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(RESEARCH ARTICLE)

Impacts of the anthropic activities of the decade of politic and army crisis on the diversity of the woody forest plants in the south of the Sangbé Mount national park, Côte d'Ivoire

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Abstract

This study relates to the impact of the anthropic activities of the decade of Politic and army crisis of Côte d'Ivoire, on the dynamics of the woody plants family of the Southern part of the National park of the Sangbé Mount. The main aim was to characterize the impact of these activities on the dynamics of the arborescent ligneous family of the Park. In a specific way, it was: (1) to identify the sources activities of impact; (2) to analyze and evaluate the impacts of these activities on the dynamics of the ligneous family and (3) to put forward measures of attenuation or corrective to compensate for the losses in biodiversity. With this intention, floristic inventories were carried out according to the method of the surface in a device made up of 20 small squares of 2000 m ^{2} (50 m × 40 m) each one gathered in five blocks directed according to the cardinal points. Got results shows that the anthropic activities caused a strong reduction of the density, diameter, size and a reduction of the diversity of the woody plants family particularly that of the woody species with particular status. The compensation of these losses can result from the fight against the aggressions of the park by the sensitizing of the bordering populations and the biological control of *Chromolaena odorata*.

Keywords: Impact; Anthropic activities; Woody plants family; Dynamics; Diversity

1. Introduction

During the period of 2002-2012, Côte d'Ivoire underwent a series of politic and Army crises which have affected various fields. The sector of the environment which does not have escaped with the effects of these crises recorded many negative impacts on its various components. Most national parks and reserves of this country of which that of the Sangbé Mount, which before the crisis constituted a preciously preserved national heritage, was the object of various plundering which carried seriously reached to its integrity [1]. For this park, one noted as of the beginning of the crisis of 2002, a massive infiltration of the bordering populations which literally invaded its southern part [2]. They installed occupying cocoa plantations there of important surfaces. The resources of the park then were the object of anarchistic exploitations to the number of which appear the poaching, the taking away of the plants, the farm, the exploitation of the woody plants, the wood-cutting of heating, the traditional wood sawing; taking away of the non-woody forest products, and bush fires [2]. Thus, after the crisis, one does not have any information on the state of the diversity and the availability of the natural resources of this heritage. However the compensations and/or the proposals of corrective measures or an attenuation of the gradual losses in biodiversity require the knowledge of what exists firstly. In addition the proposal for a plan of rigorous management of the park must integrate measurements of compensation of losses in biodiversity; which losses knew disproportionate proportions during the decade of crisis. Also, the southern zone of the

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park sampled for the present study is the place where the anthropic activities because of the richness of the soil were concentrated.

The present study relating to the impacts of the anthropic activities of the decade of politic and army crisis on the diversity of the woody forest plant in the south of the Sangbé Mount national park was initiated to make up these deficits of data and/or information in order to put forward measures of attenuation or corrective to compensate for the losses in biodiversity.

2. Material and methods

2.1. Zone of study

The National park of Mount Sangbé (PNMS) is located in the west of Côte d'Ivoire between 7°51' and 8°10' of northern latitude and 7°03' and 7°23' of western longitude (Fig. 1). It comprises 33.5 km of conventional limits, 102 km of limit consist the waterways and 5 km of limit in tracks [3].

The PNMS is located at the transition from the subequatorial and tropical climates, marked by the passage of a bimodal pluviometric mode to a unimodal mode. The dry season hard from five to six months (November to March /avril) while the rainy season extends over seven months (from April to October). Annual precipitations vary between 1100 and 1600 mm. They are more abundant from June to July and especially in September. The great dry season lasts 5 even 6 months and is accentuated by 2 to 3 months of harmattan [3]. The annual average temperature of the zone of the park is of 24,5°C with minima lower than 10°C often recorded in December or in January; the annual average relative humidity of the zone of the park is 75%. The PNMS is located in a mountainous area belonging to the Guinean dorsal who is between Guinea and Côte d'Ivoire. The soils of the park are ferralitic type more or less unsatured. On the level of the fairly unsatured soils, there are the altered ferralitic soils

