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Ecological characterization of the Vegetation in the artisanal mining sites of the protected areas in Mayo-Rey Division (Cameroon)

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Abstract

Study on the assessments of vegetation impact of artisanal mining in protected areas in Mayo-Rey National Parks was conducted to conserve its ecosystem. The inventory of the vegetation was performed on the plots of 20 m × 20 m(4.8 ha) for all the plots of radius for the trees and 5 m of radius for the bushes. Data analysis using software Excel and STATGRAPHICS Plus 5.0 showed that the overexploited savannas and the gallery forests are highly threatened with a very alarming regression rate because of anthropogenic activities. Resultsshow that individuals with heights less than or equal to 2 m (8717 individuals) are more abundant in vegetation while individuals >10 m (2577 individuals) are less abundant. Result also shows a dominance of the strength of the diameter class between 0.15 m and 0.45m in the vegetation. These indicate that vegetation has an "L" structure, obtained when the DBH and height was taken into consideration. The diversity of species in the gold panning area is influenced by the practice of directing the total destruction of the vegetation cover. It would be important to study the mechanism of species adaptation and restoration of degraded sitesin this locality and to develop a sustainable management will require the integration of populations in decision making for the protected areas conservation and protection of Mayo-Rey.

Keywords: Ecological characterization, Vegetation, artisanal mining, protected areas, Mayo-Rey Division

Introduction

The protected areas of Mayo-Rey Division are located in a site whose subsoil is rich enough in ores and especially alluvial gold and sometimes Sapphire. Some areas such as the Benue River bed and many other backwaters of this river in protected areas are often invaded by about 100 people in search of this precious metal. Often whole villages move and rebuild within parks and their peripheries (ZICs) for gold mining. There is a real destruction of habitat in the center of the parks and especially poaching and other widespread illegal activities carried out by these miners (MINEF, 2000). Despite the efforts of the

National Park Conservation services to eradicate this phenomenon, gold panning continues to grow in this protected area because it is a source of alternative income for many families in the locality. Thus, there are dozens of camps for gold miners in the parks and areas of hunting interest. Every year, new sites are established on the immediate periphery of the Benue riverbed and other areas where the soil is rich in gold ore. It should be noted that gold panning in protected areas in the Mayo-Rey locality is not new, it has always existed but the proportions of recent years are more than disturbing. The objective of this article is to study ecological characterization of the vegetation in the artisanal mining sites of the protected areas in Mayo-Rey Division.

Presentation of the study zone

The research was conducted in 2016 and 2017 in the administrative district of the North-Cameroon region. They focused on artisanal mining activities in protected areas of the Mayo-Rey Division (Figure 1). Indeed, The BNP and BNNP were created by Pierre FLIZOT, French hunting inspector, classified as a wildlife reserve respectively by decree N˚ 34/32 of November 11th, 1932 and by decree N˚ 270 of July 29th, 1947 of the high commissioner of the French Republic in Cameroon. After independence, the Cameroonian State erected the Benue Wildlife Reserve in Benue National Park by Order No. 86/SDR/DEFC of 21 October 1969, while the Bouba-Ndjidda Wildlife Reserve was transformed into a park a year earlier by decree N˚ 120/SFDR of 05 December. The BNNP extends between latitude 08˚21'N and 09˚00'N, and longitude 14˚25'E and 14˚55'E. With an area of approximately 220,000 ha, it is limited: to the north by the international border between Cameroon and Chad; in the West by ZIC 11 and Mayo Vaimba and Bidjou; in the East by ZIC 23; in the south-west by the Hossere Koum mountain range and the ZIC N˚ 10 and finally in the south by the northern limit of the ZIC N˚ 12 constituted by the section of track which links the villages Koum, Mayo Djarendi and the hosséré Koum about 15 km, Terdel (2007), Dongfack *et al* (2001). The BNP and BNNP are subject to a contrasting Sudanese climate. The region is marked by a transitional climate between the southern Sudanese climate further south and the dry Sudanese climate, Suchel (1972). It is limited by the annual isohyets 1000 and 1500 mm. The average annual temperature is 28˚C, while the maximum temperature is 35˚C, the minimum is 21˚C. Soils in the study area were studied by Brabant *et al.* (1974). The study area is highly dissected by a dense hydrographic network. It includes a main collector, Benue. Its main tributaries are: mayo Mbam and Mayo Kout, Mayo Boulem and Mbay, Mayo Rey and Mayo Godi.

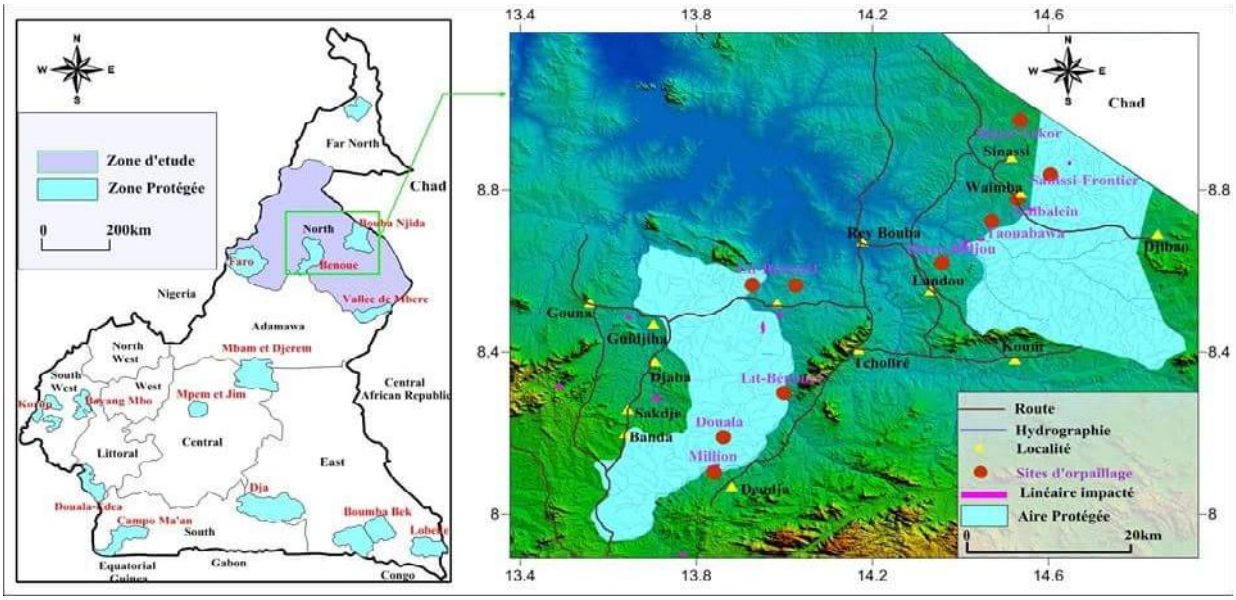

Figure 1: Map of geographical location of the study sites.

