



(RESEARCH ARTICLE)



The diversity of the woody tree flora of Mont Sangbé National Park (west of the Ivory Coast)

Tra Bi Tra Jeannot* and Kouassi Kouadio Henri

Jean Lorougnon Guédé University, BP 150 Daloa, Côte d'Ivoire.

GSC Biological and Pharmaceutical Sciences, 2021, 14(03), 050–061

Publication history: Received on 22 January 2021; revised on 27 February 2021; accepted on 01 March 2021

Article DOI: <https://doi.org/10.30574/gscbps.2021.14.3.0058>

Abstract

The present study concerns the diversity of the woody tree flora of Mont Sangbé National Park (West of Côte d'Ivoire). The main objective was to analyze the diversity of the woody tree flora of this park impacted by human activities. Specifically, it involved (1) identifying the anthropogenic factors of the PNMS, sources of impact (2) assessing the impact of these activities on the diversity of the woody tree flora of the PNMS and (3) propose measures to mitigate biodiversity losses. To carry out the study, a device of 14 square blocks of 1 ha each was used on the impacted sites and the control sites in the different biotopes of the park. Each block was subdivided into 100 square plots of 100m² each. The results show that anthropogenic activities have reduced the flora richness of the park, modified its floristic composition and caused the disappearance of some status species. It was proposed as a measure to step up surveillance of the park.

Keywords: Impact; Anthropogenic activities; Tree species; Floristic diversity

1. Introduction

The deforestation, with its multiple harmful consequences, is becoming more and more threatening for the survival of humanity. In recent decades, we have noted the drastic disappearance of huge areas of forests across the world. According to the FAO (2010), during the decade from 2000 to 2010, around 13 million hectares of forests were converted each year to other uses around the world. Regarding the intertropical zone, tropical Africa is the hardest hit by this environmental crisis. The plant formations in this region are degrading at an alarming rate. The net change in forest area in intertropical Africa is the largest of any region in the world (FAO, 2001). In Côte d'Ivoire, the fall in forest areas was spectacular from 1960 to 2012 due to the anarchic logging of forests and the successive political and military crises suffered by the neighboring populations. The natural ecosystems there have been severely damaged by various human activities (UNEP, 2015). For the protected areas in the west of the country that belong to the Guinean Forests of West Africa Hotspot, one of the 18 tropical zones of global importance for their biodiversity, the damage has been considerable. Almost all of them have suffered various looting of natural resources and even human occupation for more than a decade. This seriously damaged their integrity (Virginie et al, 2012). In this area, the case of Mont Sangbé National Park, the subject of our study, was particularly critical. We noted on this site a massive introduction of riparian populations during the period of crisis suffered by the country from 2002 to 2012. This resulted in the disappearance of large areas of forest for the benefit of cocoa plantations and food crops. (Anonymous, 2014). After these events, we have no idea about the floristic diversity of this site. The last floristic inventories carried out in this park date back more than 20 years and took place before the 2002 crisis during which the situation worsened. It is in order to contribute to a better knowledge of the diversity of the tree-like woody flora of the PNMS after its anthropization that the present study was initiated.

* Corresponding author: Tra Bi Tra Jeannot
Jean Lorougnon Guédé University, BP 150 Daloa.

2. Material and methods

2.1. Study zone

The Mont Sangbé National Park (PNMS), with a total area of 97,000 ha, is located in the west of Côte d'Ivoire between 7 ° 51 'and 8 ° 10' north latitude and 7 ° 03 ' and 7 ° 23 ' west longitude (Figure 1). It straddles the departments of Biankouma (S / P de Biankouma and Gbonné), Touba (S / P de Fougbeisso, Guintéguéla and Touba) and Sifé has 33.5 km of conventional limits, 102 km of natural limits made up of watercourses and a 5 km limit in tracks (Lauginie, 2007). According to Guillaumet and Adjanohoun (1971), the PNMS is located in the mesophilic sector of the Guinean domain, a transition zone between the dense humid evergreen forest of the rainforest domain, the open forests and the savannas of the sub-Sudanese sector. The predominant climax for the southern part is dense humid semi-deciduous forest and for the northern part, open forest. The soils are highly desaturated type ferralitic in the southwest and mountainous part of the park and moderately desaturated in the other parts of the park. The climate is a transition type between subequatorial and tropical climates with five to six months of dry season and seven months of rainy season with an annual rainfall of 1100 and 1600 mm of water. The rather rich hydrographic network is dominated by the Sassandra River in the east and its tributaries the Bafing rivers in the south and Baba in the north. The main activity of the populations is agriculture, which is strongly dominated by food crops (cassava, taro, rice and maize which occupy a prominent place). Perennial crops, on the other hand, are made up largely of coffee, cocoa, cashew and rubber plantations. Livestock farming in the neighboring villages is of the traditional type and involves cattle, sheep, goats and poultry. Figure 1 shows the geographical location of the PNMS.