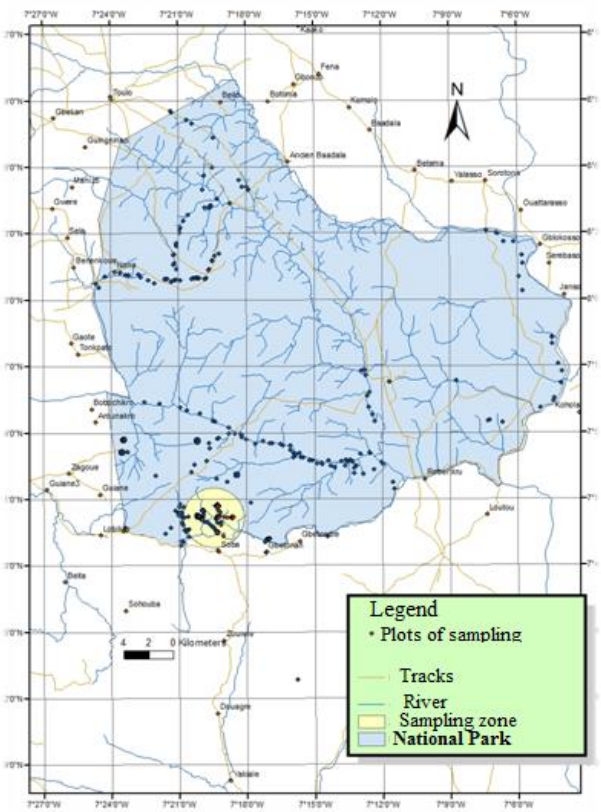

Figure 1 Map of localization of the study zone

The technical material used for the data-gathering is composed of a map of soil occupation which guided in the selection and the sampling of the sites of inventory, of a GPS for the catch of the geographical contact, of a compass for the

orientation on the soil, of a digital camera for the catches of sight, of a ribbon-meter for measurements of the circumferences of the woody plants and shears for the cutting of the specimens of flora.

2.2. Choice of the sites

The sampling of the sites of study was based on three criteria: the intensity of the anthropic activities; the representativeness of the sample whose size must be higher or equal to 10% of the surface of the southern block of the park [4-5] and the diversity of the vegetable formations and/or ecosystems.

2.3. The device of inventory

The study zone was subdivided in five blocks comprising four small squares each one. The unit blocks were laid out according to the Southern orientation, Center, Northern, and Western as Gautier et al. (1994) recommend it for the method of surface. The surface of each small square was of 2000 m ^{2} (50m X 40 m), the blocks were distant of 1000 m. the blocks and the small squares were numbered following their position (Fig.2). On the whole twenty (20) small squares were delimited within the five blocks. These blocks were mainly located the zones having known strong anthropic pressures. The Blocks North and East were taken as witnesses.

