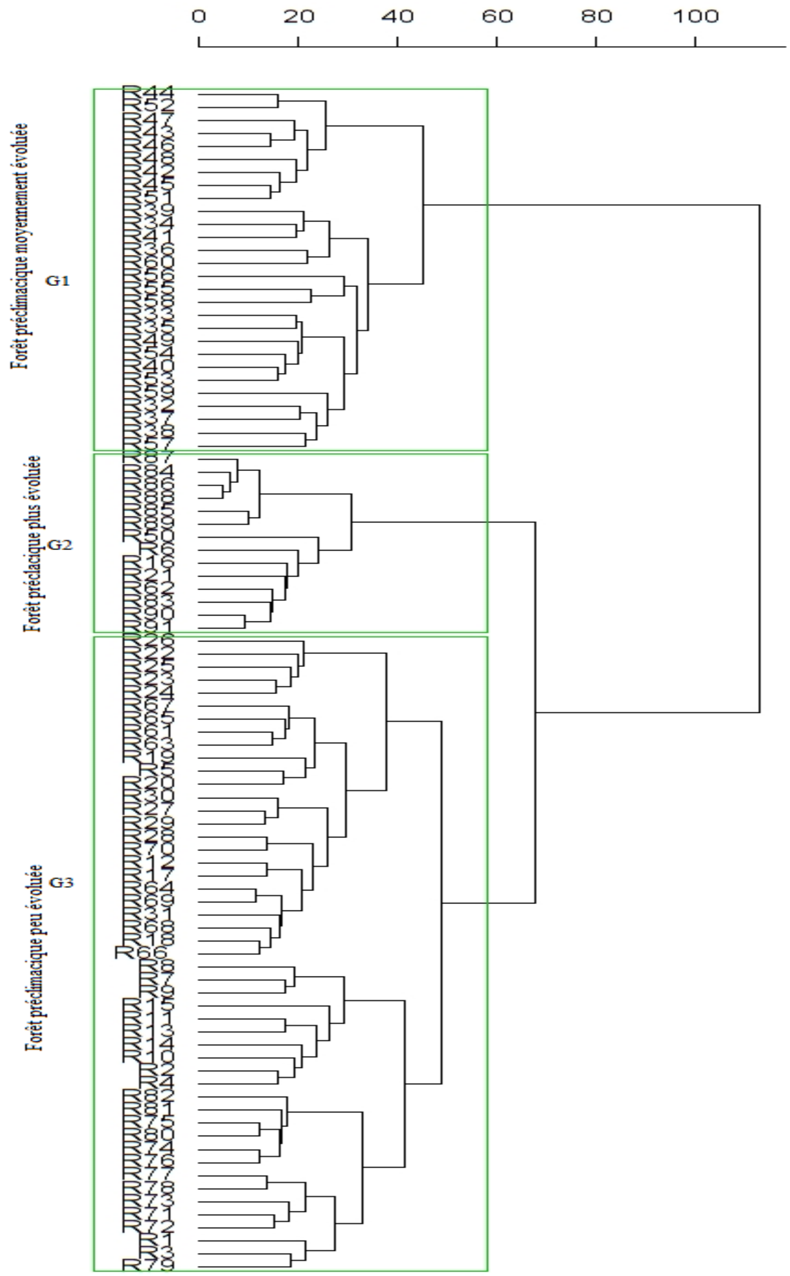

Figure 2. Dendrogram of readings (Ward's method, relative Euclidean distances)