Floristic survey method

The analysis of the impacts on the vegetation was done through the floristic inventories at the sampled sites. The inventory sheet has been prepared beforehand. It is characterized by the elementsdescribing the plot, the recovery of vegetation strata, geographical coordinates, human activities and dendro-ecological activities and other important parameters characterizing the vegetation. To do this, the experimental design is a Split-plot with completely randomized blocks (Table 1). Indeed, this method will consist of delimiting with a double decameter tape, a square area of 20 m^2 within which floristic surveys are performed. This inventory consists of recording all the woody species present in the plots. Thus, an exhaustive count of the ligneous was carried out in the plots. For each tree, the essence has been identified by its scientific name or vernacular name. The species inventory was done directly in the field and unidentified species were collected with the help of the guides and put in herbarium for identification or confirmation at the school's herbarium Garoua and Wakwa fauna. The dendrometric parameters of the plants such as the number of feet, the height, the diameter at breast height (DBH) of ligneous are recorded.

Table 1: the experimental design

	Benoue National Park (BNP)	**Bouba-Ndjidda National Park (BNNP)**
1st site	Douala (6 Plots)	Mayo-Tokor (6 Plots)
2th Site	Fimbe1 (6 Plots)	Sinassi-Frontier (6 Plots)
3th Site	Million (6 Pots)	Taouabawa (6 Plots)
4th Site	Lit-Benoue1 (6 Plots)	Mayo-Bidjou (6 Plots)
5th Site	Lit-Benoue2 (6 Plots)	Gaibalein (6 Placettes)
Control of 1st site	Control of Douala (6 Plots)	Mayo-Tokor (6 Plots)
Control of 2th site	Control of Fimbe1 (6 Plots)	Control of Sinassi-Frontier (6 Plots)
Control of 3th site	Control of Million (6 Plots)	Control of Taoubawa (6 Plot)
Control of 4th site	Control of Lit-Benoue 1 (6 Plots)	Control of Mayo-Bidjou (6 Plots)
Control of 5th site	Control of Lit-Benoue 2 (6 Plots)	Control of Gaibalein (6 Plots)

Frequency of the woody species

The absolute frequency of the species is the number of the summaries containing this species. According to Braun - Blanquet (1932), the relative frequency is the proportion expressed in percentage between the number of the summaries containing that species and the total number of summaries by 100. This method permits to determine the accidental species, minor, frequent enough, frequent and very frequent (Table 2).

Table 2 : Index of frequency (Braun-Blanquet 1932).

Indices	**Fréquences**	Type of species
I	**Fr≤20**	Accidental species
II	**20<Fr≤40**	Incidental species
III	**40<Fr≤60**	Enough species
IV	**60<Fr≤80**	frequent Frequent species
V	**80<Fr≤100**	Very much frequent species

Absolute and Relative Densities

The absolute density (Ni) or absolute abundance of a taxon is the total number of stems of this taxon per unit area. The relative density (dr) or relative abundance is the ratio between the number of individuals of a species and the total number of all individuals of all species encountered on a surface considered multiplied by 100.

Absolute and Relative Dominance

Dominance expresses the influence of a species in a community. The relative dominance (Dr) is the ratio of the basal area (Sb) of a species on the total basal area of all individuals encountered; Sb = πD2/4, D is the diameter of the rod. The total basal area (SBT) is the total sum of all the basal areas of all stems per hectare treated. It is expressed in m^2/ha.

The relative importance value of Curtis

The three statistics (dominance, frequency and relative density) are commonly used together and their sum is equal to "Value importance Curtis". Its value ranges between 0 and 300

$$\mathbf{IVC} = \mathrm{Fr} + \mathrm{Dr} + \mathrm{Dre}$$

Where Dre (%) = relative dominance;
Fr (%) = relative frequency;
Dr (%) = relative density;
IVCR (%) = Curtis Value Importance.

The floristic diversity indexes

The diversity index of Shannon: (ISH= -∑Ni/N $\log_2$ (Ni/N);

where, Ni is the number of species.

The fairness (EQ) of Pielou (1966)

EQ = ISH / $\log_2$ N; corresponding to the ratio between the observed diversity and the maximum diversity number of species N possible.

The diversity index of Simpon

D = 1/∑ (Ni/N)2 (Begon *et al.*, 1987);

where,

D' = ∑(Ni/N)2.

The data based analysis techniques

Data collected in the field were processed and classified in Excel. The Statgraphic plus 5.0 software was used for the Analysis of Variance (ANOVA), while XLSTAT helped for Principal Components Analysis (PCA).

Results and Discussion

Frequency, Density, Dominance and Importance Value of Curtis of the species.

The frequency, density and relative abundance permit to know the ecological importance of the species in the vegetation of the artisanal mining in protected areas of Mayo-Rey Division. In general, the species which has most Important Value of Curtis in our inventory is found in the non-gold panning control areas in both national parks. The species *Combretum nigricans* (116,368%), *Combretum glutinosum* (108,781%), *Terminalia macroptera* (103,630%), *Terminalia laxiflora* (103,139%) has most Important Value of Curtis in our inventory (Table 3).This proves that the diversity of species in the gold washing zone is influenced by the gold panning which is at the origin of a total destruction of the vegetal cover. These results differ from that of Letouzey (1985), which showed that savannas are mainly found in *Isoberlinia doka*, *Burkea africana*, *Terminalia macroptera*, *Afzelia africana*, and *Lophira lanceolata*; the clear forests *Anogeissus leiocarpus* in the study area.

Table 3: Frequency, Density, Dominance and Importance Value of Curtis relatives of the species (%)