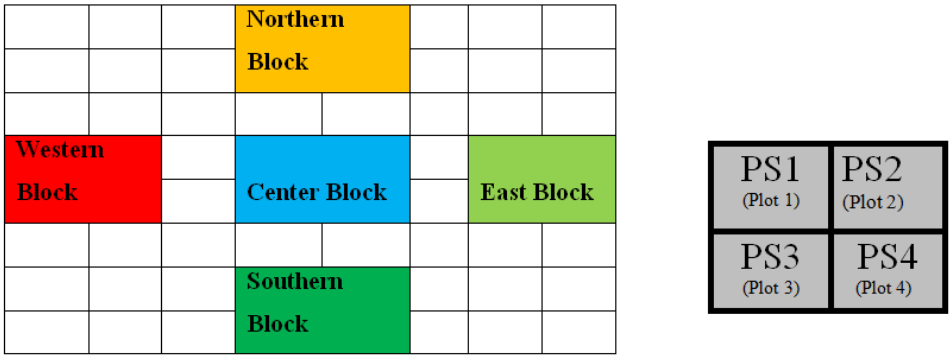

Figure 2 Device of sampling in the blocks

2.4. Data Collection

2.4.1. Inventory of the woody plants

In the small squares, linear transects of 4 m broad and 50 m long were installed for the inventory of the woody plants. During inventories, all the woody species within each block were identified. To these inventories were associated dendrometric estimates based on measurements of the sizes and the DBH (Diameter at height of chest). During measurements the specimens whose circumference was lower than 20 cm were proscribed. The blocks protected from these factors anthropic were taken as witnesses. Indeed, these blocks are the climacteric stage of vegetation of the zone. Thus, the block East was selected like witness for the pieces sampled in forest zone. The northern block was used as witness for the blocks installed in the savannas vegetations.

2.5. Method of treatment and data analysis

2.5.1. Estimate of the specific wealth and the diversity of the woody plants

The specific richness represents the number of plant species identified on the site. The diversity of the inventoried ligneous plants was estimated starting from the Shannon and Weaver index [6]. Simple, compared to other indices, the index of Shannon made it possible to estimate the specific diversity of each site of the zone of study. Independent of the sample size this index is obtained by the formula:

$$H' = -\sum_{i=1}^{n} Pix \log_2(Pi),$$

With Pi = ni/N; nor being the relative frequency of species I in the unit of sampling and N= the sum of the specific relative frequencies.

The maximum value of this index (Hmax) is equal to log (N). Thus, more the value of the H' index is high, more diversity is large. In addition, according to Adou and N'guéssan [7], the balance between the species, which corresponds to a high value of H', is regarded as characteristic of a good biodiversity likely to be maintained durably.

2.5.2. Index of equitability of Piélou

This index made it possible to give an account of the regularity of the distribution of the listed woody plants and the quality of the organization of the species. It also makes it possible to evaluate the relative abundance of each taxon (Groga, [8]). Its formula is:

$E' = H'/\log_2 N$,

With: N= full number of the species in a sample; E' takes the zero value when only one taxon dominates and 1 when all the species has the same abundance.

2.5.3. Comparison of the woody flora of the inventoried sites

From the floristic point of view the sites of the inventoried woody plants were compared by the Sorensen similarity coefficient [9]. This coefficient makes it possible to check the homogeneity of the flora of the sites when they are assembled twicely. It is determined by the following formula:

$Cs = Cs = \frac{2c}{a+b} X\ 100$,

Where A and B respectively represent the numbers of species present on the sites A and B and C the number of species common to the both (2) sites. This coefficient (Cs) varies from 0 to 100% according to whether the two sites are completely different (C = 0) or identical (a= b= c). For a coefficient equal to or higher than 50%, the two sites concerned are regarded as identical on floristic view.

2.5.4. Ecological groups

Factor analyses of Correspondences (AFC) were carried out in order to determine the ecological factors which influence the distribution of the woody plants significantly. The selected factors were the soil type, the toposequence, the presence or the absence of water supply point and the anthropic factors. The analysis was carried out starting from software XLSTAT 5.03.

3. Results

3.1. Floristic richness

The floristic inventory made it possible to count sixty-nine (69) woody plant species in the south of the National park of Sangbé Mount. These species are divided into fifty-five (55) genus and twenty-four (24) families. The dominant families are Caesalpiniaceae (10 species), Rubiaceae (8 species) and Mimosaceae (7 species). In addition, with 38 inventoried species, the block East is rich in species. The southern block is in second position, with thirty-five (35) species. The blocks North and Center with respectively twenty-four (24) and twenty-three (23) woody species are fairly rich in woody plants. The Western block is the site which recorded the lowest floristic richness with eighteen (18) woody species.