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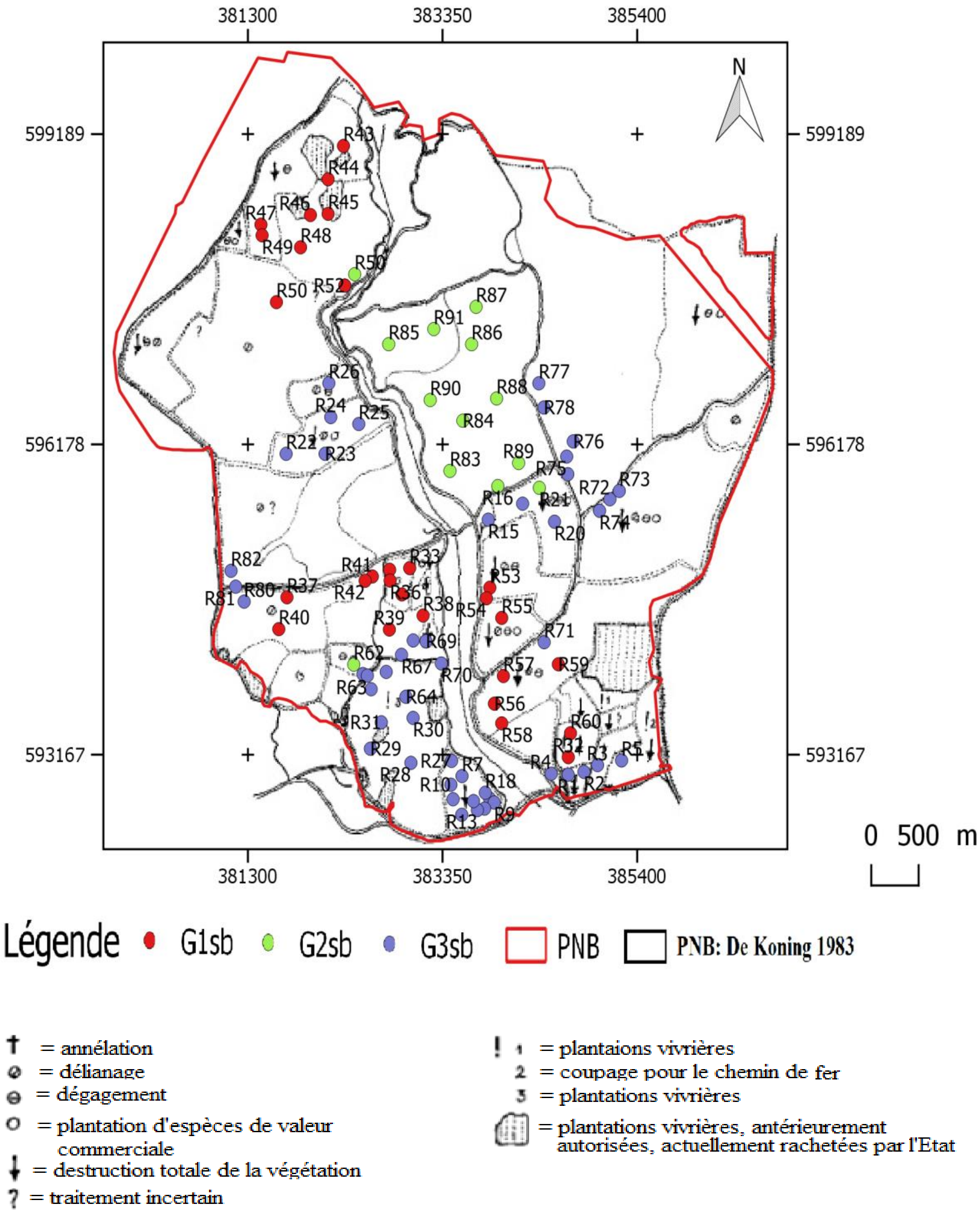

Figure 3. Syntax distribution in Banco National Park

3.1 G1 grouping or syntaxon in Cola heterophylla and Culcasia liberica

A total of 147 species are associated with this group. These are 7 constant elementary taxa, 75 accidental elementary taxa, 47 differential elementary taxa and 53 companion elementary taxa. However, the taxa Culcasia liberica, Connarus africanus, Marantochloa congensis and the pairs of taxa Cola heterophylla + Culcasia liberica, Culcasia liberica + Geophila obvallata, Connarus africanus + Culcasia liberica, Culcasia liberica + Laccosperma laeve have the significant IndVal value (P. Value ≤ 0.05). In addition, the taxon pair Cola heterophylla + Culcasia liberica better characterizes this grouping with regard to its indicator value (IndVal=0.919) higher in this syntaxon (Table 3). In terms of regeneration guild, this syntaxon is 44.90% shadow species. Heliophiles and pioneers represent 23.13% and 12.92% respectively (Figure 4).

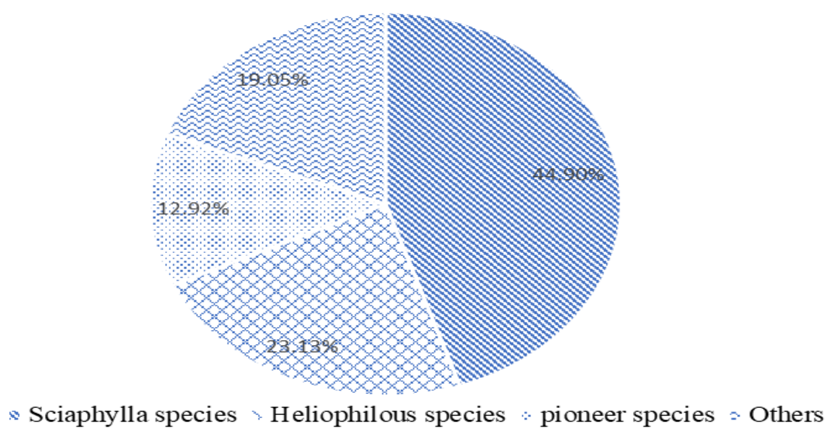

Figure 4: Syntax regeneration guild spectrum in Cola heterophylla et Culcasia liberica.

