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CHARACTERIZATION OF THE NATURAL FLORA OF THE UNDERSTORY OF THE RUBBER PLANTATIONS IN SOUTHERN COTE D'IVOIRE: CASE OF THE RUBBER PLANTATIONS OF THE CNRA ANGUEDEDOU

KONAN Djézou[1*], KOUADIO Kouassi Richard[2], GNANHOUA Guy Modeste[2], N'GUESSAN Kanga Anatole[2] and OBOUAYEBA Samuel[1]

[1]National Agricultural Research Centre, CNRA, Rubber Program, Agronomy-Physiology Laboratory, 01 BP 1740 Abidjan 01, Côte d'Ivoire

[2]National Agricultural Research Centre, CNRA, Forest and Environment Program, 01 BP 1740 Abidjan 01, Côte d'Ivoire

[*]Corresponding author

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ABSTRACT

Objective: The study was conducted in the rubber plantations of the National Agricultural Research Centre (CNRA) of Anguédédou in the south of Côte d'Ivoire, to characterize the natural biodiversity of the undergrowth of rubber plantations, through the floristic composition and the evolution of the number of species according to the age of the plantations.

Methodology and results: The methodology focused on the surface inventory. Thus, 36 surveys of 20 m x 10 m, or 200 m², were installed and inventoried through the rubber plantations of different age classes ([1 to 5 years], [6 to 10 years], [11 to 20 years] and [21 to 40 years]), abandoned rubber plantations and secondary forest. Regeneration was evaluated in plots with a 5 m (25 m²) coastline. The results have shown that rubber plantations are rich in 130 natural plant species. With the exception of rubber plantations from 1 to 5 years and especially of abandoned rubber plantations, the influence of this crop on the natural flora is felt in plantations from 6 to 10 years, with only 34 species. However, this flora evolves with the aging of the plantations. In abandoned plantations, 75 species were inventoried with a good presence of endemic species such as *Chlamydocarya macrocarpa*, *Angylocalyx oligophyllus*, *Chassalia kolly*, *Mussaenda tristigmatica*. There are also some rare and/or endangered species such as *Albizia adianthifolia*,

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Baphia nitida, Commelina benghalensis, Culcasia scandens, Gloriosa superba, Greenwayodendron suaveolens, Millettia zechiana and Milicia excelsa. The floristic similarity between abandoned rubber plantations and secondary forest, indicates a shift from abandoned rubber plantations to forest formations with high regeneration density, mainly in abandoned plantations.

Conclusion and application: The study showed that the impact of rubber culture is felt on the natural flora of young rubber plantations. However, when plantations are abandoned, the environment becomes secondary forest. This investigation deserves to be carried out in other rubber plantations of other ecological zones of Côte d'Ivoire.

Keywords: Natural flora, undergrowth, rubber plantation, age classes, southern Côte d'Ivoire.

INTRODUCTION

The problems related to the use of the environment and natural resources are the major challenges that confront man today. African forest ecosystems in general and those of Côte d'Ivoire in particular, suffer from degradation of various origins, with the most significant anthropogenic action. In a country like Côte d'Ivoire where the economy is based mainly on agriculture, the development of crops such as cocoa, coffee, oil palm and especially rubber have led to a degradation of more than 83% of forest areas (N'DA *et al.,* 2008). Rubber, a tree of forest origin, is an important source of natural rubber indispensable in the pneumatic industry, in view of the high added value products derived from it (SIPH, 2013). Rubber farming also generates significant income and contributes to poverty reduction in rural areas (Ruf, 2012). Due to the economic importance of natural rubber, its high use as an input in the pneumatic industry and its various uses (Dusotoit-Coucaud, 2012), rubber culture is developing in tropical countries, including Côte d'Ivoire. According to APROMAC (2022), rubber plantations occupy in Côte d'Ivoire, nearly a third (32.5% or about 650,000 ha) of the current national forest cover, which is about two million hectares (Sonwa *et al.,* 2000, 2001). These statistics explain that rubber culture is one of the sources of degradation of Ivorian forests. There is therefore a need to appreciate the dynamics of the natural flora of the undergrowth of rubber plantations. This is essential for thinking about the development of rubber plantations and the management of the biodiversity of their undergrowth. The general objective of this study is to evaluate the impact of rubber culture on the natural flora following an age gradient of plantations. Specifically, this will involve:

- Characterize the floristic composition of the understory of rubber plantations;

- Assess the floristic similarity between rubber plantations and forest formations;

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- Determine the evolution of the number of natural species in the understory of rubber plantations according to age.