3.2. Diversity of the woody flora of the inventoried sites

The values of the index of Shannon estimated in the various blocks are about 3.48 for the block Is, 3.47 for the Southern block, 3.04 for the Northern block, 2.96 for the block Centers and 2.76 for the Western block. These values revolve around the maximum average which is about 3.5. These values decrease of the block East to the Western block following the linear equation: = - 0,195x + 3.72. These values are strongly correlated (R^2 = 0.9246; Fig. 3). The variable indices of equitability of piélou according to the sites of study are about the order of 0.956 for the blocks East, 0.975 for the Southern block, 0.954 for the Northern block, 0.946 the block Centers and 0.954 for the Western block. These values evolve according to a linear regression = 0,0047x3- 0,0426x2+ 0,1107x +0.884. These values are strongly correlated (R^2 = 923; Fig. 4).

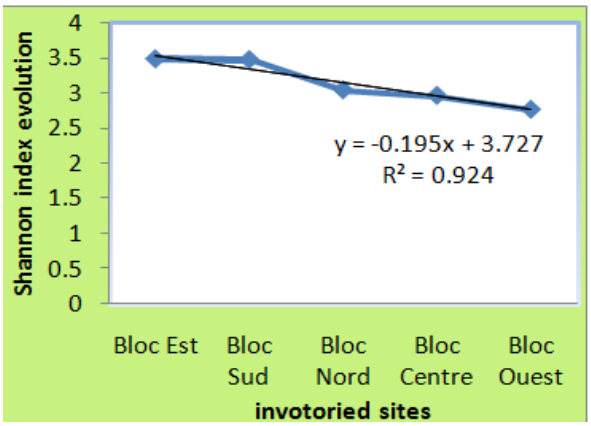

Figure 3 Evolution of the specific diversity of the plots inside the blocks

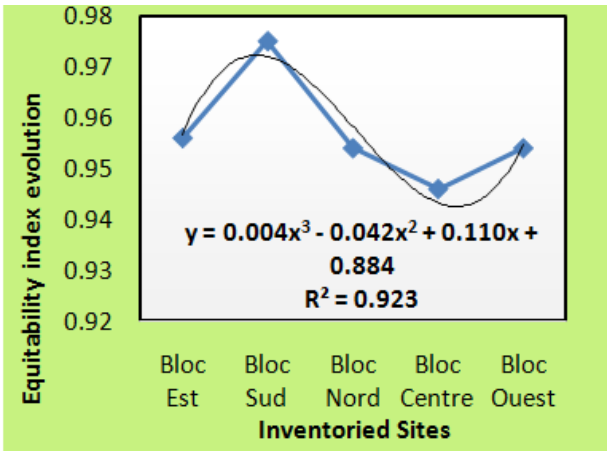

Figure 4 Evolution of the equitability of the plots inside the blocks

3.3. Floristic homogeneity of the sites of study

The estimates of Sorensen similarity coefficient made it possible to check the homogeneity of the flora of the sites. The collected data (table 1) indicate that, the similarity of the flora between four inventoried blocks is higher to 50%. The coefficient having the most raised value (63.82%) was estimated between the blocks of the North and that of the Center. Also, the Southern and Northern blocks (57.62%), South and East (52.05%) and that of East and Northern (51.61%) have a floristic resemblance. On the other hand the other values are lower than 50%. The lowest coefficient (25%) was obtained between the Centers and Western blocks.