	BNP								BNNP							
	Gold panning area				Non-gold panning area				Gold panning area				Non-gold panning area			
Scientifics names	Fr	Dr	Dre	**IVC**	Fr	Dr	Dre	**IVC**	Fr	Dr	Dre	**IVC**	Fr	Dr	Dre	**IVC**
Acacia ataxacantha	13,333	0,242	0,004	**13,579**	6,667	0,078	0,002	**6,747**	73,333	1,269	0,018	**74,620**	16,667	1,753	0,013	**18,433**
Acacia dudgeoni	6,667	0,145	0,003	**6,815**	-	-	-	**-**	63,333	1,363	0,028	**64,725**	26,667	1,156	0,009	**27,832**
Acacia hockii	16,667	0,339	0,002	**17,008**	30,000	0,078	0,001	**30,080**	50,000	1,551	0,016	**51,568**	30,000	1,455	0,014	**31,468**
Acacia polyacantha	3,333	0,048	0,001	**3,383**	3,333	0,039	0,002	**3,374**	40,000	1,928	0,019	**41,946**	23,333	1,231	0,019	**24,583**
Aciacia polyacantha var c.	6,667	0,097	0,005	**6,768**	13,333	0,118	0,007	**13,458**	26,667	0,846	0,007	**27,520**	13,333	1,082	0,010	**14,425**
Acacia senegalensis	23,333	0,485	0,008	**23,826**	13,333	0,313	0,005	**13,651**	36,667	1,128	0,023	**37,818**	13,333	0,932	0,007	**14,273**
Acacia sieberiana	70,000	1,745	0,007	**71,752**	26,667	1,176	0,006	**27,848**	46,667	1,504	0,010	**48,182**	26,667	1,119	0,009	**27,795**
Adenodouchos paniculatum	23,333	0,485	0,000	**23,818**	10,000	0,235	0,003	**10,238**	16,667	0,282	0,001	**16,949**	10,000	0,224	0,006	**10,230**
Adenolobus paniculatum	73,333	1,939	0,008	**75,280**	16,667	1,097	0,005	**17,769**	70,000	1,316	0,012	**71,328**	16,667	1,417	0,008	**18,092**
Adenolobus rufenscens	36,667	0,873	0,004	**37,543**	20,000	0,470	0,004	**20,474**	36,667	0,564	0,006	**37,237**	20,000	0,448	0,011	**20,459**
Afzelia africana	76,667	2,375	0,022	**79,063**	26,667	1,803	0,014	**28,483**	93,333	2,163	0,005	**95,501**	26,667	1,716	0,007	**28,390**
Albizia zygia	46,667	1,115	0,005	**47,787**	66,667	0,862	0,004	**67,533**	33,333	0,564	0,001	**33,898**	66,667	0,821	0,012	**67,499**
Allophyllus africanus	60,000	1,600	0,006	**61,606**	36,667	1,411	0,003	**38,080**	43,333	1,222	0,010	**44,566**	36,667	1,343	0,012	**38,021**
Annona senegalensis	26,667	0,727	0,004	**27,398**	30,000	0,431	0,001	**30,432**	20,000	0,517	0,007	**20,524**	30,000	0,410	0,009	**30,419**
Anogeissus leiocarpus	63,333	2,763	0,008	**66,105**	93,333	2,821	0,006	**96,160**	63,333	3,385	0,013	**66,731**	93,333	2,686	0,008	**96,027**
Antidesma venosum	46,667	2,327	0,005	**48,998**	63,333	1,489	0,007	**64,829**	46,667	1,222	0,021	**47,910**	63,333	1,790	0,020	**65,144**
Berlinia grandiflora	13,333	0,242	0,003	**13,578**	16,667	0,235	0,004	**16,906**	20,000	0,282	0,004	**20,286**	23,333	0,224	0,007	**23,564**
Bombax costatum	6,667	0,097	0,034	**6,798**	3,333	0,039	0,031	**3,404**	3,333	0,047	0,001	**3,382**	30,000	0,037	0,004	**30,042**
***Borassus* sp.**	43,333	0,921	0,020	**44,274**	36,667	0,666	0,013	**37,346**	36,667	0,799	0,004	**37,469**	36,667	0,634	0,009	**37,309**
Boswelia dalzielii	23,333	0,436	0,010	**23,779**	20,000	0,313	0,005	**20,318**	16,667	0,376	0,015	**17,058**	20,000	0,298	0,007	**20,306**
Boswelia papylifera	26,667	0,485	0,010	**27,161**	20,000	0,392	0,013	**20,405**	13,333	0,470	0,015	**13,818**	20,000	0,373	0,020	**20,393**
Bridellia ferruginea	90,000	3,442	0,002	**93,443**	33,333	2,665	0,001	**35,999**	100,000	2,210	0,009	**102,219**	33,333	2,536	0,005	**35,875**
Bridellia scleroclaria	3,333	0,048	0,001	**3,383**	6,667	0,078	0,002	**6,747**	6,667	0,094	0,007	**6,767**	93,333	0,112	0,009	**93,454**
Burkia africana	96,667	3,732	0,011	**100,410**	43,333	3,056	0,007	**46,397**	83,333	1,787	0,001	**85,121**	43,333	2,909	0,008	**46,251**
Cassia sieberiana	10,000	0,145	0,014	**10,159**	3,333	0,039	0,014	**3,387**	3,333	0,047	0,021	**3,402**	90,000	0,149	0,021	**90,170**
Clerodendrum capitatum	-	-	-	**-**	10,000	0,118	0,004	**10,122**	6,667	0,141	0,007	**6,815**	43,333	0,149	0,006	**43,489**
Combretum collinum	100,000	3,442	0,020	**103,461**	16,667	2,743	0,013	**19,423**	86,667	1,269	0,019	**87,955**	16,667	2,611	0,012	**19,290**
Combretum glutinosum	86,667	2,618	0,019	**89,303**	100,000	2,194	0,010	**102,204**	93,333	1,834	0,006	**95,173**	100,00	2,089	0,006	**108,761**
Combretum molle	96,667	3,781	0,012	**100,460**	83,333	3,056	0,008	**86,398**	83,333	2,727	0,006	**86,066**	83,333	2,909	0,004	**86,247**
Combretum nigricans	93,333	3,635	0,017	**96,986**	80,000	3,174	0,014	**83,188**	96,667	2,304	0,011	**98,982**	100,00	3,021	0,013	**116,368**
Combretum paniculatum	23,333	0,388	0,002	**23,723**	40,000	0,509	0,005	**40,515**	36,667	0,611	0,003	**37,281**	60,000	0,485	0,008	**60,492**
Cussonia arborea	3,333	0,048	0,001	**3,383**	10,000	0,118	0,004	**10,122**	6,667	0,141	0,002	**6,809**	40,000	0,075	0,006	**40,081**
Crossopteryx febrifuga	3,333	0,097	0,012	**3,442**	-	-	-	**-**	-	-	-	**-**	-	-	-	**-**
Daniellia oliveri	90,000	3,248	0,027	**93,275**	73,333	2,743	0,040	**76,116**	76,667	2,351	0,018	**79,036**	73,333	2,611	0,009	**75,953**
Desmodium vitelinum	46,667	0,727	0,006	**47,399**	60,000	0,705	0,009	**60,714**	30,000	0,846	0,009	**30,855**	60,000	0,671	0,013	**60,685**
Detarium microcarpum	33,333	0,533	0,006	**33,873**	33,333	0,549	0,005	**33,887**	40,000	0,658	0,010	**40,668**	33,333	0,522	0,007	**33,862**