I. STUDY SITE

The study was conducted at the Forest Research Station of the National Agricultural Research Centre (CNRA) in Anguédédou, a locality in the Abidjan District, located precisely in the municipality of Songon (Figure 1). This station is an agricultural and forestry testing site. Located in the south of Côte d'Ivoire, in an area of dense moist evergreen forest (between 5°22' and 5°25' north latitude and 4°8' and 4°1' west longitude), it bathes in a humid, sub-equatorial, warm tropical climate. This type of climate is characterized by two dry seasons and two wet seasons, with an average annual rainfall of 1784 mm (Assiri *et al.*, 2015). The soil is ferralitic from tertiary sand, with a sandy-clay texture (Kéli *et al.*, 1992; Brou, 2005). To collect data from this work, we selected rubber plantations (active) of various ages, to which we added an abandoned rubber plantation and a secondary forest used as a control plot. Twelve (12) plots were selected. The various rubber plantations studied were grouped into four (4) age classes, namely [1-5 years], [6-10 years], [11-20 years] and [21-40 years]. The abandoned rubber plantation was considered as a transitional biotope between the plantations still exploited and the secondary forest.

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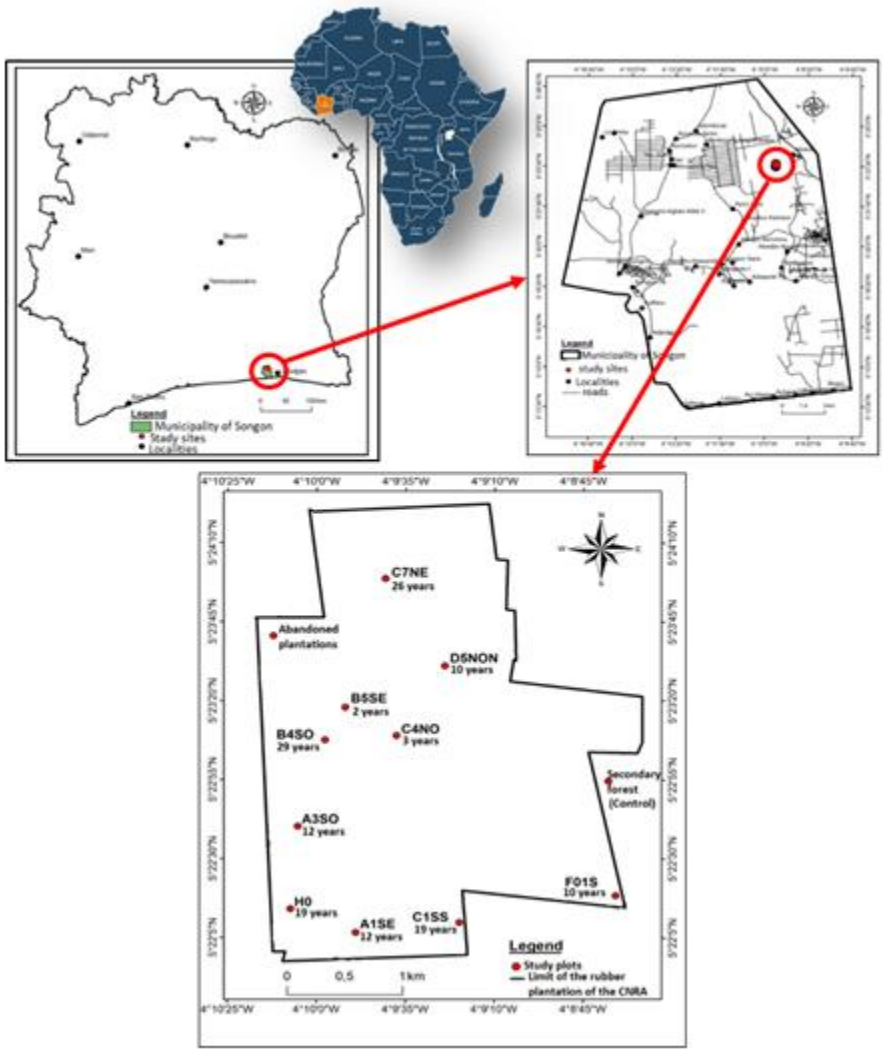

Figure 1: Location of study sites and spatial distribution of individual plots (CNRA, 2022)

II. STUDY METHODS

1. Data collection

For the characterization of the floristic composition of the undergrowth of rubber plantations, the surface survey method was adopted. Thirty-six (36) plots of 20 m x 10 m, or 200 m², were installed in twelve (12) biotopes. In each plot, all species have been inventoried. For a better knowledge of the undergrowth flora of these rubber plantations of different age classes, itinerant floristic surveys were also carried out. This botanical survey method was used by Aké-Assi (2001, 2002). It consists of walking through the environment, in all directions, noting all the plant species encountered (Aké-Assi, 1984). In order to appreciate the plant species of the

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undergrowth of the rubber plantations, the flora of a surrounding forest, considered as witness, was investigated.

2. Data analysis

2.1. Floristic Analysis

2.1.1. Specific wealth

Specific richness is defined by Aké-Assi (1984) as the number of species within the boundaries of a territory, without judging their frequency, their abundance or even the size and productivity of the species encountered. In this study, it was determined by listing and counting the plant species encountered in each biotope.