Table 1 Sorensen similarity coefficients between the various inventoried blocks in percentage

	Southern Block	East Block	Centre Block	Western Block
East Block	52,05			
Centre Block	41,37	49,18		
Western Block	45,28	25	24,39	
Northern Block	57,62	51,61	63,82	33,33

3.4. Species with particular status

Sixteen (16) species of plants with particular status were inventoried in the study zone. Among these species 13 belong to the red list of the UICN [10], one (1) is endemic of Côte d'Ivoire, and three (3) regarded as vulnerable and threatened of extinction species according to (Aké Assi [11]). No African western endemic species was inventoried. The thirteen (13) species belonging to the red list of the UICN (2016) are *Afzelia africana*, *Albizia ferriginea*, *Detarium microcarpum, Entandrophragma angolense, Garcinia afzelii, Khaya grandifolia, Gilbertiodendron bilineatum, Lannea nigritana, Millettia*

zechiana, Melicia exsalsa, Parkia filicoidea, Pterigota macrocarpa, Pterocarpus santalinoides, Shumanniophyton problematicum, and *Triplochiton scleroxylon*. Among these species, seven (7) are classified vulnerable with a risk of extinction. They are: *Afzelia africana, Albizzia ferriginea, Entandrophragma angolense, Garcinia afzelii, Gilbertiodendron bilineatum, Pterygota macrocarpas and Schumanniophyton problematicum*. Some among them do not fill the criteria of a category of higher risk, but the abundant and largely widespread plants are included in this category. These plants are: *Detarium microcarpum* and *Millettia zechiana*. Finally a last category of this list relates to the species which have the statute of Quasi threatened. In this category, the species concerned are about to fill the criteria of a category threatened in the near future. These plants are *Milicia exselsa* and *Pterocarpus santalinoides*. The endemic species of Côte d'Ivoire inventoried is *Anthonotha sassandraensis*. One (1) only rare species (*Detarium senegalensis*) was inventoried on the site. The three (3) endangered species according to Aké-Assi (1998) are: *Detarium senegalensis*, *Lannea nigritana* and *Parkia filicoïdea*.

3.5. Ecological group (distribution of the arborescent species according to the blocks)

The projection (AFC) of the arborescent woody species of the sites on the axes (X, Y), made it possible to release six (6) groups of species set out again in the factorial design formed by the first two components (Axes F1 and F2). These axes explain 61.83% of variability observed. 35, 02% of this variation are applied to the axis F1 and 26.81% to the axis F2. The G1 group related to the block Centers, located negatively on the axis F1 and positively on the axis F2, contains the following species: *Ochna afzelii, Albizzia ferruginea, Ficus glumosa, Lannea nigritana, Ximenia americanaet Pterocarpus erinaceus*. The G2 group related to the Northern block and located in the same factorial zone with the Centers Block, contains: *Lophira lanceolata, Drypetes floribunda, Pterocarpus santalinoides, Detarium senegalensis, Schumanniophyton problematicum, Daniellia oliveri, Cuviera will acutiflora*, and *Chrysophyllum subnudum*. The G3 group located at the center is composed of species common to all the blocks. These species are: *Vitex doniania, Piliostigma thonningii, Crossopteryx febrifuga, Bridelia ferruginea, Parkia filicoïdeae, Cussonia arborea, Ficus capensis, Zanthoxylum zanthoxyloides, Olax subscorpioïdea*, *Uapaca togoensis and Diospiros mespiliformis*. The G4 group, located positively compared to the axis F1 and at the axis F2 and been dependent on the Western block contains: *Erithrophleum Guinéensis, Milletia zechiana, Ceiba will pentadra, Monodora muristica, Phyllanthus discodeus, Goliath Ficus, Antiaris toxicaria, Ficus exasperata, Markhamia tomentosa* and *Terminalia glaucescens*. The G5 group related to the southern block and located positively on the axis F1 and negatively on the axis F2 is composed of: *Dialium guinéensis, Afrosersalisia knighthood, Sterculia tragacantha, Lannea Welwitschii, Kigélia africana, Holarrhena floribunda, Gardenia ternifolia, Malacantha alnifolia, Anthonotha sassandraensiset Melicia exsalsa*. The G6 group located negatively compared to the axes F1 and F2 and been dependent on the block contains: *Cola cordifolia, fragrant Anthonotha, Albizia ziggia, Gardenia erinaceus, Ficus mucuso, Bligia sapida, Carapa will procera, Trichilia prieuriana, Trichilia monadelpha, Chassalia afzelii, Parkia filicoïdeae, Anthoclesta nobilis, Afzelia africana, Psychotria vogeliana and Turraea heterophylla* (Fig.5).