Dichrostachys cinerea	-	-	-	**-**	13,333	0,157	0,005	**13,495**	10,000	0,188	0,005	**10,193**	30,000	0,112	0,007	**30,119**
Diospyros mespiliformis	16,667	0,339	0,007	**17,013**	6,667	0,039	0,009	**6,715**	3,333	0,047	0,010	**3,391**	40,000	0,075	0,013	**40,088**
Entada africana	6,667	0,097	0,003	**6,766**	36,667	0,549	0,004	**37,220**	73,333	0,658	0,004	**73,996**	73,333	0,522	0,007	**73,862**
Erytrina senegalensis	3,333	0,048	0,002	**3,384**	-	-	-	**-**	3,333	0,047	0,003	**3,383**	-	-	-	**-**
Ficus capensis	63,333	1,357	0,023	**64,713**	33,333	1,058	0,015	**34,406**	43,333	0,799	0,005	**44,138**	33,333	1,007	0,005	**34,346**
Ficus cordata	10,000	0,145	0,044	**10,189**	43,333	0,039	0,041	**43,414**	3,333	0,047	0,005	**3,385**	43,333	0,037	0,009	**43,380**
Ficus glaucescens	6,667	0,097	0,020	**6,783**	-	-	-	**-**	-	-	-	**-**	-	-	-	**-**
Ficus platyphylla	76,667	1,018	0,039	**77,723**	26,667	0,940	0,033	**27,641**	43,333	1,128	0,003	**44,464**	26,667	0,895	0,005	**27,567**
Ficus sycomorus	6,667	0,097	0,049	**6,813**	6,667	0,078	0,041	**6,786**	6,667	0,094	0,007	**6,768**	16,667	0,075	0,009	**16,751**
Ficus thonningii	40,000	0,824	0,061	**40,885**	30,000	0,470	0,049	**30,519**	10,000	0,564	0,013	**10,577**	30,000	0,448	0,014	**30,462**
Forea rachetiana	30,000	0,582	0,002	**30,583**	20,000	0,392	0,001	**20,393**	30,000	0,470	0,005	**30,475**	20,000	0,373	0,008	**20,381**
Gardenia aqualla	3,333	0,048	0,000	**3,382**	13,333	0,157	0,000	**13,490**	3,333	0,047	0,014	**3,394**	23,333	0,149	0,015	**23,498**
Grewia bicolor	16,667	0,291	0,005	**16,962**	50,000	0,784	0,007	**50,790**	36,667	0,564	0,007	**37,238**	50,000	0,746	0,010	**50,756**
Grewia flavenscens	3,333	0,048	0,008	**3,390**	10,000	0,118	0,011	**10,129**	6,667	0,141	0,012	**6,820**	36,667	0,112	0,016	**36,795**
Haematostaphis barbari	6,667	0,145	0,003	**6,815**	-	-	-	**-**	-	-	-	**-**	-	-	-	**-**
Harungana madagascaiensis	33,333	1,115	0,016	**34,465**	60,000	1,489	0,013	**61,502**	33,333	1,787	0,007	**35,127**	60,000	1,417	0,007	**61,424**
Hymenocardia acida	86,667	1,939	0,007	**88,612**	73,333	1,803	0,011	**75,147**	53,333	2,163	0,010	**55,506**	73,333	1,716	0,016	**75,066**
Isoberlinia doka	10,000	0,194	0,052	**10,246**	50,000	2,429	0,043	**52,472**	50,000	2,915	0,008	**52,923**	50,000	2,313	0,011	**52,323**
Isoberlinia tomentosa	-	-	-	**-**	76,667	3,252	0,050	**79,969**	56,667	3,197	0,014	**59,878**	76,667	3,096	0,015	**79,778**
khaya senegalensis	43,333	0,630	0,071	**44,034**	13,333	0,157	0,058	**13,548**	13,333	0,188	0,019	**13,541**	73,333	0,149	0,007	**73,490**
Kigelia africana	6,667	0,145	0,003	**6,815**	-	-	-	**-**	-	-	-	**-**	-	-	-	**-**
Klosklospermum plancini	6,667	1,406	0,007	**8,080**	43,333	1,176	0,007	**44,516**	23,333	0,376	0,011	**23,721**	43,333	1,119	0,002	**44,454**
Lannea fruticosa	3,333	0,048	0,005	**3,387**	10,000	0,118	0,009	**10,127**	10,000	0,141	0,008	**10,149**	10,000	0,037	0,014	**10,051**
Lannea humilis	10,000	0,145	0,007	**10,152**	3,333	0,039	0,010	**3,382**	3,333	0,047	0,011	**3,391**	30,000	0,037	0,014	**30,052**
Lannea kerstingi	-	-	-	**-**	6,667	0,078	0,005	**6,750**	6,667	0,094	0,010	**6,770**	80,000	0,075	0,008	**80,082**
Lannea shimperi	6,667	0,097	0,001	**6,765**	-	-	-	**-**	-	-	-	**-**	-	-	-	**-**
Lippia adoensis	-	-	-	**-**	20,000	0,235	0,010	**20,245**	16,667	0,282	0,008	**16,957**	20,000	0,186	0,015	**20,201**
Lonchocarpus laxiflorus	23,333	0,339	0,003	**23,676**	10,000	0,157	0,012	**10,168**	10,000	0,188	0,005	**10,193**	30,000	0,149	0,017	**30,166**
Lophira lanceolata	33,333	0,679	0,001	**34,013**	40,000	0,745	0,002	**40,746**	30,000	0,893	0,001	**30,895**	40,000	0,709	0,003	**40,712**
Malacantha alnifolia	-	-	-	**-**	13,333	0,157	0,008	**13,498**	6,667	0,188	0,012	**6,867**	36,667	0,112	0,012	**36,791**
Maytenus senegalensis	76,667	1,745	0,011	**78,423**	53,333	1,646	0,004	**54,983**	60,000	1,646	0,018	**61,663**	53,333	1,567	0,005	**54,905**
Mitragyna inermis	3,333	0,048	0,008	**3,390**	10,000	0,118	0,009	**10,127**	10,000	0,141	0,013	**10,154**	73,333	0,112	0,013	**73,458**
Monotes kerstingii	46,667	2,278	0,021	**48,966**	56,667	2,077	0,012	**58,755**	90,000	1,551	0,011	**91,562**	56,667	1,977	0,008	**58,651**
Nauclea latifolia	3,333	0,048	0,008	**3,390**	10,000	0,118	0,002	**10,119**	10,000	0,141	0,012	**10,154**	83,333	0,112	0,003	**83,448**
Ochna rhizomatosa	26,667	0,873	0,006	**27,545**	63,333	1,254	0,005	**64,592**	6,667	0,141	0,009	**6,817**	63,333	1,194	0,007	**64,534**
Ochna ovata	46,667	1,697	0,003	**48,367**	80,000	0,980	0,002	**80,982**	20,000	0,329	0,005	**20,334**	80,000	0,932	0,003	**80,936**
Ochna schweinfurthiana	-	-	-	**-**	60,000	0,039	0,011	**60,050**	3,333	0,047	0,002	**3,383**	60,000	0,037	0,016	**60,054**
Opilia amenthacea	23,333	1,551	0,008	**24,892**	40,000	1,058	0,005	**41,063**	36,667	0,799	0,012	**37,478**	40,000	1,007	0,007	**41,014**
Ozoroa insignis	6,667	0,145	0,004	**6,816**	6,667	0,078	0,002	**6,747**	6,667	0,094	0,023	**6,784**	80,000	0,075	0,003	**80,078**
Parinari curatellifolia	-	-	-	**-**	26,667	0,313	0,004	**26,984**	23,333	0,376	0,003	**23,712**	66,667	0,298	0,006	**66,971**
Parkia biglobosa	30,000	0,582	0,003	**30,585**	13,333	1,293	0,007	**14,633**	60,000	1,551	0,005	**61,557**	13,333	1,231	0,010	**14,574**
Pavetta crassipes	-	-	-	**-**	13,333	0,118	0,005	**13,456**	10,000	0,141	0,014	**10,155**	13,333	0,186	0,007	**13,527**