2.1.2. Ecological affinity of ligneous species

The ecological affinity of the natural plant species inventoried in the different biotopes was determined from the counts of sciaphil or shady species (sb), pioneer species (pi) and heliophilic species (nph). Pioneer and heliophilic species are species that, although present in the undergrowth, require openings for optimal development and sciaphil or shade species are those that develop freely in the shade of other species (Hawthorne, 1996). According to Molino & Sabatier (2001), a high rate of presence of sciaphil species in a disturbed environment indicates a reconstruction of a secondary forest. In this study, the evaluation of ecological affinities allowed to characterize the impact of rubber plantations on the natural flora. The proportion of these species was determined by the quotient of the number of species of each ecological affinity by the sum of all the ecological affinities of the biotope, all reduced to 100. It is expressed as a percentage.

2.1.3. Chorology and endemism of natural plant species

The study of the chorology and endemism of the inventoried plant species was based on the criteria of phytogeographical distribution. Chorology is characterized by species belonging to the Guineo-Congolese (GC) and Soudano-Zambezian (GC-SZ) regions. Endemism refers to species belonging to a restricted and well-identified geographical area. These may be species belonging exclusively to either West Africa (GCW species), Upper Guinea forests (HG species) or Côte d'Ivoire (GCi).

2.1.4. Rare and/or endangered species according to IUCN, inventoried in the various biotopes

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The assessment of rare and/or endangered species was made on the basis of the Red List prepared by the International Union for Conservation of Nature (IUCN, 2016). IUCN, based on criteria for the rarity of certain taxa at the national, regional or international level, proposed lists of species with special status, which they described as rare and/or threatened with extinction. According to this author, a species is threatened when it becomes rare nationally, regionally or internationally. This IUCN Red List includes eight (8) species categories based on different biological factors related to the risk of extinction. They are: collapsed species (CO), critically endangered species (CR), endangered species (EN), vulnerable species (VU), near threatened species (NT), species not affected (LC), Insufficient data (DD) and not assessed species (NE). The comparison of the floristic list of this study with that of IUCN (2016) made it possible to list the rare species and/or threatened with extinction of the Ivorian flora, encountered in the plantations of rubber trees still in operation, in abandoned plantations and in the forest fragment. There are three categories of species on the IUCN list. These are species not affected (LC), vulnerable (VU) and near threatened (NT). The assessment of these species in each biotope was made by the ratio between the number of rare species and the total number of species inventoried in the biotope.

2.1.5. Floristic similarity of the different inventoried biotopes

The floristic similarity of the different biotopes inventoried was made from the hierarchical upward classification (CAH) or dendrogramme «cluster analysis». The hierarchical upward classification was carried out using the binary similarity matrix of Jaccard (1901). The similarity index of Jaccard (J) measures the similarity between two surveys on the basis of the numbers of common and clean species. It is calculated according to the formula:

$$\mathbf{J = (a/a+b+c)}$$

With "**a**" number of species common between two biotopes; **"b"** the number of species specific to the biotope x and **"c"** the number of biotope-specific species y.

The values of this index vary from 0 to 1, depending on whether the two species lists have no species in common or whether the two species lists and their frequency are identical. The Jaccard similarity values were used directly to achieve the hierarchical upward classification (CAH) to group biotope pairs in order of decreasing similarity (Ward 1963). The principle of this method of analysis is based on the separation of biotopes according to their floristic composition. Hierarchical Upward Classification (CAH) was performed with XLSTAT software version 16.0.

2.2. Natural regeneration of ligneous species

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The study of natural ligneous regeneration was conducted by counting ligneous individuals with a diameter of 2.5 cm or less in 5 m (25 m²) side quadras. Individuals of all ligneous species surveyed were distributed according to biomorphological types. It is the trees of more than 30 m of height called megaphanerophytes (MP), the trees of height between 8 and 30 m qualified as mesophanerophytes (mP), the shrubs of height between 2 and 8 m which are microphanerophytes (mp) and shrubs between 0.25 and 2 m tall called nanophanerophytes (np).

2.3. Statistical Analysis

2.3.1. Evolution of the number of natural subsurface species in rubber plantations by age according to linear regression

The evolution of the number of natural subsurface species in rubber plantations as a function of age was determined through a correlation test. To test the correlation between two variables, two statistical techniques are commonly used. It's about correlation and regression. If one wishes to obtain a statistic indicating the degree of relationship between two variables, X and Y, one speaks of correlation. On the other hand, if more is done to predict a variable Y as a function of another variable X, the term regression is used (Tomassone *et al.*, 1993). In this study, X refers to the age gradient of rubber plantations and Y, the number of natural plant species in the undergrowth. Y is the dependent variable and X is the independent variable. This means that the number of species changes with the age of the plantations. In this case, where quantitative parameters were calculated, linear regression was used. The approach consisted in developing the equation to predict the variable Y (number of species) by knowing the variable X (age of plantations).