3.6. Ecological factors and repartition of the species in the southern block

The projection of the woody species and the environmental factors, on the axes (X, Y) emphasized four (4) ecological groups clearly distinguished and left again in the factorial plan formed by the first two components (Axes F1 and F2). These axes explain 84.63% of the variability observed with 52.68% applied to the axis F1 and 31, 95% with the axis F2. The groups G1 positively located on the axis F1 with a broader distribution on the axis F2 contains the species like: *Cola cordifolia, Schumanniophyton problematicum, Monodora tenuifolia Cola caricifolia, Carapa procera, Ficus glumosa, Sterculia tragacantha, Ficus capensis, Ficus mucuso, Ficus Goliath, Diospiros mespiliformis*. The species of this group are present around the water supply points and the humid zone and that of the sablo-argillaceous and argilo-sandy.type The G2 groups located negatively on the axes F1 and F2 not centred and restricted is composed of: *Afzelia africana, Terminalia schimperiana, Chrysophyllum subnudumetAlbizia ferruginea*. This group colonizes the soils with gravell, the underworld and the clay soils. The G3 groups located negatively on the axes F1 and F2 closer to the center of the factorial plan is composed of the species like: *Crossopteryx febrifuga, Bridelia ferruginea, Piliostigma thonningii, Parkia filicoïdeae, Parkia biglobosa*Cussonia arborea, *Olax subscorpioïdea, Uapaca togoensis, Ximenia americana, Pericopsis laxiflora* and *Zanthoxylum zanthoxyloides*. This group develops on the sandy-argillaceous and argiloceous-sandy soils. Finally the G4 group located negatively on the axis F1 and positively on the axis F2 is composed of all the other species and seems attached on the argilo-sandy soil type (Fig.6).