Pericopsis laxiflora	73,333	1,745	0,005	**75,083**	26,667	1,176	0,006	**27,848**	36,667	1,410	0,007	**38,084**	26,667	1,119	0,009	**27,795**
Phyllantus welwitschianus	-	-	-	**-**	10,000	1,803	0,004	**11,807**	43,333	0,658	0,012	**44,004**	10,000	1,716	0,006	**11,722**
Piliostigma thonningii	70,000	2,666	0,003	**72,669**	16,667	2,234	0,005	**18,905**	90,000	2,680	0,005	**92,685**	16,667	2,126	0,008	**18,800**
Prosopis africana	16,667	0,339	0,004	**17,010**	20,000	0,470	0,007	**20,478**	33,333	0,564	0,007	**33,904**	20,000	0,448	0,011	**20,459**
Protea occidentalis	6,667	0,145	0,007	**6,819**	13,333	0,157	0,005	**13,495**	6,667	0,188	0,010	**6,865**	26,667	0,149	0,007	**26,823**
Pseudocedrela kotschyi	53,333	3,684	0,014	**57,031**	66,667	3,840	0,013	**70,520**	76,667	2,727	0,008	**79,402**	66,667	3,655	0,012	**70,334**
Psorospermum febrifugum	50,000	1,939	0,009	**51,948**	36,667	1,881	0,008	**38,556**	80,000	1,787	0,014	**81,801**	36,667	1,790	0,012	**38,469**
Psorospermum senegalensis	6,667	0,194	0,012	**6,873**	30,000	0,745	0,006	**30,751**	46,667	0,893	0,019	**47,579**	30,000	0,709	0,009	**30,718**
Pterocarpus erinaceus	23,333	0,436	0,021	**23,791**	93,333	1,293	0,013	**94,639**	76,667	1,551	0,004	**78,222**	93,333	1,231	0,008	**94,573**
Pterocarpus lucens	36,667	0,630	0,007	**37,304**	63,333	1,411	0,014	**64,758**	83,333	1,269	0,011	**84,614**	63,333	1,343	0,020	**64,697**
Securidaca longepedunculata	13,333	0,339	0,005	**13,678**	23,333	0,549	0,004	**23,886**	43,333	0,658	0,008	**43,999**	23,333	0,522	0,007	**23,862**
Securinega virosa	56,667	1,406	0,007	**58,079**	30,000	0,980	0,003	**30,983**	56,667	1,175	0,011	**57,853**	30,000	0,932	0,004	**30,937**
Sterculia setigera	3,333	0,048	0,006	**3,388**	-	-	-	**-**	-	-	-	**-**	-	-	-	**-**
Stereopermim khunthianum	6,667	0,145	0,001	**6,813**	13,333	0,157	0,005	**13,495**	10,000	0,188	0,002	**10,190**	20,000	0,149	0,007	**20,157**
Steganotaenia araliacea	-	-	-	**-**	10,000	0,157	0,004	**10,161**	6,667	0,188	0,008	**6,863**	20,000	0,112	0,020	**20,132**
Strychnos innocua	6,667	0,097	0,003	**6,767**	3,333	0,039	0,004	**3,376**	3,333	0,047	0,005	**3,385**	-	-	-	**-**
Strychnos spinosa	-	-	-	**-**	16,667	0,235	0,006	**16,908**	6,667	0,141	0,001	**6,809**	93,333	0,224	0,009	**93,566**
Swartzia madagascariensis	16,667	0,339	0,008	**17,014**	10,000	0,118	0,006	**10,123**	10,000	0,141	0,012	**10,154**	43,333	0,112	0,008	**43,453**
Syzygium guineense var. g.	6,667	0,388	0,068	**7,123**	23,333	0,274	0,017	**23,625**	13,333	0,329	0,018	**13,680**	90,000	0,261	0,021	**90,282**
Syzygium guineense var.m.	16,667	0,291	0,023	**16,981**	43,333	0,745	0,014	**44,092**	30,000	0,893	0,013	**30,906**	43,333	0,709	0,006	**44,048**
Tamarindus indica	20,000	0,388	0,007	**20,395**	16,667	0,313	0,046	**17,026**	20,000	0,376	0,011	**20,387**	16,667	0,298	0,012	**16,977**
Terminalia laxiflora	63,333	2,860	0,060	**66,253**	100,000	3,605	0,034	**103,639**	83,333	3,103	0,012	**86,449**	100,000	3,133	0,006	**103,139**
Terminalia avicennioides	76,667	4,266	0,051	**80,983**	83,333	3,801	0,031	**87,165**	93,333	3,620	0,008	**96,961**	83,333	2,872	0,004	**86,210**
Terminalia glaucescens	96,667	4,702	0,057	**101,425**	100,000	3,879	0,047	**103,926**	90,000	3,244	0,011	**93,255**	100,000	3,245	0,013	**103,258**
Terminalia macroptera	93,333	3,635	0,055	**97,023**	60,000	3,017	0,038	**63,055**	100,000	3,620	0,010	**103,630**	60,000	2,163	0,008	**62,171**
Trichilia emetica	6,667	0,145	0,001	**6,813**	6,667	0,078	0,004	**6,749**	6,667	0,094	0,002	**6,763**	40,000	0,075	0,006	**40,081**
Uapaka togoensis	-	-	-	**-**	23,333	0,313	0,012	**23,659**	26,667	0,376	0,008	**27,051**	63,333	0,298	0,008	**63,640**
Uvaria chamae	6,667	0,097	0,003	**6,767**	10,000	0,118	0,006	**10,123**	10,000	0,141	0,005	**10,146**	73,333	0,037	0,009	**73,379**
Vitellaria paradoxa	30,000	0,679	0,019	**30,698**	60,000	0,784	0,014	**60,798**	36,667	0,564	0,001	**37,232**	60,000	0,746	0,013	**60,759**
Vitex doniana	16,667	0,339	0,008	**17,014**	3,333	0,078	0,005	**3,416**	6,667	0,094	0,012	**6,773**	33,333	0,075	0,007	**33,415**
Vitex simplicifolia	16,667	0,533	0,011	**17,211**	30,000	1,097	0,005	**31,102**	20,000	0,423	0,018	**20,441**	30,000	0,485	0,007	**30,492**
Ximenia americana	6,667	0,388	0,008	**7,063**	40,000	1,646	0,009	**41,655**	33,333	0,517	0,013	**33,863**	40,000	1,194	0,013	**41,207**
Ziziphus abiscenia	20,000	0,339	0,007	**20,346**	60,000	0,784	0,004	**60,788**	63,333	0,940	0,011	**64,284**	73,333	0,746	0,007	**74,086**
Ziziphus mucronata	6,667	0,145	0,008	**6,820**	40,000	0,627	0,003	**40,630**	50,000	0,752	0,012	**50,765**	40,000	0,485	0,004	**40,489**
Zyzyphus mauritiana	23,333	0,436	0,008	**23,777**	6,667	0,078	0,004	**6,749**	36,667	0,611	0,012	**37,289**	33,333	0,448	0,005	**33,786**
Total	**100,000**	**100,000**	**100,000**	**300,000**	**100,000**	**100,000**	**100,000**	**300,000**	**100,000**	**100,000**	**100,000**	**300,000**	**100,000**	**100,000**	**100,000**	**300,000**

Diametrical structure of species vegetation in gold panning sites

In terms of vertical structure, the distribution of trees in height classes is a function of the type of zone of gold panning sites. Note in figure 2 below an "L" structure of vegetation in all gold panning sites according to DBH. It can be seen that the numbers of individuals in the height classes are higher in the control area than the area exploited in the sites. The analysis of woody inventories in the vegetation of our study area by diameter class shows a bell-like appearance, indicating that intermediate classes are better represented than the extremes. This reflects a strong regeneration of woody plants in the sites and shows that the vegetation has a better future if we manage to stop this phenomenon of gold panning. These results are similar to those of Tchobsala (2011) which showed that the vegetation in the peri-urban savannas of Ngaoundere is dominated by shrubs of small size.