Table 3: Indicator value (IndVal) of taxa or taxa combinations of the syntaxon in Cola heterophylla and Culcasia liberica.

Taxa and pairs of taxa	A	B	IndVal	p.value	sig
Cola heterophylla + Culcasia liberica	0.9846	0.8571	0.919	0.001	***
Culcasia liberica	0.9800	0.8571	0.917	0.001	***
Culcasia liberica + Geophila obvallata	1.0000	0.8214	0.906	0.001	***
Connarus africanus + Culcasia liberica	1.0000	0.6786	0.824	0.001	***
Marantochloa congensis	0.9242	0.6786	0.792	0.001	***
Culcasia liberica + Laccosperma laeve	0.9846	0.6071	0.773	0.001	***
Geophila obvallata + Marantochloa congensis	0.9800	0.6071	0.771	0.001	***
Culcasia liberica + Strombosia pustulata	0.9719	0.6071	0.768	0.001	***
Connarus africanus	0.7372	0.7857	0.761	0.001	***
Connarus africanus + Geophila obvallata	0.7679	0.7500	0.759	0.001	***
Strombosia pustulata	0.5231	0.7143	0.611	0.022	*
Cola heterophylla + Microdesmis keayana	0.5597	0.5357	0.548	0.041	*

Legendre: A=Specificity, B=Fidelity, Prob=Probability, Sig. = Level of significance

Significance codes: 0 `***' 0.001 `**' 0.01`*' 0.05

3.2 G2 grouping or syntaxon in Culcasia angolensis and Drypetes chevalieri

Three constant elementary taxa, 20 companion elementary taxa, 59 accidental elementary taxa and 3 differential elementary taxa out of a total of 86 species were identified in this group. However, 2 pairs of taxa including Cola chlamydantha + Drypetes chevalieri, Culcasia angolensis + Drypetes chevalieri, and 2 taxa Cola chlamydantha and Drypetes chevalieri have significant indicator value (IndVal) (P.Value ≤ 0.05), see Table (4.). However, the pair of taxa Culcasia angolensis and Drypetes chevalieri, although having the lowest indicator value (IndVal=0.657), characterizes this syntax better because of Culcasia angolensis, a species specific to the undergrowth. The spectrum of the regeneration guild (Figure 5) presents a high proportion of shade species (50.64%) than heliophilous species (29.87%) and pioneer species (7.79%).

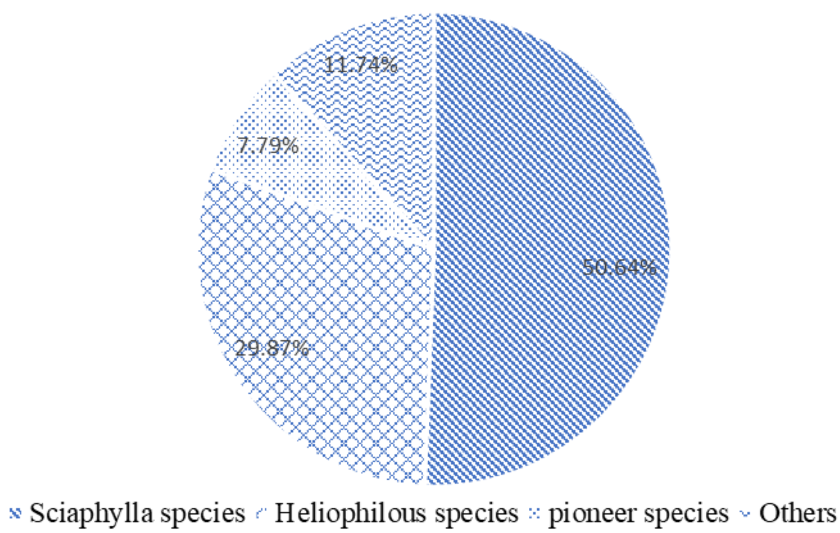

Figure 5: Syntax regeneration guild spectrum in Cola chlamydantha et Drypetes chevalieri

Table 4: Indicator value (IndVal) of taxa or combinations of taxa of the Culcasia angolensis and Drypetes chevalieri grouping

Taxa and pairs of Taxa	**A**	**B**	**IndVal**	**p.value**	**Sig**
Cola chlamydantha + Drypetes chevalieri	0.6296	0.8571	0.735	0.001	***
Drypetes chevalieri	0.7778	0.6429	0.707	0.001	***
Cola chlamydantha	0.6992	0.7143	0.707	0.001	***
Culcasia angolensis + Drypetes chevalieri	0.8621	0.5000	0.657	0.001	***

Legend: A=Specificity, B=Reliability, Prob =Probability, Sig. = Level of significance

Significance codes: 0 `***' 0.001 `**' 0.01 `*' 0.05.