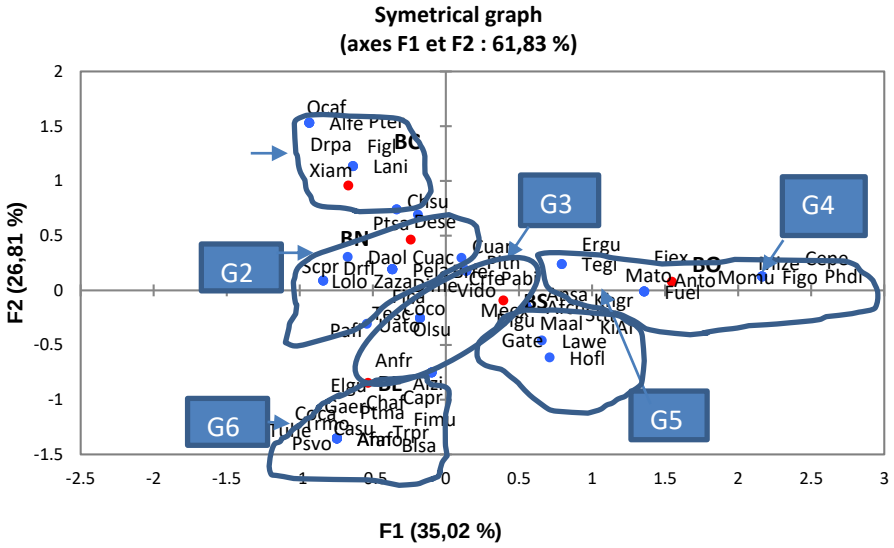

Figure 5 Projection of the arborescent woody species and the blocks on the axes

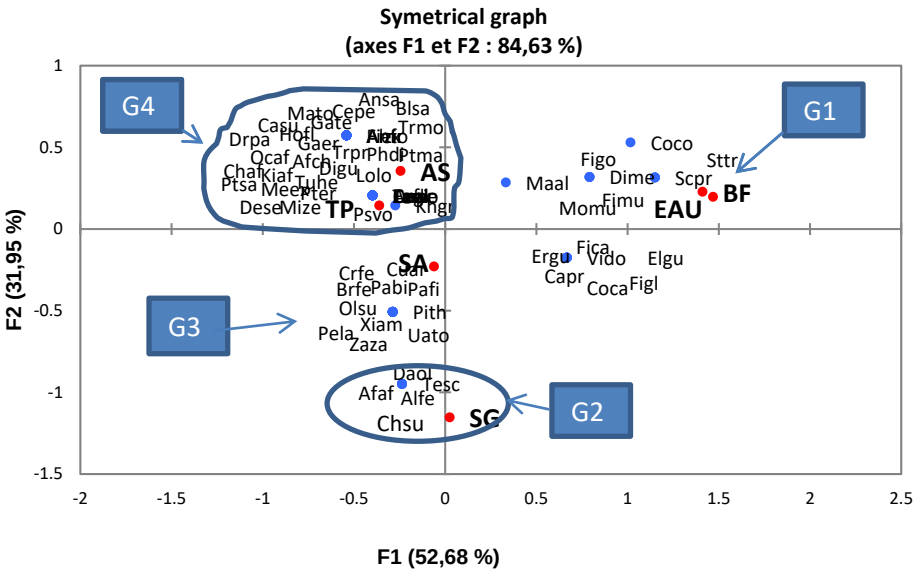

Figure 6 Projection of the arborescent woody species and the ecological parameters on the axes

4. Discussion

4.1. Diversity of the woody species of the study zone

The woody flora of the Southern zone of the PNMS is fairly diversified. It contains only sixty-nine (69) woody species left in twenty-four (24) families and fifty-five (55) genuses. The dominant families are Caesalpiniaceae, Rubiaceae and Mimosaceae. ENGREF [12] and Poilecôt [13] had inventoried five hundred forty-five (545) floristic species including 300 woody species in the PNMS. Compared with the results of Poilicôt (1996) and ENGREF (1996) the number of arborescent species inventoried in this study is much reduced. The sample size is the factor which discriminated the number of woody species. Indeed, the work of these authors concerned the entire park whereas the present study was limited only to the south of the park and on a surface equivalent to the 1/10e of the total surface area of the park. In addition to the sample size, the reduction amongst woody species can also be related to the impact of the anthropic activities which involved the disappearance of certain species in the zone of study. Indeed, the inventories made it possible to count several woody species died; which mortalities were caused by fire.

The abundance of the Rubiaceae in the study zone would be explained by the fact that this site is in the Guinéo-Congolese forest area wich is the field of predilection of Rubiaceae as it was announced by Aké-Assi [14]. In addition, although the zone of study is fairly diversified in woody plants, one noted a variation of the floristic diversity of a site to the others. Thus, the diversification of the flora of the southern block in spite of the intense farm that it underwent, would be related to the resumption of the vegetation of this site after the decade of exploitation.

The strong anthropisation which is a factor of disturbance is the engine of this diversification as it underlined by Barima *et al*., [15] and Bogaert *et al*., [16]. The flora of the Southern Block having been under pressures, the processes of regeneration of the plant species is more important there compared to the other parts of the site.

The low floristic diversity of the western block was caused by the intense exploitation of the sawlog within this formation. Indeed, forestry holding even contributes to the vegetable degradation This activity creates artificial ecosystems such as the zones of demolition, the tracks of exploitation, the parks of loadings, the burned zones, etc, thus disorganizing the natural ecosystem, as it was mentioned by Kouamé [17]

The Centers and Northern blocks are diversified than the Southern and East blocks. This situation is related to the variation of the ecological medium. Indeed, these sites are in a wooded savanna where according to Adou, [18] floristic diversity is low than that of the forest zones. The Southern and East blocks present the greatest homogeneity, whereas the least homogeneous flora are those of the Centers, Western and Northern blocks. The high value of the floristic homogeneity of the Southern block would be due to the strong resumption of the vegetation on this site after the stop of the farmings. The block East which did not undergo any disturbance, shelters the woody species which kept their ecological condition intact. The floristic richness and the homogeneity of the center block would be related to the passages of fires which destroyed certain more fragile species to the profit of the pyrophytes.