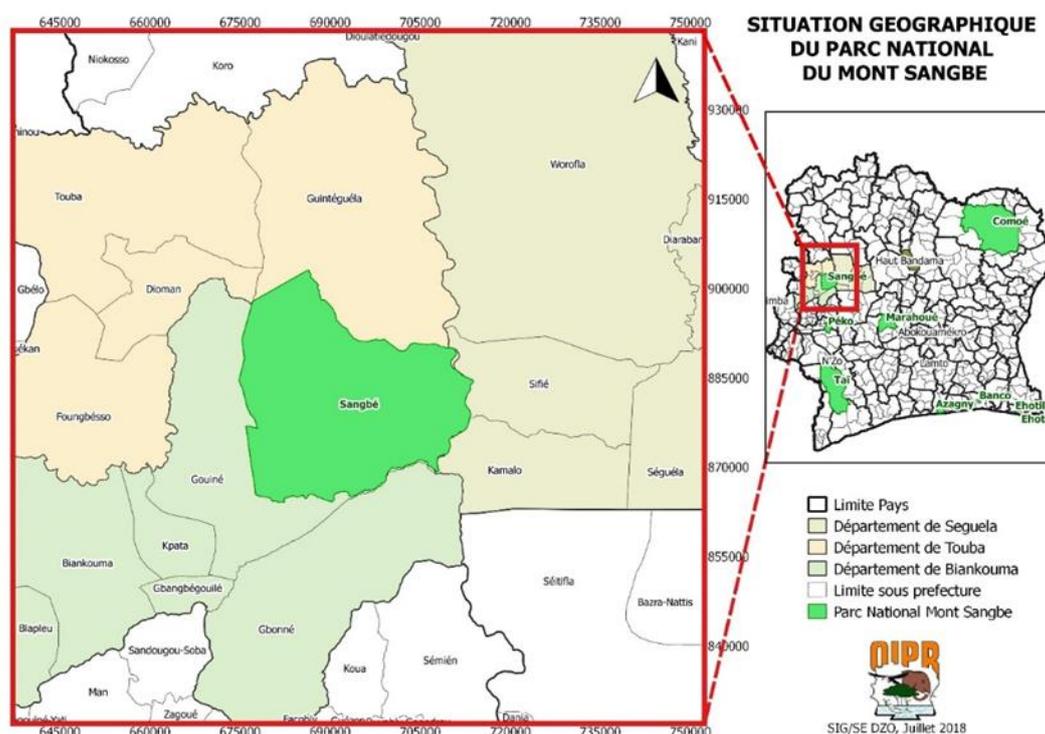


Figure 1 Situation géographique du Parc National du Mont Sangbé

2.2. Collection of data

The data was collected using three survey methods: surface surveys, traveling surveys and linear transects surveys. The surface survey method consisted in delimiting on the selected sites square plots of one hectare in area subdivided into 100 square plots of 100 m² each (10 m x 10 m). Each of these plots was covered entirely by recording the names, diameters at breast height (DBH) and sizes of all the woody species encountered. These surface surveys have been associated with the traveling method, which consists of traversing the plots in all directions in order to identify the species that the plot method has not been able to identify. For the line transect method, it consisted in delineating transects 500 m long and 20 m wide in areas of riparian forest which are quite narrow. All the species that border the watercourses and which are located within these transects have been recorded. The identification of the species was made from the flora of Aké-Assi (1982) and the UJLOG herbarium.

2.3. Data analysis

The richness of the tree flora of the site was determined from the number of species inventoried on the different blocks. Concerning the floristic composition, the analysis of the biological types was made based on the classification method proposed by Raunkiaer (1934) and the classification of species according to their phytogeographic distribution from the work of Aké-Assi (2001; 2002). Finally, the determination of species with special status, including endemic species, rare species and threatened species, was made from the IUCN red list (2019) and that of Aké-Assi (1998). The Shannon index (1848) was used to measure site specific diversity and the Pielou Equitability index (1966) to analyze the regularity of species distribution. Family Importance Values (VIF) and Species Importance Index (IVI) values were determined by summing the relative frequencies, relative dominances and relative densities (Mori et al. 1983). These indices are expressed as a percentage and are equal to 300 for all the families or species encountered on a studied area. The relative frequency of a family or a species is the ratio of the number of species found in that family to the total number of species found in a sample. The relative dominance and the relative abundance of a family or a species have the same definitions, at the taxonomic level. Finally, Sorensen's Coefficient of Similarity (1948) was used to discriminate study blocks. Its mathematical formula is: $C_s = (2c) / (a + b) \times 100$ where a and b respectively represent the numbers of species present on sites A and B and c the number of species common to the 2 sites. This coefficient (C_s) varies from 0 to 100% depending on whether the two sites have totally different ($c = 0$) or identical ($a = b = c$) plant compositions. For a similarity coefficient greater than or equal to 50%, the two sites concerned were considered to be floristically identical. The variability of the woody richness of the sites investigated was evaluated by the Kruskal-Wallis test. The Past software was used for performing the statistical tests.

3. Results

3.1. Evolution of qualitative diversity

3.1.1. Floristic wealth

A total of one hundred and eighty-seven (187) tree species have been identified, divided into one hundred twenty-five (125) genera and forty (40) botanical families. The riparian forest witness block (BFRT) with 56 species is the richest and the block impacted by agriculture in forest areas dense (BAFD) with 16 species is the least rich. The number of species in the other blocks are between these two extreme values. Table 1 presents the wealth in the blocks.

Table 1 Floristic richness of the inventoried sites.

Sites inventoried	Number of species	Number of genres	Number of family
BTFR (Ripicultural Forest Witness Block)	56	49	22
BTFD (Dense Forest Control Block)	52	43	23
BFRA (Forest Ripicole Agricole Block)	48	43	23
BTFC (Light Forest Witness Block)	47	41	24
BEF (Lumbering Block)	38	33	21
BF (Block impacted by Fire)	36	32	18
BDF (Cleared Block impacted by fire)	32	29	19
BPL (Woody sampling block)	28	25	16
BPT (Control Pasture Block)	28	28	18
BD (Cleared Block not impacted by fire)	26	20	15
BEAF (Block of Agriculture and lumbering)	19	19	12
BP (Pasture Block)	19	18	11
BAS (Agricultural block in savannah)	17	17	13
BAFD (Agricultural Block in Dense Forest)	16	15	11

Statistical test data

$t = 9.1218$ $p = 5.1704E-07$

Significant differences

In terms of genera, out of the one hundred and twenty-five (125) recorded, thirty-one (31) include at least two (2) species, i.e. 24.8% and 94, only one species, i.e. 75.2%. The majority of genera identified in the study area are therefore

represented by a single species. *Ficus* and *Cola* are the most represented genera of the PNMS. Table 2 shows the detail of the richest genres in the blocks. Across the PNMS as a whole, the most represented families, in decreasing order of the percentage of species, are: Caesalpiniaceae (10 p.c.), Rubiaceae (9 p.c.) and Moraceae (7 p.c.). In the blocks located in the savannah zone, namely BF, BAS and BTFC, the richest families are the Caesalpiniaceae, Euphorbiaceae, Fabaceae, Rubiaceae and Mimosaceae. Bignoniaceae were noted in the BAS block.