2.3.2. Means Comparison Tests

An analysis of variances and comparison of means was applied to the various calculated parameters, to observe or not any significant differences between biotopes, with an error of 5% ($p < 0.05$). For $p < 0.05$, the difference is significant, but when $p > 0.05$, the difference is not significant. This analysis was performed with XLSTAT software version 7.1.

III. RESULTS

1.1. Floristic composition of the understory of rubber plantations

1.1.1. Specific Wealth

The global flora from inventories (itinerant inventories and surface surveys) of all four age classes of rubber plantations, abandoned rubber plantations and secondary forest is rich in 152 plant species (Table 1). In this flora, we find 18.88% herbaceous species, 15.38% lianescent

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species and 65.73% ligneous species. Of all the biotopes surveyed, the secondary forest is the richest, with an average number of 103 species, mostly composed of ligneous species (60%). Abandoned rubber plantations and the youngest plantations from 21 to 40 years follow with 75 and 48 species, respectively. Plantations between 6 and 20 years old recorded fewer natural plant species in the undergrowth with an average number varying between 34 and 40 species. The proportion of herbaceous species, which was 37.21% in 1-5 years plantations, declined as plantations age. It is 16.22% in plantations from 21 to 40 years. However, herbaceous plants are again important in abandoned plantations (27.45%). The same is true for ligneous species, which, reduced considerably in plantations from 6 to 10 years (34.38%), became abundant in plantations over 21 years (59.46%) and abandoned (50.98). This shows that as rubber plantations age, the number of natural plant species increases, especially ligneous ones.

Table 1: Floristic richness of the various inventoried biotopes

		Total number of species	Floristic composition (%)		
			Herbaceous species	Lianescent species	Ligneous species
	Global inventory of all biotopes	152	18.88	15.38	65.73
Exploited and abandoned rubber plantations (130 species)	[1-5 years]	43 ± 8.2 c	37.21	20.93	41.86
	[6-10 years]	34 ± 8.2 d	28.13	37,50	34.38
	[11-20 years]	40 ± 7.8 d	17.86	17,86	64.29
	[21-40 years]	48 ± 8.1 c	16.22	24,32	59.46
	Plant. aband.	75 ± 8.2 b	27.45	21,57	50.98
Control	Secondary forest	103 ± 8.2 a	10	30	60
	p-value	0,001***			

Significance threshold of tukey tests : *< 0,05 ; **< 0,01 ; ***< 0,0001

1.1.2. Ecological affinity of ligneous species

The study of the ecological affinities of ligneous species in the six (6) biotopes investigated shows that pioneer species (species of open environments) are more abundant in rubber plantations from 1 to 5 years with a rate of 69.77% (Figure 2). The proportion of these species decreases with the aging of plantations up to 51.22% in plantations over 21 years of age. Their rate is still low in abandoned plantations (47.50%). Heliophilic species (species of open and/or closed environments) are best represented in the 11 to 40 year rubber plantations with proportions ranging from 17.07% to 20.59%. In abandoned plantations, this rate is 15.50%. At the level of sciaphil species (species of closed environments), the highest proportion was observed in secondary forest with 57.28% recovery rate. Abandoned plantations follow with

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37% of species of closed environments. According to these results, it should be remembered that the ligneous pioneer species, characteristic of open environments, dominate the flora of very young rubber plantations. On the other hand, in abandoned plantations, the coverage rate of sciaphil ligneous species (species of closed environments), described as forest species, and becomes important in the undergrowth. That would mean that an abandoned rubber plantation could be restored to a secondary forest.

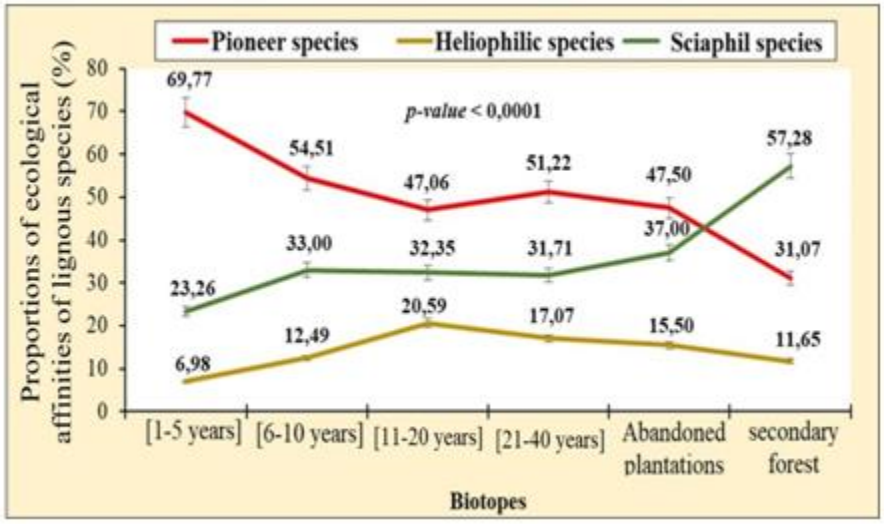

Figure 2: Distribution of ecological affinities of the natural ligneous species of the various inventoried biotopes (%)