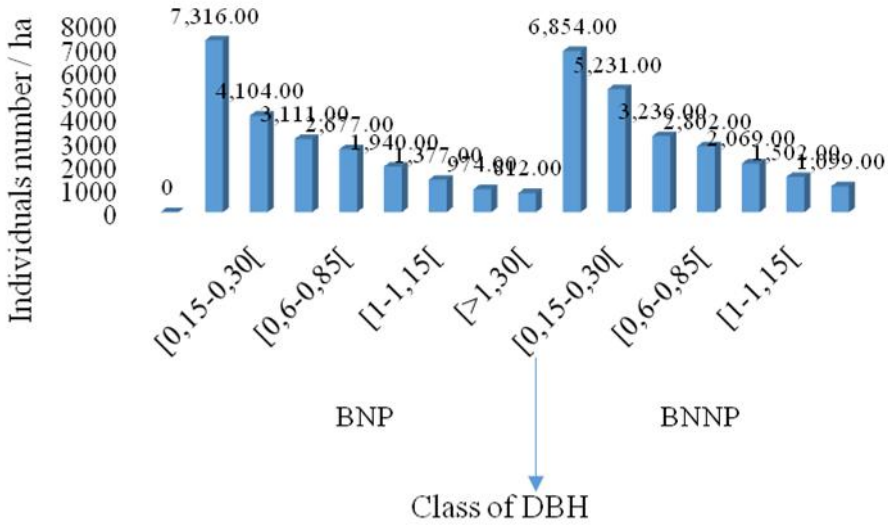

Figure 2: Distribution of individuals according to the diameters of their bunch

Diametric distribution of vegetation on the gold panning sites in and around the parks

Figure 3 shows the diametric distribution of vegetation based on gold panning sites in and around the parks. The distribution of stems by diameter class in the study area according to the gold panning sites highlights some structural differences clearly discriminated by the number of individuals. The diametric measurement in the DBH class of trees in our study area shows curves in the form of "L". Such a translated structure reflects the expression of a strong anthropic action linked to gold panning on ligneous trees. Indeed, this figure indicates a dominance of the strength of the diameter class between 0.15m and 0.45m. The representation of the different classes of diameters in gold panning sites has a decreasing exponential distribution, a sign of ecological vigor.

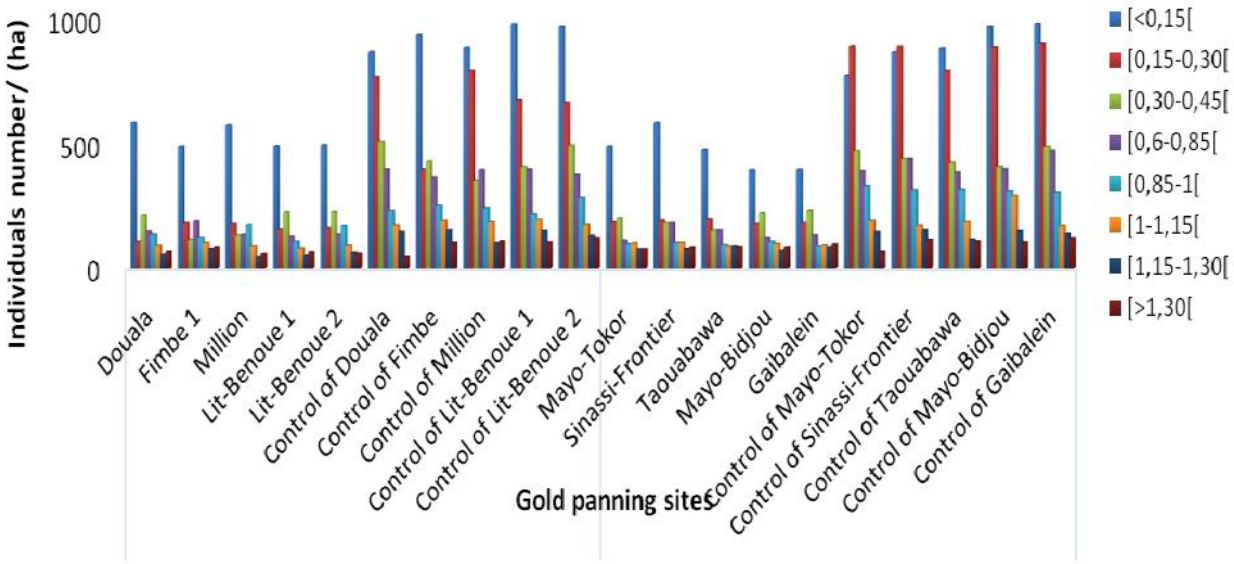

Figure 3 : Distribution of individuals according to the diameters of their bunch in the sites

Structure of the vegetation according to the height of the species in the gold panning sites

The tree structure in gold-mining sites by diameter class shows an "L" pattern indicating that low diameter classes are better represented than larger ones (Figure 4). This shows that individuals with heights less than or equal to 2 m are more abundant in vegetation. The analysis of variance shows a highly significant difference (0.0000<0.001) between height classes. However, the "L" structure is indicative that the ecosystem as a whole is in a state of degradation because adult individuals are threatened. The importance of young individuals comes mainly from climatic conditions and anthropogenic impacts. These results are in agreement with those of Monsou *et al.* (2016) in the Botanical Garden of Bingerville (District of Abidjan, Ivory Coast). What justifies the anthropic action on these species by the clearing of the vegetal cover in this zone. And so it reflects a strong regeneration of woody sites and shows that vegetation has a better future in its evolutionary dynamism. Variations in soil water availability are, however, one of the main causes of the heterogeneity of the soil cover which conditions the water distribution at the watershed scale under the influence of runoff.