Table 2 Species richness of genera and families in blocks

Sites inventoried	Genera richer in species	Family richer in species
BTFR	<i>Baphia, Diospyros, Ficus et Garcinia</i>	Caesalp.(11%), Rubi., Euphor., Faba.(9%)
BTFD	<i>Albizia, Anthonotha, Khaya, Millettia, Pavetta</i>	Morac.(12%), Rubia.(10 %), Melia.(8%)
BFRA	<i>Ficus et Cola</i>	Morac.(13%) Melia., Sterc., Faba. (7%)
BTFC	<i>Ficus, Cola, Terminalia et Anthonotha</i>	Caesalpi.(15%), Rubia. (13%)
BEF	<i>Ficus et Albizia</i>	Méliaceae (15%), Moraceae (13%)
BF	<i>Ficus, Cola et Terminalia</i>	Caesalp.(17%), Rubi., Eupho. Mim (8%).
BDF	<i>Ficus et Cola</i>	Bignoniaceae (26%), Moraceae (26%)
BPL	<i>Ficus, Anthonotha et Parkia</i>	Caesal (12%), Bigno., Mélia., Mimo., Rub.(9%).
BPT	-	Combret. (14%) Anacar., Mimo., Rub.(10%)
BD	<i>Ficus</i>	Caesal.(19%), Mora..(15%), Bignon. (11%)
BEAF	-	Morac.(15%), Anaca., Caesa., Meli. Mimos(10%)
BP	-	Caesalpiniaceae (16%), Mimos. (16%)
BAS	-	Fabac.(18%), Bigno., Caesal.et Morac.(12%)
BAFD	-	Caesalpi.(18%), Bigno.,Combret., Fabac., Sterc.(12%)

3.1.2. Floristic composition

The microphanerophytes are the most represented with 1448 individuals (49 p.c.), followed by the mesophanerophytes with 807 individuals (28 p.c.) and megaphanerophytes with 512 individuals (17 p.c.). The nanophanerophytes are the least represented with 162 individuals or 6 p.c. The microphanerophytes are dominant in almost all of the blocks except the BDF, BEAF, BD, BEF, BTFD and BAS blocks. Mesophanerophytes are in the majority in BDF, BD, BEF and BAS blocks. Nanophanerophytes are in the minority at all sites. Finally, the Megaphanerophytes are dominant in the BEAF and BTFD blocks. FIG. 2 shows the percentages of the biological types of PNMS and FIG. 3, the proportions of these biological types in the different inventoried blocks.

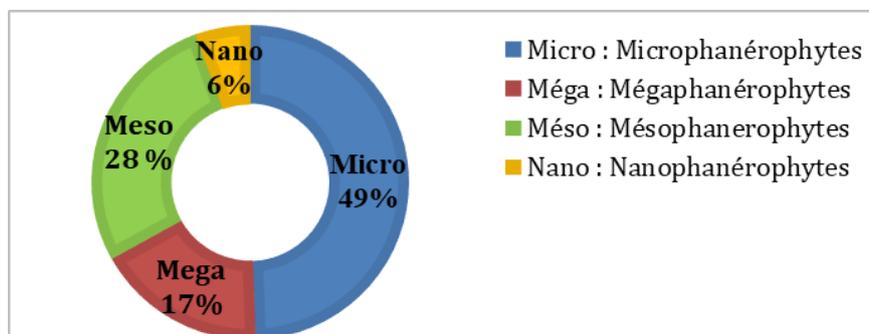


Figure 2 Spectrum of biological types of woody species inventoried at PNMS.

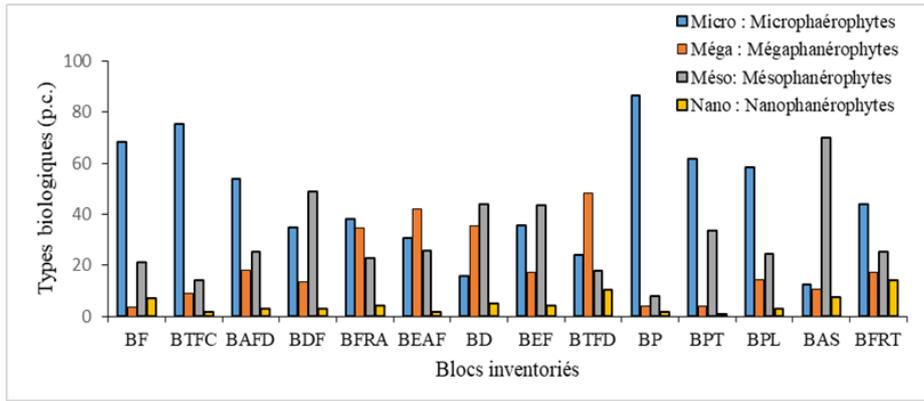


Figure 3 Histogram of the biological types of species inventoried in the blocks

The spectrum of the phytogeographic distribution shows that the Guineo-Congolese (GC) species are the most abundant, followed by the Guineo-Congolese and Sudano-Zambezi (GC-SZ) species see Figure 3. The species of continental tropical Africa (Afr- Tr) and the West African endemic (GCW) and Ivorian endemic (Gi) species are present on the site with 2 pc of the species. As for the introduced species (I) they were recorded there with (1p.c.) and species with a pantropical distribution (Pant) with 4 p.c. Finally, Afro-Malagasy species (Am) were recorded in the park with 2 p.c.