1.1.3. Chorology and endemism of natural plant species

The study of chorology shows that the flora of all age classes of the rubber plantations and the secondary forest considered as control are given by the Guineo-Congolese species (GC), especially in plantations of 6 to 10 years with 84.38% of its flora (Table 2). The other five (5) biotopes follow with proportions ranging from 70.87% (secondary forest) to 74.42% (plantations from 1 to 5 years). The few species in the Guineo-Congolese and Soudano-Zambezian (GC-SZ) regions surveyed are more confined in secondary forest (21.30%), in abandoned rubber plantations (18.33%) and in the youngest plantations from 1 to 5 years (16.28%). These species are rare in plantations from 6 to 40 years with very low coverage rates ranging from 8.82% to 9.76%. As for endemic species, they are more represented by species endemic to West Africa (GCW), especially in plantations from 11 to 40 years old with more than 14% of representativeness in the flora (Table 3). Thesespecies are*Angylocalyx oligophyllus, Anthocleista vogelii, Chassalia kolly, Chlamydocarya macrocarpa, Cnectis ferruginea, Napoleonaea vogelii et Tiliacora dinklagei*. Plantations from 1 to 5 years follow with only 9.3% GCW species. These

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are *Anthocleista vogelii, Campylospermum flavum, Cnectis ferruginea, Emilia praetermissa and Landolphia membranacea*. The proportion of GCW species is lower in young plantations aged 6-10 years (6.25%; *Cnectis ferruginea and Luffa cylindrica*), in abandoned plantations (6.67%; *Anthocleista vogelii, Mussaenda tristigmatica and Landolphia membranacea*) and in secondary forest (6.85%; *Campylospermum flavum, Maesobotrya barteri, Pavetta owariensis and Strephonema pseudo-cola*). For species endemic to the Ivorian flora (GCi), only 0.97%, 2.44% and 2.94% were inventoried, respectively in the secondary forest (*Albertisia cordifolia*) and in plantations from 11 to 20 years and from 21 to 40 years with the species *Albertisia cordifolia and Leptoderris miege*. At the level of species related to the flora of Upper Guinea (HG), abandoned plantations were the biotope to contain 1.67% in their flora. This is *Cola caricaefolia*. This indicates that the natural flora of the undergrowth of abandoned rubber plantations is relatively rich in endemic species.

Table 2: Chorology and endemism of natural plant species inventoried in the different biotopes

	Chorology (%)		Endemism (%)		
Biotopes	**GC**	**GC-SZ**	**GCW**	**Gci**	**HG**
[1-5 years]	74.42 b	**16.28 c**	9.30 b	0.00 c	0.00 b
[6-10 years]	**84.38 a**	9.38 c	6.25 c	0.00 c	0.00 b
[11-20 years]	73.53 b	8.82 c	**14.71 a**	**2.94 a**	0.00 b
[21-40 years]	73.17 b	9.76 c	**14.63 a**	**2.44 a**	0.00 b
Aband. Plant.	73.33 b	**18.33 b**	6.67 c	0.00 c	**1.67 a**
Secondary forest	70.87 b	**21.30 a**	6.85 c	0.97 b	0.00 b
p-value	0.034	0.0001	0.0012	0.0001	0.0001

1.1.4. Rare and/or endangered species according to IUCN, inventoried in the various biotopes

The floristic inventory of exploited and abandoned plantations and then secondary forest gives a list of nine (9) rare and/or endangered species according to the IUCN Red List (Table 3). Of these, seven (7) are species not affected by current extinction, but in the future (LC). These are *Albizia adianthifolia, Baphia nitida, Commelina benghalensi, Culcasia scandens, Gloriosa superba, Greenwayodendron suaveolens and Millettia zechiana*. These species are best represented in the flora of the youngest plantations from 1 to 5 years with a proportion of 11%. In this list, a nearly threatened species (NT) has been observed in almost all age classes of exploited rubber plantations. This is *Milicia excelsa*. Another species known as vulnerable (VU)

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has been recorded in the secondary forest (*Lophira alata*). Despite strong anthropogenic pressures in rubber plantations, they still contain in the undergrowth some rare species and/or threatened with extinction.