3.3 G3 grouping or syntaxon in Cola heterophylla and Palisota hirsuta.

228 elementary taxa, distributed between 6 constant species, 45 companions, 175 accidental, and 86 differential species have been listed in this syntaxon. However, 3 pairs of taxa (Cola heterophylla + Palisota hirsuta, Geophila obvallata + Palisota hirsuta, Angylocalyx oligophyllus + Cola heterophylla) and 4 taxa (Cola heterophylla, Palisota hirsuta, Angylocalyx oligophyllus, Culcasia angolensis) have the significant value (IndVal) greater than 0.50 (Table 6). The taxon pair Cola heterophylla + Palisota hirsuta, with the highest indicator value (IndVal = 0.688), best characterizes this syntax.

Shade species (40%), heliophilous species (27%) and pioneer species (12%), constitute the regeneration guild (Figure 6).

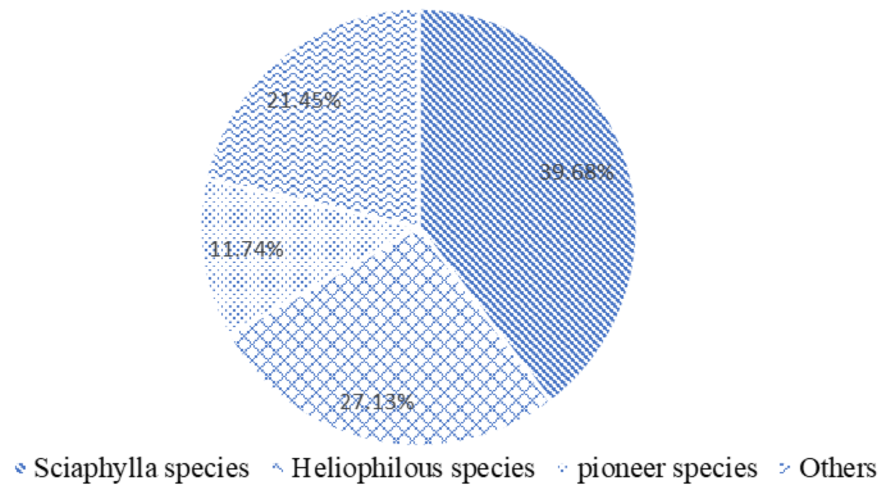

Figure 6: Syntax regeneration guild spectrum in Cola heterophylla and Palisota hirsuta

Table 6: Indicator value (IndVal) of taxa or combinations of taxa of the Cola heterophylla and Palisota hirsuta group

Taxa and pairs of Taxa	**A**	**B**	**IndVal**	**p.value**	**Sig**
Cola heterophylla + Palisota hirsuta	0.8273	0.5714	0.688	0.001	***
Cola heterophylla	0.4768	0.8980	0.654	0.002	**
Palisota hirsuta	0.5901	0.6327	0.611	0.006	**
Angylocalyx oligophyllus + Cola heterophylla	0.5760	0.5918	0.584	0.017	*
Angylocalyx oligophyllus	0.5103	0.6531	0.577	0.029	*
Geophila obvallata + Palisota hirsuta	0.5519	0.5306	0.541	0.042	*
Culcasia angolensis	0.5383	0.5306	0.534	0.045	*

Legend: A=Specificity, B=Reliability, Prob =Probability, Sig. = Level of significance

Significance codes: 0 `***' 0.001 `**' 0.01 `*' 0.05

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4. DISCUSSION

These results show that undergrowth of the forest reserve represented by syntaxon with Culcasia angolensis and Drypetes chevalieri presents a floristic procession different from undergrowth of old disturbed sites (syntaxon with Cola heterophylla and Palisota hirsuta, syntaxon with Cola heterophylla and Culcasia liberica). Diversity of undergrowth of Banco National Park would therefore be the product of history of this space. The two groups of old disturbed sites could justify the particular nature of disturbances.