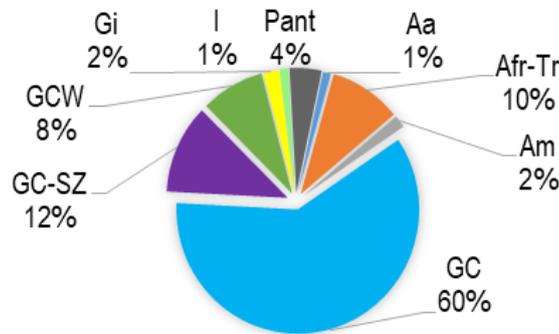


Figure 4 Phytogeographic distribution of tree species in PNMS

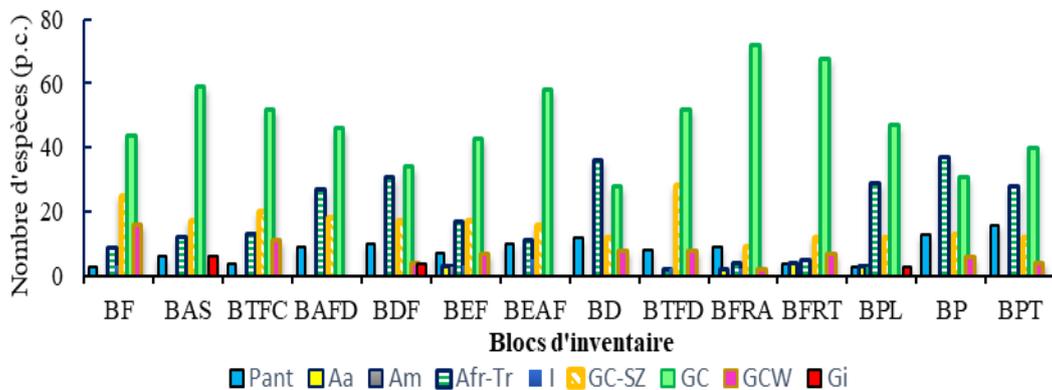


Figure 5 Histogram of the phytogeographic distribution of species in the blocks

At the level of species with special status ten (10) endemic West African species (GCW) including three Ivorian endemics have been recorded. They are *Anthonotha sassandrensis* Aubrév. & Pellegr, *Cassia fiki-fiki* Aubrév. & Pellegr and *Gymnostemon zaizou* Aubrev. & Pellegr. The BTFD block is the richest with three endemic West African species namely,

Gymnostemon zaizou (Gi), *Daniellia thurifera* and *Eriocoelum pungens*. For rare and endangered species, according to Aké-Assi (1998), six (6) species have been counted, namely *Afraegle paniculata*, *Parkia filicoidea*, *Lannea nigritana*, *Detarium senegalense*, *Syzygium guineense* and *Nauclea xanthoxylon*. At the level of IUCN (2019), seventeen (17) vulnerable species (VU), two (2) near threatened (NT) and four (4) endangered (EN) have been identified in the park. . Table 3 presents the threatened species according to IUCN (2019).

Table 3 List of endangered tree species of the PNMS according to IUCN (2019).

Catégorie	Espèces	Familles	Sites
IN (Endangered species)	<i>Cassia fiki-fiki</i> Aubrév. & Pellegr.	Caesalpiniaceae	BAS
	<i>Eriocoelum pungens</i> Radlk.ex Engl.	Sapindaceae	BF, BTFD
	<i>Mansonia altissima</i> (A. Chev.)	Sterculiaceae	BTFD
	<i>Pterocarpus erinaceus</i>	Fabaceae	BF, BTFD, BP, BTFC et BPT
NT (Near Threatened Species)	<i>Lannea welwitschii</i> (Hiern) Engl.	Anacardiaceae	BFRT, BDF, BP, BEAF, BTFD, BPT, BPL
	<i>Milicia excelsa</i> (Welw.) Berg.	Moraceae	BFRT, BDF, BD, BEF, BTFD
VU (Vulnerable species)	<i>Azelia africana</i> Sm.	Caesalpiniaceae	BF, BAS, BTFC, BTFD, BFRT
	<i>Albizia ferruginea</i> (Guill.et Perr.) Benth.	Mimosaceae	BEF, BFRA
	<i>Antrocarion micraster</i> A. Chev. & Guillaumin	Anacardiaceae	BTFC
	<i>Berlinia occidentalis</i> Keay	Caesalpiniaceae	BDF
	<i>Entandrophragma angolense</i> (Welw.) C. DC.	Meliaceae	BEAF, BPL, BTFD, BEF
	<i>Entandrophragma candollei</i> Harms	Meliaceae	BFRA, BFRT
	<i>Garcinia afzelii</i> Engl.	Clusiaceae	BFRT
	<i>Gilbertiodendron bilineatum</i> (Hutch.et D	Caesalpiniaceae	Hord-bloc
	<i>Gymnostemon zaizou</i> Aubrev. & Pellegr.	Simaroubaceae	BEAF, BTFD, BFRA, BEF
	<i>Khaya grandifoliola</i> C. DC.	Meliaceae	BEAF, BEF, BPL, BTFD
	<i>Khaya ivoriensis</i> A. Chev.	Meliaceae	BTFC, BTFD
	<i>Khaya senegalensis</i> (Dess.) A. Juss	Meliaceae	BEF
	<i>Nesogordonia papaverifera</i> (A.Chev) Ca	Sterculiaceae	Hord-bloc
	<i>Pseudospondias microcarpa</i> (A. Rich.)En	Anacardiaceae	Hord-bloc
	<i>Pterygota macrocarpa</i> K.Schum.	Sterculiaceae	BFRA
<i>Ricinodendron heudelotii</i> (Baill.) Heckel	Euphorbiaceae	BFRA, BFRT	
<i>Schumanniphyton problematicum</i> (A.Chev) A	Rubiaceae	Hord-bloc	

3.2. Evolution of quantitative diversity

3.2.1. Predominant families

The first three most prominent families of PNMS in decreasing order of their VIF are: Sterculiaceae, Caesalpiniaceae and Euphorbiaceae. The Sterculiaceae present the most dominant (12.97 p.c.), but the least frequent (6 p.c.). The Caesalpiniaceae family is the most frequent (11.2 p.c.) and the Euphorbiaceae family the least frequent (3 p.c.), but the most dense (12.73 p.c.). At the level of the inventoried sites, the predominant families are made up of the same

processions of families from the Guinean-Congolese regions of the tropical forests, namely the Caesalpiniaceae, the Fabaceae, the Euphorbiaceae, the Mimosaceae, the Combretaceae, the Bombacaceae, the Moraceae, the Apocynaceae, the Sterculiaceae, the Meliaceae and the Rubiaceae. However, Bignoniaceae have been reported in BAS, BDF, BD and BPL blocks. Table 3 shows the various predominant families.