Table 3: Proportion of rare and/or endangered species in the natural flora of the undergrowth of the various biotopes inventoried

Biotopes	Species of special status					
	Speciesnot concerned (LC)		Vulnerable species (VU)		Near-threatened species (NT)	
	Proportion (%)	Species	Proportion (%)	Species	Proportion (%)	Species
[1-5 years]	**11.63**	*Albizia adianthifolia* *Baphia nitida* *Commelina benghalensis* *Culcasia scandens* *Gloriosa superba*	-	-	**2.33**	*Milicia excelsa*
[6-10 years]	**9.38**	*Albizia adianthifolia* *Baphia nitida* *Culcasia scandens*	-	-	-	-
[11-20 years]	**5.88**	*Albizia adianthifolia* *Baphia nitida*	-	-	**2.94**	*Milicia excelsa*
[21-40 years]	**7.32**	*Baphia nitida* *Culcasia scandens* *Millettia zechiana*	-	-	**2.44**	*Milicia excelsa*
Plant. aband.	**5.00**	*Albizia adianthifolia* *Baphia nitida* *Culcasia scandens*	-	-	-	-
Secondary forest	**2.91**	*Baphia nitida* *Culcasia scandens* *Greenwayodendron suaveolens*	**0.97**	*Lophira alata*	-	-

1.2. Floristic similarity of different biotopes inventoried

The ascending classification of the six (6) biotopes based on the presence or absence of the species indicates four (4) groups following the truncated discontinuous line (Figure 3). Thus, depending on the degree of floristic resemblance, the young plantations of 6 to 10 years and 11

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to 20 years form a group, distance from the secondary forest. This would mean that from 6 to 20 years, the natural flora of the rubber plantations is almost similar, but different from that of the secondary forest. The abandoned rubber plantations and secondary forest form another group. This observation shows that when rubber plantations are abandoned, the natural plant species that regenerate there are practically similar to a secondary forest (Figure 4a and b). Plantations of 1 to 5 years are between the groups of plantations of 6 to 20 years then abandoned plantations and secondary forest. This means that the flora of the youngest rubber plantations from 1 to 5 years, constitutes a transition between forest formations and plantations in full farms.

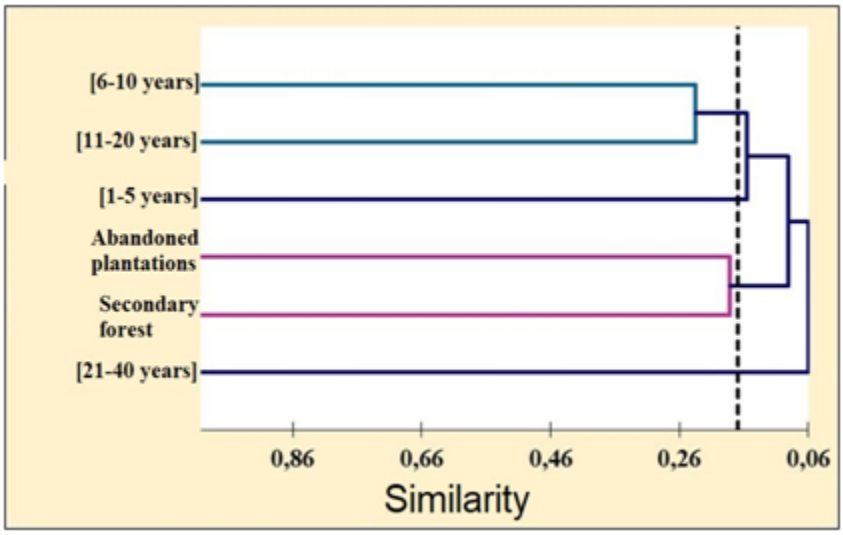

Figure 3: Hierarchical classification of the six inventoried media based on the Euclidean Bonding Distance Index

Figure 4: Appearance of an abandoned rubber plantation (a) and secondary forest (b) surveyed

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1.3. Evolution of the number of natural subsurface species in rubber plantations by age according to linear regression

The assessment of the correlation between the number of species and the age of rubber plantations through linear regression (Figure 5) shows that point clouds are more or less adjusted on the lines of equations y = 3.4x + 17.5 for herbaceous species and y = 3.7x + 6.5 for ligneous species. The values of the coefficient of determination (R^2) tend towards 1, indicating a relationship between the two parameters. These results show that there is a negative (y = 3.4x + 17.5) and strong (R^2 = 0.78) correlation between the number of herbaceous species and the age of rubber plantations, and a positive (y = 3.7x + 6.5) and strong (R^2 = 0.85) correlation between the number of ligneous species and the age of the plantations. This means that the number of herbaceous species in rubber plantations decreases with the aging of the orchard. In contrast to ligneous, which increase with the ageing of plantations.