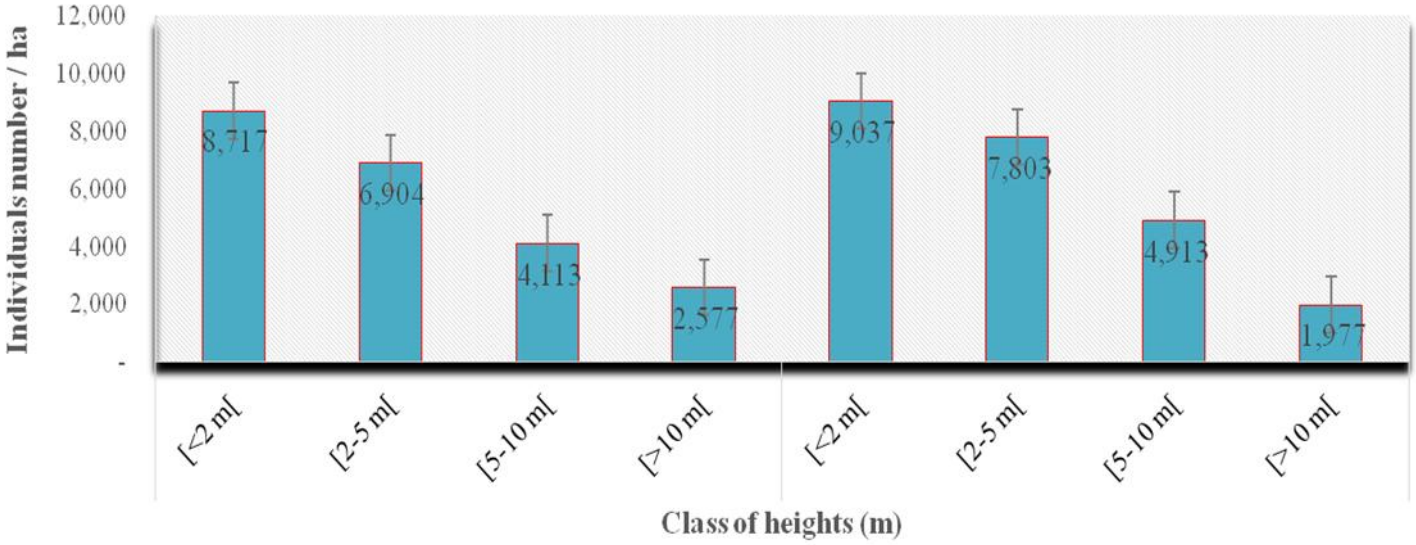

Figure 4: Structure of the vegetation according to the height of the species

Vegetation structure according to gold mining sites in the study area

Figure 5 shows the vertical structure that the distribution of species has "L" shapes represented by a very large number of future stems and very few adult stems. This distribution of stems by height class in gold panning sites on either side of each national park highlights some structural differences clearly discriminated by the number of individuals. Thus, we notice on this same figure a dominance of the class strength of heights inferior to 5 m. However, the practice of gold panning inside the national parks of the Mayo-Rey Division and its surroundings has an influence on the structural distribution in term of the height of the trees. This justifies the pressure of this practice through its destructive effects such as cutting wood, uprooting and so on. These results corroborate those of Diouf *et al.* (2002), Sandjong *et al*. (2013), and Boubacar (2010) who have shown that one of the characteristics of savanna ecosystems is generally composed of individuals of relatively average size.

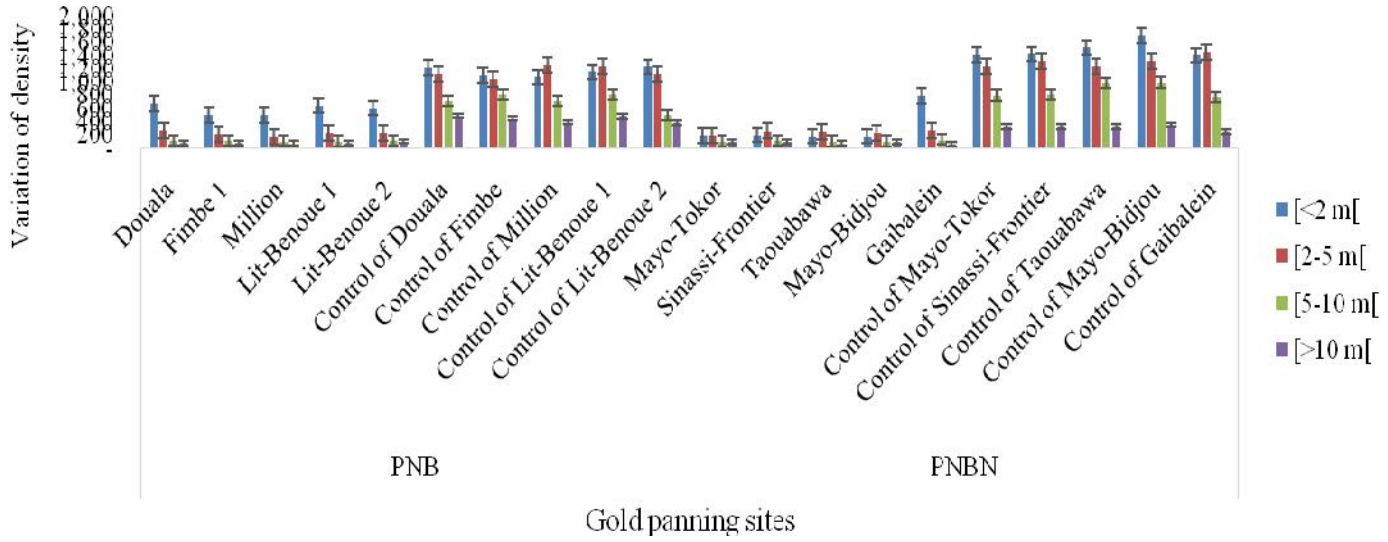

Figure 5 : Distribution of stems by height class in gold panning sites on either side

Indices of species floristic diversity in gold panning sites

The Shannon diversity index is very high in the Fimbe site (4, 56 bits), the Million (4, 56 bits) and Sinassi-Frontier control (4,36 bits) (Table 4). This reflects a high specific diversity of vegetation in the control area as in the gold panning area. These results are different from those obtained by Ouattara *et al.* (2016) in the open forests in the Sudanian zone of northwestern Cote d'Ivoire with a Shannon index varying around 5.37 bits. The fact that these results are higher than our results is explained by the fact that the forests where they did their studies are less impacted than ours. As for the Equitability of Pielou they are proportional to the calculated index of Shannon. The calculated values of the Equitability of Pielou in the different artisanal mining are weak with the biggest value seen in the control of Fimbe 1, that's equal to 1, in the control of Million, with a value of 0.996 and in the control of Douala with a value of 0.994. These weak values show that the studied vegetation is not too weak in term of biodiversity but artisanal mining has the impact on this vegetation.