3.2.2. Predominant species

In PNMS, the top three most prominent species in descending order of their IVI are: *Cola cordifolia*, *Uapaca togoensis* and *Hollarhena floribunda* (Table 4). *Cola cordifolia* is the most frequent with 8.55 pc and the most dominance (12.16 pc), while *Uapaca togoensis* is the most dense (10.55 pc) and the least frequent (5.59). The preponderance of species varies by site. In savanna, *Uapaca togoensis*, *Pericopsis laxiflora*, *Piliostigma thonningii* are the most preponderant in BF and BTFC, while in the BAS block they are: *Ceiba pentandra*, *Markhamia tomentosa* and *Malacantha alnifolia*. For the dense forest blocks namely BAFD, BEAF, BEF, BDF, BD, BPL and BTFD, the predominant species consist of *Cola cordifolia*, *Hollarhena floribunda*, *Ceiba pentandra*, *Parkia biglobosa*, *Ficus capensis*, *Combretum glutinosum* (for BAFD) etc. However *Gymnostemon zaizou* and *Tricalysia coriacea* are recorded only in the control block BTFD. Table 4 presents the lists of the first three predominant species of the park and of the blocks.

Table 4 Lists of predominant families and species of the PNMS and inventoried blocks

Sites	Families Preponderant	FR	DR	DoR	VIF	Species Preponderant	FR	DeR	DoR	IVI
PNMS	Sterculiaceae	6	10,1	12,97	29,07	<i>Cola cordifolia</i>	8,55	8,84	12,16	29,55
	Caesalpiniaceae	11,2	9,26	7,78	28,24	<i>Uapaca togoensis</i>	5,59	10,5	7,16	23,3
	Euphorbiaceae	3	12,7	7,912	23,64	<i>Hollarhena floribunda</i>	6,31	7,43	6,17	19,91
BF	Caesalpiniaceae	16,6	22,8	21,84	61,37	<i>Uapaca togoensis</i>	14,2	23,0	31,86	69,15
	Fabaceae	8,33	19	9,73	37,1	<i>Pericopsis laxiflora</i>	12,8	14	5,65	32,5
	Euphorbiaceae	2,78	0,47	32,73	35,98	<i>Daniellia oliveri</i>	8,71	6,32	7,11	22,14
BAS	Bignoniaceae	21,5	30,9	13,68	66,14	<i>Ceiba pentandra</i>	5,9	4,12	50,48	60,51
	Bombacaceae	6,15	4,12	50,48	60,76	<i>Markhamia tomentosa</i>	19,1	27,8	12,27	59,23
	Sapotaceae	21,5	26,8	8,981	57,32	<i>Malacantha alnifolia</i>	20,6	26,8	8,981	56,37
BTFC	Euphorbiaceae	4,1	40	40,85	85,02	<i>Uapaca togoensis</i>	20,9	34,6	37,32	92,91
	Caesalpiniaceae	14,5	17,3	16,15	48,06	<i>Piliostigma thonningii</i>	7,08	9,2	2,58	18,86
	Fabaceae	6,25	8,48	7,3	22,03	<i>Lophira lanceolata</i>	7,08	4,69	4,61	16,38
BAFD	Moraceae	17,6	15	7,07	39,79	<i>Ficus capensis</i>	16	16,4	13,35	45,83
	Combretaceae	11,7	20,5	4,19	36,49	<i>Cola cordifolia</i>	12,5	13,4	13,3	39,23
	Sterculiaceae	5,88	17,8	5,15	28,84	<i>Combretum glutinosum</i>	14,3	13,4	11,51	39,22
BDF	Bignoniaceae	15,6	26,6	19,20	61,48	<i>Hollarhena floribunda</i>	15,7	16	10,91	42,6
	Bombacaceae	3,12	0,89	35,56	39,57	<i>Ceiba pentandra</i>	1,16	0,88	35,56	37,6
	Apocynaceae	3,12	16	10,92	30,03	<i>Malacantha alnifolia</i>	13,37	19,1	2,02	34,5
BEAF	Sterculiaceae	14,3	48,8	44,46	107,5	<i>Cola cordifolia</i>	2,22	45,1	42,62	109,9
	Mimosaceae	9,52	4,87	15,17	29,57	<i>Parkia biglobosa</i>	3,7	2,44	14,65	20,79
	Meliaceae	14,3	7,31	3,90	25,50	<i>Terminalia glaucescens</i>	7,4	6,09	5,09	18,58
BEF	Bombacaceae	5,55	1,78	45,27	52,60	<i>Hollarhena floribunda</i>	28,27	31,45	26,35	86,07
	Apocynaceae	2,78	21,8	9,73	34,39	<i>Ceiba pentandra</i>	23,44	31,9	19,89	75,25
	Moraceae	11,1	7,14	7,98	26,23	<i>Tricalysia coriacea</i>	3,45	2,82	16,51	22,78
BD	Sterculiaceae	7,14	31,9	26,50	65,56	<i>Cola cordifolia</i>	17,2	21,87	9,73	48,8
	Bignoniaceae	7,14	34,2	21,14	62,55	<i>Markhamia tomentosa</i>	1,61	1,34	33,81	36,76

	Moraceae	14,3	4,69	12,84	31,81	<i>Ceiba pentandra</i>	5,91	7,14	0,32	13,37
BPL	Caesalpiniaceae	10,8	14,1	26,29	51,18	<i>Erythrophleum suave</i>	1,61	1,41	17,59	20,61
	Bignoniaceae	8,11	11,3	8,486	27,86	<i>Terminalia glaucescens</i>	8,06	8,45	3,51	20,02
	Combretaceae	5,40	14,1	5,588	25,07	<i>Bridelia ferruginea</i>	8,06	7,04	2,83	17,93
BTFD	Sterculiaceae	7,69	23,8	2,61	34,14	<i>Cola cordifolia</i>	19,46	27,33	21,07	67,86
	Bombacaceae	1,92	5	18,54	25,46	<i>Hollarhena floribunda</i>	6,48	6,21	5,55	18,24
	Mimosaceae	15,4	2,69	3,82	21,89	<i>Gymnostemon zaizou</i>	6,48	5,28	3,69	15,45
BP	Combretaceae	15	70,9	60	145,9	<i>Combretum glutinosum</i>	44,16	54,92	47,2	146,3
	Caesalpiniaceae	15	4,22	6,63	25,85	<i>Terminalia glaucescens</i>	15	14,55	11,37	40,92
	Anacardiaceae	10	3,75	11,39	25,15	<i>Lannea welwitschii</i>	5,83	3,28	10,29	19,4
BPT	Combretaceae	10,34	27,9	21,12	59,32	<i>Hollarhena floribunda</i>	11,61	16,06	6,88	34,55
	Mimosaceae	10,34	12,8	13,62	36,75	<i>Pterocarpus erinaceus</i>	10,1	9,83	14,18	34,11
	Fabaceae	6,89	11,1	15,5	33,54	<i>Terminalia glaucescens</i>	11,1	11,14	11,47	33,72
BFRA	Caesalpiniaceae	5,66	4,60	21,32	31,58	<i>Ricinodendron heudelo</i>	5,93	4,82	13,97	24,73
	Méliaceae	9,43	7,67	8,84	25,94	<i>Bombax buonopozens</i>	1,69	1,37	17,88	20,95
	Mimosaceae	5,66	4,60	14,33	24,59	<i>Carapa procera</i>	7,63	6,20	5,62	19,45
BFRT	Caesalpiniaceae	11,67	17,9	9,121	38,75	<i>Erythrophleum suaveo</i>	7,92	8,26	15,99	32,17
	Fabaceae	10	10,6	5,738	26,38	<i>Berlinia grandiflora</i>	5,94	7,43	11,23	24,59
	Rubiaceae	10	7,98	0,167	18,15	<i>Pterocarpus santalinoid</i>	6,93	7,85	9,79	24,57