Indeed, some works have caused total destruction of vegetation in places in addition to village plantations and crops of valuable species (De Koning, 1983). These disturbances have therefore favored development of several species and increased their abundance in these sites. Moreover, the Malvaceae Cola heterophylla, one of characteristic species of the forest at Uapaca (Mangenot, 1955) would be the species most adapted to these old disturbed sites, whatever the mode of treatment undergone by the site. Moreover, dispersed by zoochory mode, this species very widespread in the undergrowth of these sites thanks to the ecological role it plays in this formation serves as food for primates (Adingra et al. 2014). Its dispersal would therefore be due to the movement of the latter, which eat a few seeds and drop the rest (De Koning, 1983). Drypetes chevaleri, one of characteristic species of the psammo-hygrophilous forest, is the most widespread species in the forest reserve.

Furthermore, Heisteria parvifolia, an indicator species for the association with Turraeanthus africanus and Heisteria parvifolia, is very rare today in this forest. These two species of Conopharyngion alliance would replace each other in this part of the forest. Thus for Chevalier and Guinier (1953), each species has its own area and each area is likely to regress or expand from one year to another depending on environmental conditions. This transformation of the flora leads to constant modification of biocenoses (Maley, 1990). Natural dynamics would therefore be the cause of mutations within plant community present in the forest reserve (Riera et al., 1990). Whereas in old disturbed sites, impact of the disturbances is manifest through repercussions on species richness, composition and distribution of abundances (Gosselin, 2004).

In addition, various individuals of associations present several species characteristic of Schnell's (1950) class of Pycnanthetea including Monodora myristica

, Dracaena surculosa, Baphia nitida, Pycnanthus angolensis, Cola caricaefolia, Strombosia pustulata., of the order of Uapacetalia, Cola digitata, Cola heterophylla, Coula edulis, Diospyros sanza-minika, Funtumia elastica, and Maesobotrya barteri and several species of the Conopharyngion alliance, Chrysophyllum subnudum, Drypetes chevalieri, Turraeanthus africanus, Buchholzia coriacea, Xylopia acutiflora (Mangenot, 1955).

However, of the three common species of the Turraeantho-Heisterietum association, Dichapetalum cymulosum, Heisteria parvifolia, and Calycobolus parviflorus (Mangenot, 1955), Heisteria parvifolia and Calycobolus parviflorus are present in the syntaxon in Culcasia angolensis and Drypetes chevalieri. The lack of comprehensive surveys in the forest reserve would justify the absence of Dichapetalum cymulosum in the data. This syntaxon corresponds to the undergrowth of the Turraeantho-Heiterietum association. The other syntaxa (Cola heterophylla and Palisota hirsuta syntaxon, Cola heterophylla and Culcasia liberica syntaxa) would represent the healing syntaxa of the Turraeantho-Heiterietum subwoods or degraded facies of this association.

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In terms of diversity indices, the relative specific poverty of the Turraeantho-Heisterietum association had already been indicated by Mangenot (1955), De Beaufort (1972) and Guillaumet & Adjanohoun (1971). According to these authors, this association is the poorest of all the associations of the dense humid forest in Côte d'Ivoire, which justifies the low diversity in the syntaxon at Cola heterophylla and Culcasia liberica, a conserved environment. While the low diversity in the syntaxon at Culcasia angolensis and Drypetes chevaleri, would be a sign of a stage of development close to that of the forest reserve. Whereas in Cola heterophylla and Palisota hirsuta syntaxon, the average diversity index would be due to the impact of disturbances (Ponge, 2012). Pielou's equitability (E) shows a regular distribution of species, indicating that several species abound within communities (Frontier & Pichod-Viale, 1995)

5. CONCLUSION

The study of the impact of disturbances in the undergrowth of Banco National Park identifies three individuals of association or syntaxa. These plant communities contain several species of Pycnanthetea class, species of the order of Uapacetalia and the Conopharyngion alliance and have different stages of evolution. The value of the diversity index (Shannon) is low for the syntaxon of Culcasia angolensis and Drypetes chevalieri, whose records are mainly from the forest reserve and for the individual of association with Cola heterophylla and Culcasia liberica whose stage of development is close to that of the forest reserve. This value is average for the plant group at Cola heterophylla and Palisota hirsuta which has a low stage of development. The plant community with Culcasia angolensis and Drypetes chevalieri is said to characterize the understory of the Turraeantho-Heisterietum association. The other syntaxa would correspond to the cicatricial syntaxa of the undergrowth of the Turraeantho-Heiterietum association or the degraded facies of this association. The forestry activities and village plantations carried out in Banco National Park have still obvious impacts on the undergrowth in terms of floristic diversity and the distribution of their abundance.

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