Table 4: Indices of species floristic diversity in gold panning sites

Parks	Sites	Shannon Index	Equitability (EQ) of Pielou	Simpson Index
BNP	**Douala**	3,96062	0,98191	0,02284
	Fimbe1	4,04643	0,97979	0,02087
	Million	3,99939	0,92809	0,01801
	Lit-Benoue1	3,88716	0,96287	0,02247
	Lit-Benoue2	3,79593	0,93241	0,02124
	Control of Douala	4,09052	0,99415	0,02067
	Control of Fimbe	4,56235	1	0,01235
	Control of Million	4,56235	0,99576	0,02197
	Control of Lit-Benoue 1	4,08377	0,98166	0,01945
	Control of Lit-Benoue 2	4,09052	0,99415	0,02067
BNNP	**Mayo-Tokor**	3,89452	0,90242	0,0152
	Sinassi-Frontier	4,20344	0,98215	0,0185
	Taoubawa	4,15366	0,90242	0,0152
	Mayo-Bidjou	3,8514	0,89266	0,0151
	Gaibalein	3,86345	0,89563	0,0152
	Control of Mayo-Tokor	4,15395	0,98674	0,0181
	Control of Sinassi-Frontier	4,3573	0,9396	0,0138
	Control of Taoubawa	4,1721	0,98674	0,0181
	Control of Mayo-Bidjou	4,10876	0,97643	0,018
	Control of Gaibalein	4,13589	0,98306	0,0181

Relationship between DBH and the height of the species in Mayo-Rey gold panning sites

Figures 6a, 6b, 6c and 6d show the relationship between DBH and height by plants species. The linear regression curves performed between these two parameters show a positive correlation. These correlation coefficients are distributed as follows: R2 = 0.4659 for the gold panning area of the Benoue National Park (BNP) against R2 = 0.4284 for the non-gold panning part of the same park; R2 = 0.1108 for the gold panning zone of the Bouba-Ndjdda National Park (BNNP) against R2 = 0.4284 for the non-gold panning part of the same park.

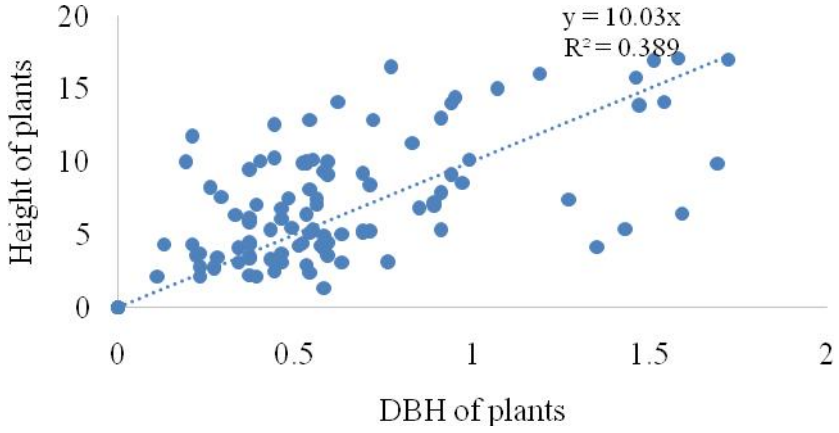

Figure 6 a : **Correlation between DBH and Height in the gold panning of BNP**

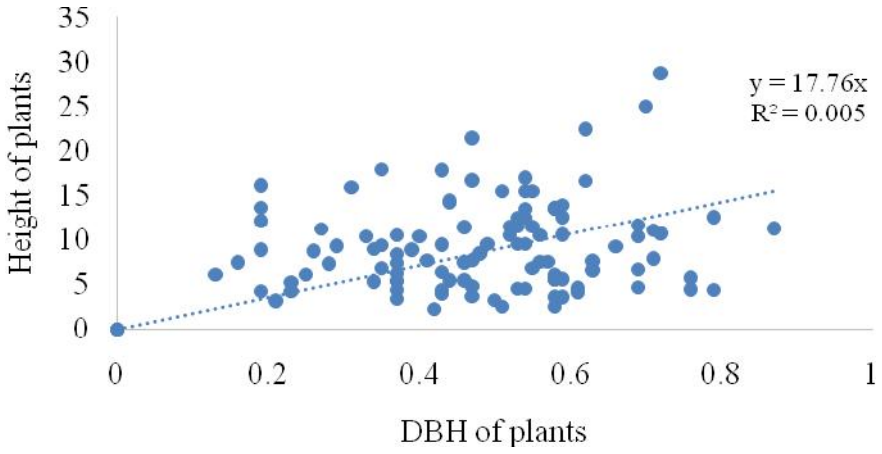

Figure 6 b : **Correlation between DBH and Heightinnon-gold panning of BNP**

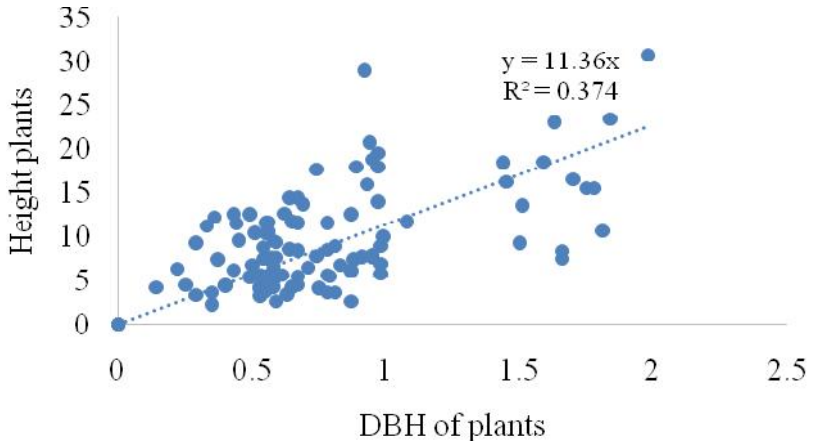

Figure 6 c : **Correlation between DBH and Height in the gold panning of BNNP**

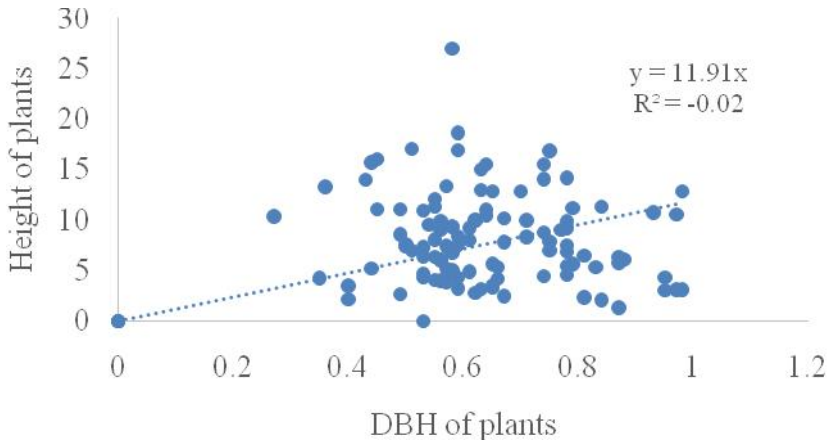

Figure 6d : **Correlation between DBH and Height in non-gold panning of BNNP**

Conclusion

This study has evaluated ecological characterization of the Vegetation in the artisanal mining sites of the protected areas in Mayo-Rey Division in the North region of Cameroon. It has revealed a regressive evolution of the ligneous species, most of which have a low DBH. The immediate consequences of deforestation were materialized by the rapid modification of species structure into the "L" shape, as related to their DBH that reflects a high regeneration rate of species. It can be seen from this result that the Shannon diversity indices are more representative in the non-gold mining thangold mining zone. It would therefore be important to undertake ways and means of improving the restoration of these mining sites. It is suggested to the civil and administrative authorities to create local unities in this locality focused on the protection and safeguarding of forest, and to recruit qualified personnel trained in forestry to monitor activities in the field.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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