The study made it possible to identify sixteen (16) species with particular status. These species were categorized according to the UICN (2016) list and that of Aké-Assi (1998). Whereas Poilecôt [19] and Aké-Assi (2002) had identified 22 rare or endemic and sixty-five species (65) rare or vulnerable species on three hundred and fifty (350 the) rare ones or endemic which account the flora of Côte d'Ivoire (Lauginie, 2007). Also, the presence of these species in the parck indicating a site with value of conservation of vegetable diversity. As mentioned above the low number of plant inventoried is dependent in keeping with the sample and with the anthropic activities which significantly limited the number of the floristic species in general and particularly as that of the arborescent woody plants. Indeed, the quoted authors carried out the floristic inventories on a wider surface. Also the anthropic activities resulted in the destruction of the forest, do not support the survival of these species which search a particular microclimate as it was mentioned by Sangne *et al*., [20]

4.2. Floristic homogeneity of the sites of study

The strongest floristic rates of homogeneity were noted between the Northern and the Centers blocks which shelter the same type of vegetable formations. The floristic resemblance between the Southern and Northern blocks, is related to the regeneration of the savannas species in the southern block. The floristic similarity of the Southern and East blocks would be related to the membership of these two blocks to the same forest ecosystem. But the dissimilarity of the Western and Northern blocks is related to the typology of the ecosystems to which these blocks belong. Indeed, the Western block is entirely located in a small island of forest and does not comprise enough species of savanna, whereas the Northern block comprises primarily species of savanna.

4.3. Space distribution of the species

The results of the AFC highlighted two independent groups of factors which influence the space distribution of the woody species. These factors are: the anthropic and the environmental factors. Among the anthropic factors which influence this distribution, agriculture appears in pole position. Indeed the Itinerant agriculture containing monoculture of cacao-tree which almost does not save an arborescent woody species is however what prevails in the zone. This factor anthropic thus influenced the space distribution of the woody species.

The second group of factors which influences the space distribution of the woody species is constitute of the environmental factors such as: the presence of water, soil types, geomorphology and the toposequence. The water proximity creates a microclimate which supports the impact strength of the species to the perverse effects of the climate changes. This fact is what explains the massive presence of numerous arborescent species around the water supply points. In addition, the soil and the toposequence are parameters of selections which influence the distribution of the species significantly.

5. Conclusion

This study relating to the characterization of the impact of the anthropic activities on the dynamics of the woody plants of the southern part of the National park of the Sangbé Mount lasting the decade of crisis made it possible to highlight the strong disturbance of the southern part of the Park. This disturbance created the reduction of the density, the diameter and the size of the woody species. Among these activities sources of impact, the itinerant agriculture was the most incidental factor. In addition to the reduction of the density of the woody plants, it caused the loss of numerous species with particular status. The impact of criminal fires on the dynamics of the woody plant was less compared to other anthropic factors. These various reductions of density of the woody plants and the disappearance of the large trees, caused a significant reduction of the diversity of the woody flora and several other consequences on the ecosystem of the study zone. One records today in this zone a modification of the floristic composition. The Southern and Western blocks located in forest zones are dominated today by species of savanna, pionniers species and heliophilous species. Arborescent numerous species still present are gathered around the water supply points thus testifying to the influence of the environmental factors which discriminate the regrouping and the distribution of these species.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

This article is not the object of any conflict of interest and has not been submitted to other journal for publication. Consequently we authorize the journal to publish it.

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