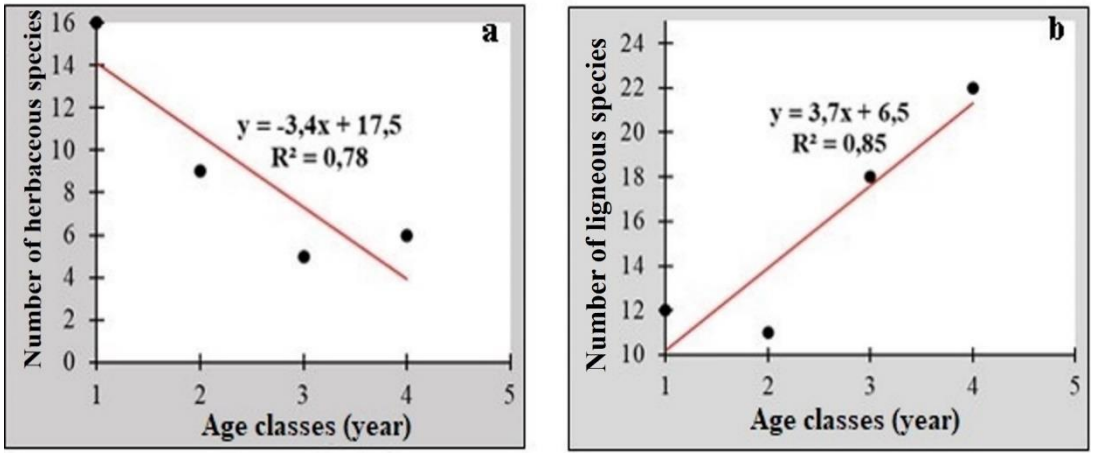

Figure 5: Diagrams of linear regressions of the number of herbaceous species (a) and ligneous species (b) according to the age of rubber plantations.

1: age classes1-5 years; 2: age classes 6-10 years; 3: age classes11-20 years; 4: age classes 21-40 years and 5: abandoned plantations

1.4. Natural regeneration of ligneous species

The study of the natural regeneration of ligneous indicates a high density of regeneration in abandoned plantations (35 ind./25 m²) and in old plantations of more than 20 years (31 ind./25 m²). In this regeneration, the density of shrubs (mp) is highest in all biotopes with values ranging from 15 ind./25 m² (1-5 years plantation) to 31 ind./25 m² (secondary forest), dominated by *Baphia nitida and Microdesmis kaeyana*. The trees best represented in the regeneration of rubber

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plantations of all ages are *Funtumia africana and Antiaris africana*. These results indicate that natural regeneration of ligneous trees is ensured in rubber plantations.

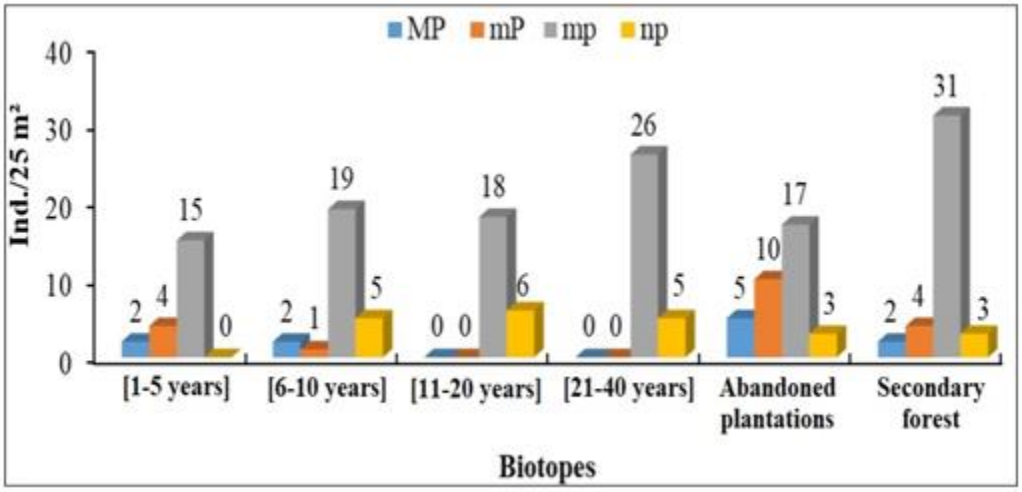

Figure 6: Histogram of the regeneration density of ligneous species of exploited and abandoned rubber plantations and secondary forest

PM: tree over 30 m tall; mP: tree between 8 and 30 m tall; mp: shrub between 2 and 8 m tall; np: shrubs between 0.25 and 2 m tall

IV. DISCUSSION

The study of the specific richness made it possible to inventory 130 natural plant species in rubber plantations. This floristic richness is less important than that recorded by Konan (2009) in the plantations of cocoa trees (143 species), a margin of 13 species. The low floristic wealth observed in the rubber plantations can be explained by the technical route used for this speculation. Indeed, when a rubber plantation is set up, all the original vegetation is systematically destroyed (Ballo, 2019). This is contrary to cocoa cultivation, where farmers in the early years of planting maintain a large number of ligneous after forest clearing (Sonwa *et al.*, 2001; Adou Yao and N'Guessan, 2006; Koulibaly, 2008). With the exception of the youngest rubber plantations of 1 to 5 years and especially of abandoned plantations, the influence of this crop on the natural flora is felt in plantations of 6 to 20 years, where we observe a drastic decrease in the number of species. Indeed, from 43 species in the youngest plantations of 1 to 5 years, this flora is reduced to 32 species in those of 6 to 10 years and to 34 species for 11 to 20 years. This is due to regular maintenance of these young plantations from 6 to 20 years old in order to reduce the nutritional competition with rubber trees in order to increase production. The emphasis on plantation maintenance with the intensive use of herbicides in this age class is due to the ease of bleeding and coagulum collection operations (Attobra *et al.*, 2012). Regular