3.3. Specific diversity indices

The Shannon Index value for the entire PNMS is 4.26. At the level of the blocks, this index decreases from the BFRA block to the BP block following the trend line: $y = -0.1107x + 3.7504$ with $R^2 = 0.9699$. The agricultural block in the riparian forest zone (BFRA) is the most diversified site with 3.76 and the least diversified site is the grazing block (BP) with a value of 2.09 (Figure 6). As for the Simpson index, the values recorded in the blocks vary from 0,023 to 0.227. Unlike the Shannon index, these values are increasing from the BFRA block to the BP block following the trend line: $y = 0,0015x^2 - 0,0108x + 0,0581$ with $R^2 = 0.8245$. The lowest value is recorded in the BFRA block and the highest in the BP block (Figure 7). The Pielou Fairness Index also varies from one site to another, the calculated values are between 0,698 and 0,947. The largest estimated value of 0,947 was recorded in the BFRA block and the smallest (0,698), in the BP block. These values close to 1, are in regression from the BFRA block to the BP block following the curve of equation $y = -2E-05x^4 - 0,0001x^3 + 0,01x^2 - 0,0863x + 1,0398$ with $R^2 = 0.7558$ (Figure 8).

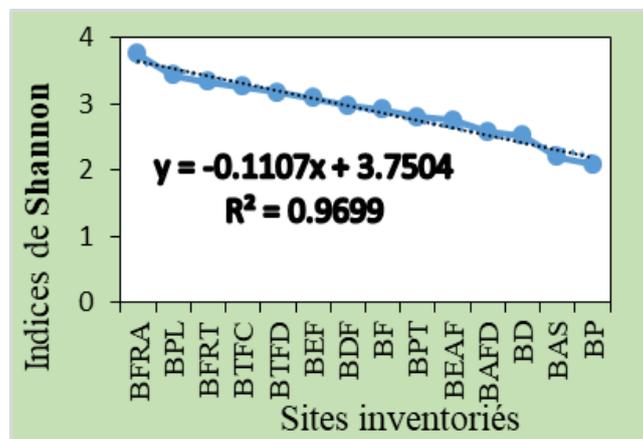


Figure 6 Evolution of specific diversity

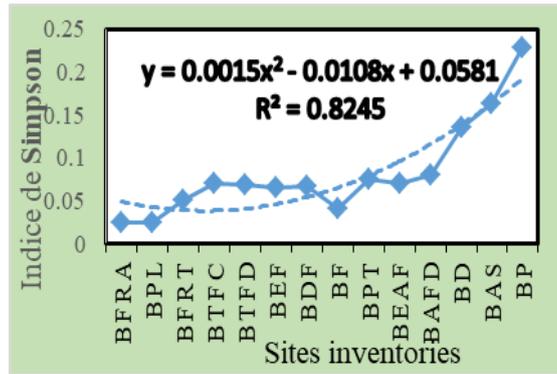


Figure 7 Evolution of the probability of belonging of the species drawn to the same site

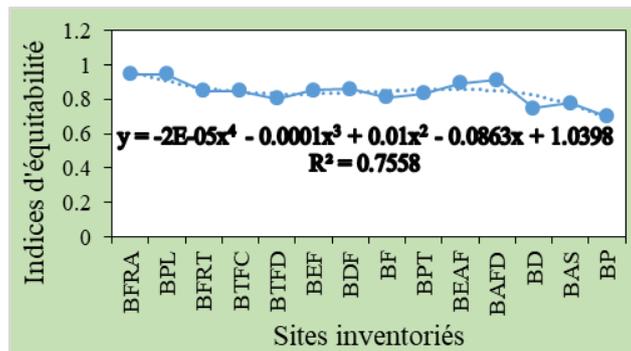


Figure 8 Evolution of the regularity of species distribution on the sites

3.3.1. Similarity between inventoried blocks

The greatest value of the similarity coefficient was observed between the BF and BTFC blocks. It is estimated at 64.28 p.c. the similarity between the pasture block (BP) and the control block (BPT) is estimated at 55 p.c. We also note a strong similarity on the one hand between the BD clearing block and the d block. Forest and agricultural exploitation BEAF estimated at 50 pc, and between the BD block and the agricultural block of dense forest (BAFD) estimated at 50 pc The lowest coefficient (5.40 pc) was recorded between blocks BF and BEF. Table 5 shows the different coefficients of similarity between the inventoried blocks.

Table 5 Matrix of the values of the coefficient of similarity between the blocks.

	BF	BAS	BTFC	BADF	BDF	BFRA	BFRT	BEAF	BD	BEF	BTFD	BP	BPT
BF	—												
BAS	28,6	—											
BTFC	64,28	28,12	—										
BADF	22,6	28,57	31,2	—									
BDF	23,5	43,47	40,5	36,7	—								
BFRA	13	11,43	12	20	25,9	—							
BFRT	29,54	21,92	29,41	20,89	21,17	32,72	—						
BEAF	24,5	33,33	24,3	47	45,3	27	10,67	—					
BD	28,1	33,33	30	44	50	32	24,69	50	—				
BEF	5,40	8,51	9,40	18,2	28,6	30	18,60	31	30,7	—			
BTFD	22,7	27,69	30,3	26	42,9	30	30,76	33	42,5	46,15	—		
BP	39,3	29,41	38,8	38	35	8,2	24,65	44	33	10	22,2	—	
BPT	34	28,57	40	26,7	40	15	27,16	25	30	19	28	55	—
BPL	37,8	15,68	44,7	36,4	43	22	26,67	44	39	34,7	33	41	40

4. Discussion

According to the results one hundred and eighty-seven (187) species of woody tree flora were inventoried in the PNMS against 206 species for previous studies (ENGREF, 1996; Poilecot, 1998). Furthermore, a comparison of our list with the old list, indicates that 129 species recorded by these authors registered on our list and 77 species are not found there. On the other hand, 44 species recorded by the present study are not mentioned in the old list. These data seem to reflect a loss of floristic richness and a modification of the floristic composition of the inventoried sites. If we take into account data from Pascal (1988), who estimates the tree richness of tropical rainforests between 120 and 200 species, it appears that the woody tree flora of the PNMS is moderately diverse. This richness is higher in the control block of riparian forest because of the watercourse that allows both the development of species of dense semi-deciduous and evergreen forests, as well as those that are directly in contact with the water (Lauginie, 2007). On the other hand, the BAFD and BAS blocks record the lowest wealth because of agricultural practices which have led to the massive destruction of woody plants. Indeed, according to Adjanohoun (1964), during clearing, cultivators often use ax and machete for felling trees and daba for establishing mounds and cleaning crops. When there is tree vegetation, it is completely felled and burned over the entire area. For the grazing site, the loss of floristic richness would be due to trampling of young plants by herds of oxen and to overgrazing which, according to Kessler & Geerling (2006), leads to a reduction in the natural regeneration of woody plants. For the bushfire site, this loss of wealth, according to Guillaumet and Adjanohoun (1971), comes from the impoverishment of the original flora and the reduction in soil fertility by recurrent fires. Regarding logging, Lauginie (2007) notes that certain operations such as setting up camps, creating access tracks the fall of trees and deforestation around the logs to be cut are the cause of the disappearance of some species. At the level of botanical families, the predominance of Caesalpiniaceae, Rubiaceae and Moraceae is not specific to PNMS, because the majority of tropical forests in West Africa (Etien and Traoré, 2005,) and Central Africa (Tchouto, 2004) is dominated by the same processions of families. Regarding the biological types, the predominance of microphanerophytes reflects the disturbance of the environment by human activities (Sangne, 2009). For the phytogeographic distribution, the strong dominance of Guinean species in the flora background of the PNMS constitutes, according to Sonké (1998), proof that this site does indeed belong to the Guinean-Congolese region of White (1986). Moreover, this percentage associated with those of endemic Ivorian (Gi), West African (GCW) and transitional (GC-SZ) species, gives a total of 82 p.c. of species. This means, according to White (1986), that the PNMS has a remarkably pure Guinean-Congolese type flora. The phytogeographic distribution of this flora has therefore not been significantly impacted by human activities. However, the high proportions of widely distributed species such as Afr-Tr, Am, Aa, Pant, noted in some blocks seem to reflect disturbances caused by anthropogenic activities. In fact, agricultural practices, clearing and harvesting of ligneous plants cause openings which favor the invasion of sites by species from other regions (Lubini, 1981). For species with special status, their abundance in the PNMS attests that this is indeed a conservation site belonging to the "Guinean Forests of West Africa Hotspot". In addition, the increase in the number of threatened species according to IUCN (2019) is due to the appearance of new species on degraded sites. Finally, according to Tchouto (2004) and Van Gernerden (2004), according to Tchouto (2004) and Van Gernerden (2004), the high number of species with special status recorded in undegraded forest areas compared to impacted sites where they are absent shows that these species are the most sensitive to the disturbances caused. by the man. Because, according to these authors, anthropogenic activities, the result of which is the destruction of the forest, do not promote the survival of these species which looking for a particular microclimate.

In addition, the preponderance of Bignoniaceae in the BAS, BDF, BD and BPL blocks reflects the degradation of these sites by human activities. Indeed, according to Aubreville (1959), the Bignoniaceae constitute a family which often invades clearing sites and whose introduction is due to the modifications made by man to the primitive environment. The predominant species found on these sites, such as *Ceiba pentandra*, *Markhamia tomentosa* and *Malacantha alnifolia*, corroborate this fact. Effect, according to Protá (2020), *Ceiba pentandra* is a pioneer species of secondary and rainforest that grows rapidly in openings in the canopy caused by disturbance. *Malacantha alnifolia*, on the other hand, is a pioneer species that tolerates fire and regenerates abundantly in regularly burned forests Protá (2020). Finally, *Markhamia tomentosa* is a species with winged seeds easily dispersed by the wind, on cleared sites. Regarding the Shannon diversity index, with the value of 4.26 it confirms that the flora of the PNMS is moderately diverse. At the level of the similarity coefficients, the floristic similarities between the blocks BTFC and BF, BP and BPT, BD and BDF would be linked to their belonging to the same type of plant formation which are respectively, open forest, shrub savannah and forest island. The greatest dissimilarities recorded between blocks BF and BEF, BEF and BAS and between BEF and BTFC could be explained by the difference in the types of vegetation to which they belong. Indeed, the BEF block is located in dense semi-deciduous forest, while the BF, BAS and BTFC blocks are in the savannah.

5. Conclusion

The study of the diversity of the tree-like woody flora of the PNMS has enabled us to list 187 species divided into 125 genera and 34 families. This moderately diversified flora has been strongly impacted by human activities which have caused a reduction in their richness of about 9 p.c. and a modification of the floristic composition by the appearance of new species in the degraded areas of the park. These more marked impacts on former farming sites have led to the disappearance of a number of special-status species that were abundant in the PNMS in the past. Invasive species, including *Chromolaena odorata*, have now invaded the former degraded sites of the park, preventing the regeneration of the forest species that were there. This modification of the landscape could be at the origin of the disappearance of certain animal species linked to these habitats. There is therefore an urgent need to combat the degradation of the park and the spread of invasive species by restoring degraded habitats and conserving the remaining special status species.