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maintenance and especially the frequent use of herbicides negatively impacted endemic species in plantations from 6 to 10 years. According to Tchouto (2004) and Faucon (2009), endemic species are very sensitive to strong anthropogenic disturbances that can even cause the extinction of some typically habitat-related species. However, some rare and/or endangered species on the IUCN Red List (2016) have been observed in this undergrowth flora in rubber plantations of all ages. Over 20 years of operation, there has been a reduction in the frequency of maintenance of plantations and especially a low use of herbicides, following the closure of the canopy of the rubber trees. This has encouraged an increase in the number of natural plant species in older plantations. Indeed, from 32 species in plantations of 6 to 10 years, the number of species inventoried increased to 41 in those of 21 to 40 years and to 60 in abandoned plantations. The work of Sonwa *et al.* (2000) in Cameroon, Konan (2009) in Côte d'Ivoire and Mangaza *et al.* (2022) in Congo have shown that the scarcity of human actions in cocoa plantations promotes the gradual increase in the number of species with the age of plantations in the undergrowth. This floristic evolution could also be due to the rejection of strains and roots, and the germination of the seed stock of the soil under favourable conditions (Konan, 2016). In this evolution of the number of species of rubber plantations with age, a gradual decrease in the number of herbaceous species was observed in favour of ligneous. This may be due to the closure of the vegetation canopy that would have prevented the regrowth of herbaceous plants (Schnitzler *et al.*, 2012). The closure of the canopy of abandoned rubber plantations explains a good regeneration of the species of closed environment (sciaphil or shade species), characteristic of a forest in full restoration (Bakayoko, 2005). This observation would mean that an abandoned rubber plantation could be reconstituted into a secondary forest. Indeed, Dupuy (1998) and Pascal (2003) have shown that the process of reconstituting a degraded environment in a secondary forest follows a succession of species of open environment (pioneer or light species), species tolerant to both light and shade (heliophilic species) and closed species (sciaphil or shade species). The floristic similarity between the abandoned rubber plantations and the reference, secondary forest, highlighted by the ascending classification, is more indicative of the evolution of abandoned rubber plantations towards forest formations. This indicates that after several years of exploitation, a rubber plantation is able to recover into a secondary forest. In other words, rubberizing does not constitute a brake on the reforestation of degraded areas. The study of the ligneous regeneration of rubber plantations indicates a predominance of shrubs. The abundance of shrubs in this regeneration could be explained by the thinning that took place during the planting. The work of Konan (2016) has shown that the discovered environments are favorable to germination of the seed stock of shrubs. Indeed, according to Menzies (2000) and Nusbaumer (2003), shrubs are more tolerant of open environments while developing adaptive and competitive strategies. The good regeneration density of the ligneous could be explained by the quality of the soils of the old rubber plantations. Indeed, the extensive development of the rubber

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tree root system increases porosity and improves soil infiltration capacity. In the same way, the canopy is a real protective shield against the evaporation of water from the ground as well as temperature variations.

V. CONCLUSION

The characterization of the natural flora of the undergrowth of the rubber plantations of different age classes made it possible to follow and understand the impact of rubber culture on the natural flora. Cultivation techniques based on clearing, felling and slash-and-burn cultivation, cause degradation of biodiversity, mainly in young rubber plantations from 6 to 2 years old. In these biotopes, there is a drastic decrease in the number of species, due to frequent maintenance and the intense use of herbicides. However, as these plantations age, floristic diversity potentially increases, due to the scarcity of maintenance and herbicide use. The reconstitution of the flora in the old rubber plantations is done with a gradual decrease of the number of herbaceous species in favor of the ligneous ones, especially when the rubber plantations are abandoned. This flora is quite rich in endemic species such as *Chlamydocarya macrocarpa, Angylocalyx oligophyllus, Chassalia kolly, Mussaenda tristigmatica. It also contains some rare and/or endangered species which are Albizia adianthifolia, Baphia nitida, Commelina benghalensi, Culcasia scandens, Gloriosa superba, Greenwayodendron suaveolens, Millettia zechiana and Milicia excelsa.* The study of floristic similarity reveals that abandoned rubber plantations and secondary forests have a fairly large number of plant species in common. This means that when rubber plantations are abandoned, their vegetation gradually replenishes into a forest formation with a high density of ligneous regeneration. In other words, rubber chloride is not a barrier to the restoration of biodiversity in degraded areas. In view of the considerable potential for natural wood regeneration in abandoned plantations, it would be desirable to carry out further studies combining the conservation of biodiversity and the securing of natural resources, increased production of peasant rubber plantations in the form of agroforestry.

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