Compliance with ethical standards

Acknowledgments

I am very grateful to Professor Kouassi Kouadio Henri, Captain Keulai Minty and the West Zone Director of OIPR for their support which made this work possible.

Disclosure of conflict of interest

This article is not subject to any conflict of interest and has not been submitted to another journal for publication. We therefore authorize its publication.

References

- [1] Aké-Assi L. In « Nguessan K. et al. Inventaire de la diversité floristique de la zone d'intervention du projet GEPRENAF. SOS Forêts, Abidjan. 1998.
- [2] Aké-Assi L. Flore de la Côte d'Ivoire 1, catalogue, systématique, biogéographie et écologie. Genève, Suisse : Conservatoire et Jardin Botanique de Genève ; Boissieria. 2001; 57: 396.
- [3] Aké-Assi L. -Flore de la Côte d'Ivoire 2, catalogue, systématique, biogéographie et écologie. Genève, Suisse : Conservatoire et Jardin Botanique de Genève ; Boissieria. 2002; 58.
- [4] Anonyme. Rapport de mission de la Brigade Mobile de la Direction de Zone Ouest de l'OIPR chargée de la surveillance, du 23 au 27. octobre 2014; 8.
- [5] Aubreville A. La flore forestière de la Côte d'Ivoire, 2nd Edition, 3 Vols., Centre Technique Forestier Tropical, Nogent-sur-Marne. 1959.
- [6] ENGREF-Montpellier. 1996. -Parc national du Mont Sangbé – Contribution à l'étude du parc et de sa périphérie. 35 p + annexes. 1996.
- [7] FAO. Situation des forêts du monde. Rome, 2001. Rapport de synthèse. 2001;135.
- [8] FAO. Evaluation des ressources forestières mondiales 2010. Organisation des Nations Unies pour l'alimentation et l'agriculture, Département des forêts. Rapport national-Côte d'Ivoire. 2010; 60.
- [9] Guillaumet Jean-Louis, Adjanohoun Edmond. La végétation de la Côte d'Ivoire. In : Avenard Jean-Michel, Eldin Michel, Girard Georges, Sircoulon Jacques, Touchebeuf de Lussigny, Perraud Alain. Le milieu naturel de la Côte d'Ivoire Paris ORSTOM. 1971; 391 .
- [10] Kessler J, Geerling C, 2006. Profil Environnemental du Burkina Faso, rapport final. Université Agronomique de Wageningen, Pays-Bas. 2006.
- [11] Lauginie F. Dans Conservation de la nature et aires protégées en Côte d'Ivoire. NEI/ Hachette et Afrique Nature, Abidjan. 2007; xx + 668.
- [12] Le Figaro. Côte d'Ivoire : ¾ de la forêt disparus. Journal publié le 20/10/2014; à 21: 18.
- [13] Lubini A. (1981). Flore et végétation des jachères, arbustives des zones périphériques de Kisangani (Haut-Zaïre). Dissertation de défense de diplôme d'études supérieures en Sciences, Fac. Des Sciences. 1981; 108.

- [14] Mori SA, Boom BM, De Carvalino AM, Dos Santos TS. 1983.-Southern Bahia moist forest, Bot. Rev. 1983; 49(2) : 155-232.
- [15] OIPR. Loi n°2002-102 du 11 février 2002 relative à la création, à la gestion et au financement des parcs nationaux et des réserves naturelles de Côte d'Ivoire. 2002; 18.
- [16] Pascal (J.-P.). Wet evergreen forests of the Western Ghats of India. — Institut français de Pondichéry, Travaux de la Section scientifique et technique, tome XX bis. 1988; 345.
- [17] Piélou EC. The measurement of diversity in different types of biological collections. Journal of theoretical biology. 1966; 13: 131-144.
- [18] PNUE. Côte d'Ivoire, évaluation environnementale post-conflit, rapport publié en juillet 2015 par le Programme des Nations Unies pour l'Environnement. 2015.
- [19] Prota. Plant Ressources of Tropical Africa: Ceiba pentadra.16 Decembre 2020.
- [20] Prota. Plant Ressources of Tropical Africa: Malacantha alnifolia. Malacantha alnifolia. Protologue: Bull. Inst. Franç. Afrique Noire. 1953; 15: 1417.
- [21] Raunkiaer C. The life forms of plants and statistical plant geographic, Oxford University Press, London (England). 1934; 632.
- [22] Sangne YC. Dynamique du couvert forestier d'une aire protégée soumise aux pressions anthropiques : cas de la Forêt Classée de Téné dans le Département d'Oumé (Centre-ouest de la Côte d'Ivoire). Thèse de Doctorat, Université de Cocody-Abidjan. 2009.
- [23] Shannon-Weaver. The mathematical theory of communication, Urbakaun. Press Illinois. 1948.
- [24] Sorensen T. A method of establishing group of equal amplitude in plants sociology based on similarity of species content. Det Kongelige Danske Videnskabskader. Biologiske Skrifter. 1948; 5(4): 1-34.
- [25] Sonké B. Etudes floristiques et structurales des forêts de la réserve de faune du Dja (Cameroun). Thèse de Doctorat, Université Libre de Bruxelles. 1998; 267.
- [26] Tchouto GPM. Plant diversity in Central African rain forest: implication for biodiversity conservation in Cameroon. PhD. Thesis, Department of plant sciences, Biosystematic Group, Wageningen University. 2004; 208.
- [27] UICN. Liste rouge de l'UICN. 2019; 2.
- [28] Van Gemerden BS. Disturbance, diversity and distributions in Central African rain forest. Ph-D. thesis, Wageningen University. 2004; 199.
- [29] Virginie Verges René M. Evaluation rapide de la diversité faunique terrestre : l'état des lieux de quatre parcs nationaux : Azagny, Marahouet, Mont Péko et Mont Sangbé. Afrique Nature International. Rapport d'étude. 2012; 33.
- [30] White F, Bamps P. (trad.) La végétation de l'Afrique : mémoire accompagnant la carte de végétation de l'Afrique UNESCO/AETFAT/UNSO. Paris : ORSTOM ; UNESCO. 1986; 20: 385.